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Observations on the foraging behaviour of sheep using a high-level feeder technique

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In the Name of Allah,
the Compassionate, the Merciful,
Praise be to Allah, Lord of the Universe,
and Peace and Prayers be upon
His Final Prophet and Messenger.

OBSERVATIONS ON THE FORAGING BEHAVIOUR OF SHEEP USING A HIGH-LEVEL FEEDER TECHNIQUE

by

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Dedication

This work is dedicated to my parents, my wife
and my twin sons
who are more entitled to be treated with
the best companionship by me.

Acknowledgments

Contributions to the development and progress of this study have been so varied that it would be impossible to do justice in an acknowledgment page such as this to all who have helped me. The persons to whom my appreciation is due are numerous but I must thank my supervisor Dr. I. Ap Dewi to whom I owe a great debt for his very valued help in the statistical work and his constant personal interest in this study and his willingness to discuss and comment on it as it progressed have been invaluable. I am also very grateful to supervisory committees members Professor J.B. Owen and Mr. R.F.E. Axford for their encouragement and advice. Also I would like to thank all the technicians of College Farm for their help during doing my practical work. My profound gratitude goes to all the members of both my family as well as my wife's family. Despite my long absence, they have shown patience, and their continuous encouragement and endless support made my task easier. My final debt is to my wife, Aminh Al-Rajeh, for her patience and with understanding of an academic husband. Her help and forbearance have done much to sustain me all through the period of this research. I really thank her.

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Table of Contents

List of Tables

List of Figures

List of Appendices

Summary

This study was carried out to investigate the use of high-level feeders (HLF) in both in-door and out-door experiments to study the foraging behaviour of sheep. The work was based on a series of experiments: (1) Preliminary study to investigate the use of high-level feeder to examine the foraging behaviour of sheep; (2) The effect of alternative feed sources on the behaviour of Welsh Mountain and Cambridge ewes given access to ivy on a high-level feeder; (3) Interaction between breeds and alternative feed sources on the behaviour of sheep given access to ivy on a high-level feeder in a grazing environment; (4) The effect of forage quality on the behaviour of Welsh Mountain ewes when sources are available separately; (5) The effects of location of forage on the behaviour of sheep when medium quality forage is available; (6) Selection of forages by sheep when sources are available simultaneously; (7) The extent to which sheep will overcome an obstacle in order to eat from a high-level feeder; (8) The effect of prior-foraging experience on the foraging behaviour of ewes given access to ivy; and (9) The effect of forage locations on the feeding behaviour of sheep when good quality forage was available. The expriments demonstrated that the high-level feeder technique can be used to simulate foraging from a tree since the behaviour of ewes during eating ivy and sycamore from the HLF was similar to that observed when they ate from a real tree. Some aspects of ewes behaviour was affected by the availability of other feed sources. The provision of hay and concentrate supplement did not significantly reduce the intake of ivy but ewes tended to spend less time eating ivy from the HLF when hay and concentrate supplement were available. There was no breed effect on the time spent grazing or eating from a HLF. A reduced intake per ewe in a mixed-breed treatment grazing was the result of competition between ewes particularly related to size and the increase in numbers of ewes eating together. Ewes selected ivy > hay > straw. They spent more time eating from the HLF when good quality forage was available (18.8%), less at medium (9.3%) and very little (0.1%) if poor quality forage was available. Welsh Mountain ewes had an ability to select their diet from different types of forage available to them simultaneously. Both the HLF and obstacle techniques are useful techniques when the degree of preferences for feeds is to be studied. They can also be used to test if an animal species is willing to work to obtain particular foods. It was concluded that sheep have the ability to take a decision to work harder in order to move faster to preferred feeds. Preference for location was affected by factors associated with the location (height, safety), the forage available at each location and prior experience. Prior-foraging experience or training increased the time spent eating ivy from the sources that sheep were accustomed to eating from. Ewes ate ivy from different locations in the order hurdle > HLF > floor. Eating ivy from sources that they did not have experience of indicates that the drive to eat was stronger than their preference for a location. The results of this study also showed that ME obtained from ivy did not meet the maintenance requirement for ewes. In order to meet the daily maintenance requirement ewes would have to eat ivy for longer and considerably increase their intake.

Abbreviations

AT	Artificial tree
Camb.	Cambridge
Conc.	Concentrate
F	Floor
FCNH	Hay on the HLF (Forage) + Concentrate + No hay on the side-feeder.
FCH	Hay on the high-level feeder + Concentrate + Hay on the side-feeder.
NFCH	No forage + Concentrate + Hay on the side-feeder.
GS	Grass silage
H	Hay
HF	Holstein-Friesian
HLF	High Level Feeder
H	Hurdle
JER	Jersey
MS	Maize silage
SI	Simmental
WCC	Welsh Mountain ewes + Cambridge ewes + concentrate supplement.
WCH	Welsh Mountain ewes + Cambridge ewes + hay.
WOC	Welsh Mountain ewes + concentrate supplement.
WM	Welsh Mountain
WOH	Welsh Mountain ewes + hay.

CHAPTER 1

INTRODUCTION

In behavioural terms a sheep can be defined as a defenseless, vigilant, tight-flocking, visually-alert, wool-covered ruminant that evolved within a mountain grassland habitat (Kilgour and Dalton, 1984). Sheep have many characteristics that make them valuable domesticated animals around the world. They can live almost every place on earth except for Antarctica, and can eat a wide range of shrubs, grasses, forbs and lower forms of plant life (Lynch *et al.*, 1992). They are kept to produce meat, milk, wool/hair, skins and manure. In many areas they act as a source of investment where no banking or finance facilities are available.

It is important to understand the eating behaviour of sheep because feed is one of the major inputs in a sheep production system and inadequate feed is usually considered as a major factor limiting sheep production. Eating behaviour is a complex concept that includes actions described by a variety of terms including grazing, browsing, eating, foraging, rumination, drinking and mastication. Table 1.1 shows the definitions of some of these terms.

Table 1.1 Definitions

Terms	**Definitions**
Browse	Is a term referring to the food that is derived from trees and shrubs and includes leaves, shoots, buds and twigs (Dalal-Clayton, 1981; Skerman *et al.*, 1988; Ivory, 1990).
Browsing	Is a term referring to the process of harvesting (picking or biting) browse products (Forestry Commission, 1986). The animals can consume leaves, twigs, stems, bark, shoots, buds, seeds pods of trees and shrubs.
Eating	Is the consuming of food (Lexicon Webster Dictionary, 1925).
Feed	Is a portion of food offered to an animal in which the size and material is determined by man. (Forbes, 1995; Chapman, 1953)
Foraging	is a term referring to searching and eating process of the roughage (Campbell and Lasley, 1985).
Forage	Is a term referring to roughage of high feeding value. Grasses and legumes cut at the proper stage of maturity and stored without damage (Campbell and Lasley, 1985). Chapman (1953) referring this term to fodder especially hay and straw as distinct from growing grass. Raymond (1966) referred the term forage to the feeds ranging from straw and browse plants.
Grazing	Consumption of standing vegetation by livestock or wild animals (Campbell and Lasley, 1985).
Supplementary feed or supplement	It is a term referring to the addition of food for an animal when the basal diet is insufficient or of poor quality Campbell and Lasley (1985).

Consumption of food can be described by "eating" but the other terms provide a better reflection of what it is eating and how it is eats. Browsing conveys eating material from trees and shrubs away from the ground. Grazing represent eating grasses or legumes at ground level, when grazing sheep harvest grass by jerking a bunch of grass forward and then tearing the bunch so that it is cut off. Alternatively, they can bite between their lower incisors and upper hard pad (Campbell and Lasley, 1985; Forbes, 1995). In contrast, while browsing sheep harvest browse products by picking or biting (Forestry Commission, 1986). The action described by each of the terms in Table 1.1 has complex factors which affect it. For example, browsing is affected by several factors e.g. quality of browse, palatability, availability, quantity, acceptability by an animal and presence of toxic compounds.

Browse species are very important resources of feed for both wild and domestic animals in the Mediterranean basin, the dry tropics, sub-Saharan Africa, North America, Latin America, Australia and, to a lesser extent, the hill farming areas of Europe (Hughes, 1994). Browse can represent 40% of the livestock feed in Mediterranean Africa, and 20% in tropical Africa. Browse is used by animals directly or through the deliberate cutting of shrubs and trees (cut and carry systems) and feeding to free-grazing, tethered or confined animals. Traditionally, the use of shrubs and trees as a source of forage for domesticated animals has been mostly opportunistic, based on farmers knowledge that some indigenous shrubs or trees are palatable and have a reasonable or good nutritive value for livestock, particularly during periods of feed shortage. It is only recently that there has been a deliberate policy to plant multi-purpose trees and shrubs around houses or on farms to supply feed to livestock and improve animal productivity throughout the year (Nair and Fernandes, 1985; Ivory, 1990; Lawton, 1980).

Grazing, particularly on grasses or grass-legume pastures, represents a major feed input in many sheep production systems. McDonald *et al.* (1988) divided grasslands into two main groups, natural grassland consisting of a large number of species of grasses, legumes and herbs, and cultivated grassland consisting usually of mixtures of a relatively small number of species.

Supplementary feeds are materials provided in addition to a basal diet comprised of browsing or grazing. Supplementary feeds are given to sheep in several cases, such as when their basal diet is of poor quality or when there are shortages of forage (Hunter and Siebert, 1982). They are particularly valuable in late pregnancy to avoid nutrient deficiencies (Pattinson *et al.*, 1998). Supplementary feeds can be in the form of grains, feed blocks, fluids or extruded feeds (Lynch *et al.*, 1992).

High quality forage can be used to supplement poor quality forage (Manyuchi *et al.*, 1994). For example, fodder from trees and shrubs have been considered as a supplementary feed in sheep and goats (Coates, 1995 and Devendra, 1995).

Studying feeding behaviour (grazing and browsing) on rangeland is difficult and expensive. It is often difficult to observe animals due to the large areas involved. It is expensive in terms of labour and transport. Under natural conditions it is also difficult to control the access to food and the type and availability of food. Studying feeding behaviour under controlled conditions therefore, has advantages.

The objectives of the study were (1) to develop a technique that allowed the eating behaviour of sheep, particularly browsing, to be examined under controlled conditions and (2) to use this technique to examine the feeding behaviour of sheep with regard to a high-level feeder (HLF) designed to simulate a tree. In order to address these objectives, a series of experiments were conducted to examine aspects of sheep behaviour in a situation where they had access to a high-level feeder placed away from the boundaries of a pen. Nine experiments were conducted. The objectives and hypothesis for each experiment are described in Table 1.2.

Table 1.2 Main objectives and hypothesis of each experiment

Experiment and Chapter	Objectives	Hypothesis
1 Chapter 3	Evaluate the use of HLF	That sheep of two breeds will eat from HLF.
2 Chapter 4	Investigate effect of supplement type on the eating behaviour of Welsh Mountain and Cambridge ewes with Ivy on the HLF as a feed source.	That sheep of two breeds will eat from HLF when other feed sources are available.
3 Chapter 5	Investigate the extent to which the behaviour of Welsh Mountain ewes (small breed) was affected by the presence of Cambridge ewes (large breed) in a grazing environment.	That eating behaviour from HLF is affected by breed under a grazing situation.
4 Chapter 6	Investigate the effects of different forage sources on the behaviour of Welsh Mountain ewes when they are available separately.	That sheep will spend more time eating when high quality forage offered in the HLF.
5 Chapter 7	Investigate the effect of location of forage when a medium-quality forage is available.	That sheep will not eat from a feeder when the same medium-quality feed is provided in the HLF.
6 Chapter 8	Investigate the selection of forage when three sources of forages were available simultaneously.	That sheep will demonstrate feed selection when sources are available in HLF simultaneously.
7 Chapter 9	Examine the extent to which sheep overcome an obstacle in order to eat from HLF.	That sheep will overcome an obstacle to eat from the HLF.
8 Chapter 10	Examine whether there is an effect of prior-feeding experience on selection of feed from alternative sources.	That sheep with experience of eating ivy from HLF will spend more time eating ivy from HLF than those that had an experience to eat ivy from the floor (F).
9 Chapter 11	Investigate the effect of locations of feed when a high-quality forage is available.	That sheep will not eat from alternative locations when high-quality feed is provided in the HLF.

HLF = High-level feeder (described in detail in section 3.2.3).

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL INTRODUCTION TO SHEEP FEEDING BEHAVIOUR

2.1.1 Factors affecting sheep feeding behaviour

The most dominant daily activity in sheep is eating. Their food consists primarily of plants and plant products. In farm animals the terms feeding, eating, foraging, grazing and browsing are used to describe the action of consuming or harvesting food.

Sheep feeding is not a simple issue. The decision as to which food should be given, in what quantities and at what times is difficult because it depends on several factors including the quality and quantity of available foods. The selection and intake of food is also affected by the animal's experience. Provenza and Balph (1988) reported that the feeding behaviour of an animal is determined both genetically and through learning. Feeding behaviour differs from one species to another, due to the genetic make up of the species and to some acquired behaviours. For example, biting of grass by cattle and sheep differs due to differences in their mouth morphology. Tolerance for tannins is also considered an example of a genetic factor. Devendra (1995) stated that goats are more tolerant of tannins than sheep and they secrete more saliva than sheep do.

The initiation or termination of feeding by an animal is considered as another example of a physiological factor playing a significant role in feeding behaviour because it is controlled by centers in the brain (satiety and hunger centers). For example, Broom and Fraser (1990) stated that food intake occurs when the flow of energy from the food absorption process becomes too small (at which stage the animal feels hungry) and stops again when the absorption of energy flow becomes adequate. This mechanism is controlled by the satiety centers in the brain of the animal. The satiety centers in the hypothalamus receive a signal from the digestive system of the animal informing it of the level of energy flow resulting from the absorptive process. The hypothalamus, accordingly, issues messages resulting in the inhibition of the desire for further feeding.

Regarding the effect of learning in the feeding behaviour of sheep, Thorhallsdottir *et al.* (1990), Mirza and Provenza (1990 and 1992a) and (Mirza and Provenza, 1992b) stated that young lambs foraging on rangelands learn which food to eat from their mothers, and avoid novel foods as a result of neophobia (fear from new feed). As the age of lambs increases, and as they become more independent of their mothers, learning about foods through trial and error becomes important (Burritt and Provenza, 1991). Key and Maclver (1980) conducted an experiment with cross-fostered lambs and found that Clun Forest and Welsh Mountain lambs preferred the distinctly improved pasture or tussock and heather eaten by their foster mothers. They also stated that sheep are not born with innate behavioural patterns that determine their grazing habits, but rather that the latter are acquired by copying the habits of their natural or foster mothers through learning.

Feeding behaviour also depends on external factors, including the physical and mechanical properties of the food, the availability of water, the nutrient content of food, and the effects of disturbances caused by competition from other members of the species or due to the danger of predation (Broom and Fraser, 1990).

The association of animals into groups or flocks is a commonly observed behaviour in ruminants and is important from the point of view of feeding behaviour. Provenza *et al.* (1988) stated that gregariousness (grouping) could be a major force in the evolution of foraging behaviour in livestock. Flocking also affects the time spent grazing. Penning *et al.*

(1993) and Williams (1988) stated that sheep in smaller groups spent less time grazing than sheep in large groups. Flocking also plays an important part in the synchronisation of sheep at the time of grazing. Rook and Penning (1991) stated that sheep in a flock tend to synchronise themselves at the start of their grazing bouts, but they were less synchronised at the end of these bouts.

2.1.2 Diet Selection

Diet selection is based on sheep making a decision concerning what plant species, individual plants and parts of plants it will eat (Lynch *et al.*, 1992). Diet selection by sheep depends on the animal requirement, the quality and quantity of available food, and the ability of sheep to use their senses to differentiate between two or more foods. Theories of diet selection have been described by Provenza and Balph (1990). They analysed five theories of diet selection drawing on literature associated with animal and plant science, psychology and wildlife ecology. These theories which are not mutually exclusive are: (i) nutritional wisdom; (ii) hedyphagia; (iii) morphophsyiology and size; (iv) optimal foraging; and (v) learning by consequence.

Euphagia or 'nutritional wisdom' suggests that animals have the innate ability to select specific nutrients. Hedyphagia, or the selection of a diet 'pleasing' to the special senses and avoiding what is not, is based on the concept that through the evolutionary process, what is pleasing will be nutritious. Morphophysiology and size of species may result in ruminants ingesting herbage that differs in physical and chemical characteristics either because of body size and metabolic requirements or because they have evolved in environments with plants of vastly different digestibility. The nutritional optimization (optimal foraging) theory has similar problems related to individuality. Learning by consequence is based on positive and negative post-ingestional consequences and experiences which may have either social or individual trial and error experiences.

Diet selection is also affected by the species of the animal and the quality of the available feeds. For example, Bartolome *et al.* (1998) studied diet selection by sheep and goats on Mediterranean heath-woodland range (composed of *Quercus ilex* and *Calluna vulgaris-Erica arborea*). They used faecal analysis to estimate diet selection. Their results showed that even though goats and sheep grazed together, their diets were significantly different (18-60%). The outstanding difference was the avoidance of the tree, *Quercus ilex*, by the sheep while the goats selected it throughout the year. Sheep selected graminoids throughout the year while goats tended to avoid them.

Cropper *et al.* (1985, 1986) showed that sheep select proportions of low and high protein foods to give a protein intake matched to their presumed requirements for growth.

Black and Kenney (1984) reported that when grass or hay is offered in the long, unchopped form, animals have the opportunity to select between stem and leaf. The proportion of leaf selected by sheep increases with the amount of straw offered. Sheep given unchopped barley straw in sufficient amounts so as to leave uneaten 20, 30, 40, 50, and 70% of that on offer ate increasing amounts of leaf blade as the allowance increased, in a linear manner, at the expense of stem (Bhargava *et al.*, 1988).

The experience and foraging skill of sheep can also play an important role in feed selection. Provenza and Balph (1990) noted that the foraging behaviour of livestock when they encounter new food is affected by at least two factors: lack of acceptance of the foods and lack of foraging skill. Flores *et al.* (1989) found that lambs with experience of foraging on the shrub Serviceberry (*Amelanchie alnifolia*) more successfully prehended Serviceberry and thus had higher intake rates per unit time than inexperienced lambs or lambs experienced in foraging only on grass. Furthermore, lambs with experience of eating grass ingested more grass per unit time than did lambs experienced in eating shrubs (Flores *et al.*, 1989b,c).

2.1.3 The mechanism of harvesting plants by sheep

There are several mechanisms which sheep use to harvest plant materials. By grazing very close to the ground sheep can harvest many prostrate plants. Grasses are prehended then torn when the head or jaws are moved posteriorly with a sudden jerking movement. The head may swing laterally and more food is prehended while the fore or hind leg takes one step forward. When eating shrubs, sheep can either strip the branch of leaves, break twigs and chew them, or pick off discrete leaves. Sheep will dig through soft snow to search for vegetation if there is no other food available and can survive on seeds in what appears to be barren paddocks (Lynch *et al.*, 1992).

When browsing, sheep can eat leaves either in a standing position or standing on their hind legs with a jerking movement of the head. Gatenby (1986) reported that sheep can eat vegetation up to about 1 or 2 m high depending on their size and ability to stand on their hind legs. Flores *et al.*

(1989a) described two prehension patterns during observations of the foraging skill of lambs. These were jerking (gripping tillers with the teeth while jerking the head forward or backward) and chewing (removing the tillers by biting with the teeth).

2.2 GRAZING BEHAVIOUR

Sheep undertake periods of grazing that are slightly less rigid than cattle but are diurnal and change according to season (Kilgour and Dalton, 1984). The amount of time spent grazing is variable, depending on the quantity and quality of the available herbage and on the physiological state of animals (Forbes, 1995). Kilgour and Dalton (1984) stated that sheep can graze up to 8 hours daily in temperate climates, but if feed is in short supply and they are hungry then they can graze up to 10 hours. Arnold and Dudzinski (1978) reported that sheep can graze for up to 13 hours. Forbes (1995) reported that grazing in sheep is most intensive in the evening and Penning *et al.* (1991) observed that whereas 70-99% of grazing was during daylight, 25-48% of the total was concentrated in the 4 h before sunset. A grazing time of more than about 9 h indicates that herbage mass is limiting intake and the animal is having to extend its grazing time to get enough food to eat (Forbes, 1995). Bechet (1978) observed that lactating ewes in the spring spent 587 minutes per day eating and 423 minutes ruminating; in the summer, after weaning, the times were 450 minutes eating and 382 minutes ruminating.

2.2.1 Important measurements during observation of grazing behaviour

Lynch *et al.* (1992) reported that grazing behaviour is composed of three behavioural variables or measurements, grazing time, bite size and bite rate. Bite size and bite rate are the results of the interaction between animal morphology, behaviour and sward structure (Forbes, 1988; Ungar *et al.*, 1991; Laca *et al.*, 1992). Bite rate is a function of the time spent per bite on "searching" (Locomotion, recognition and decision) and "handling" (gathering, ingestion, mastication and swallowing). Bite size is related to width and depth of the mouth cavity (Lynch *et al.*, 1992).

The relationship between searching time and bite weight is complex. In heterogeneous environments there is a trade-off between the animal's selectivity and the mean travelling time between selected bites. A negative relationship between bite weight and bite rate is expected under conditions of increasing heterogeneity of bite weight (Ungar and Noy-Meir, hours. Penning *et al.* (1991) reported that grazing time of more than about 9 h indicates that herbage mass is limiting intake and the animal is having to extend its grazing time to get enough food to eat.

Sward height also has had an effect on ingestive behaviour. Gong *et al.* (1996b) found that sward height had a greater effect on ingestive behaviour than did other sward characteristics. Dumont *et al.* (1995) found that time spent grazing increased with sward height in both sheep and cattle.

Regarding the role played by the species of the animal in intake, Bakker *et al.* (1998) studied The effect of three different vertical structures of a perennial ryegrass (*Lolium perenne*)-dominated sward, defined by pseudostem heights (cm) - 1.3 low (L), 2.5 medium (M) and 3.5 high (H) - grazed by sheep and guanacos (*Lama guanicoe*). They found that there were differences in diet composition between species that were related to differences in selection for plant parts. Sheep had a higher proportion of green leaf in the diet than did guanacos in L and M swards. Also Gong *et al.* (1996a.) compared bite weight, bite rate and bite dimensions (depth, area and volume) among six sheep and six goats individually confined indoors in metabolism crates, grazing monoculture turves. They found that when tall, stemmy reproductive

1984; Soedomo *et al.*, 1986), Nepal (Sapkota, 1988), the Philippines (Hensleigh and Holloway, 1988), Thailand (Topark - Ngarm and Gutteridge, 1986) and Egypt (Heneidy, 1996). Brewbaker (1986) listed a wide range of leguminous tree species that can be used as animal feed. For example, the genera that have shown promise include *Acacia* (NAS, 1979; Turnbull, 1987), *Acacia saligna and A. salicina phyllodes* (Degen *et al.*, 1997), *Calliandra* (NAS, 1983), *Caesalpinia* (Giller and Wilson, 1991), *Desmodium, Gliricidia* (Chadhokar, 1982; Falvey, 1982; Withington *et al.*, 1987), *Leucaena* (Pound and Martinez-Cairo, 1983; NAS, 1984), *Sesbania* (Wood and Larkens, 1987), *Prosopis* (NAS, 1979), and *Papilionoideae* (Giller and Wilson, 1991). Appendix 4 Lists trees and shrubs of potential value as animal fodders as published by Skerman (1977), ILCA (1985), Brewbaker (1986), Turnbull *et al.* (1986), and Blair (1990).

Devendra (1990, 1993 and 1995) described the benefits of using forages from shrubs and trees in the context of their role as a diet supplement. This role relates to their supply of dietary nitrogen, energy, minerals and vitamins. The first benefit is increased live weight gain or milk production. Secondly, in many instances, the beneficial response (milk and meat) is associated with a reduced cost of production (for example, Wong *et al.*, 1987). Thirdly, of the forage supplements used, the leguminous forages have been particularly advantageous, among which leucaena has been popular. Also the browse legumes have a distinct advantage over tropical grasses in terms of their superior nutritional value, particularly during the dry season. Fourthly, stall-feeding or cut-and-carry systems are the most common production system used compared with the grazing situation.

Poppi and Norton (1995) concluded that tree legumes improve feed intake of ruminant animals and that they are most effective when the quality of basal diet is low.

Chandrasekharaiah *et al.* (1996) found that Leucaena leucocephala could be included in the diet of sheep and goats as part of a balanced ration.

Bergstrom (1992) noted that the large herbivores, wild and domestic, are often classified into two groups, grazers and browsers, according to the plant groups which make up most of their diet. This classification is supported by the anatomy of the gastro-intestinal tract (Hofmann and Stewart, 1972) and other adaptations (Owen-Smith, 1982). Hofmann and Stewart (1972) identified four main groups of feeders: concentrate selectors (browsers), intermediate feeders preferring browse, intermediate feeders preferring grass, and bulk and roughage feeders (grazers). Ecologically, it is probably more correct to see the browser-grazer classes as part of a continuum (McNaughton, 1986). Mysterud (1998) tested the roles of body size and feeding type (CS: concentrate selectors, IF: intermediate feeders, GR: grass-roughage eaters) on the activity time of temperate ruminants (the data of the study was obtained from the literature for 18 of temperate ruminants. The results indicated that activity time decreased with increasing body weight, but there was also a tendency for an effect of feeding type. However, his hypothesis lead to the conclusion that IF are more active than GR or CS due to their opportunistic use of high-quality forage of both types (concentrate and grass-roughage; on average better quality and hence shorter rumination time), though possible confounding effects of observation methods and varied behaviour with respect to cover among CS, IF, and GR should also be evaluated.

Pratt and Gwynne (1977) noted that cattle, buffaloes, sheep, equines, wildebeest, most antelopes, gazelles, white rhino and hippo are mainly grazers but these species, especially in dry or cold seasons, become browsers in order to balance their diet. Other species, such as goats, camels, eland, impala, kudu, elephant, giraffe, black rhino, deer, elk and many antelopes, are browsers to a large extent and can ensure normal growth on a pure browse diet.

Robbins *et al.* (1995) examined the hypotheses presented by Hofmann (1973) that described the difference between browsers and grazers, namely that (1) fibre digestion by browsers is lower than that of grazers, (2) salivary gland size is larger in all browsers than in grazers, (3) the browser's larger salivary glands produce larger volumes of thin serous saliva than those of grazers, and (4) browsers have higher liquid passage rates than do grazers. Robbins *et al.* (1995) found that the extent of fibre digestion did not differ between browsers and grazers, although fibre digestion was positively related to herbivore size. In general, salivary gland size is approximately 4 times larger in browsers than grazers, but some browsers (e.g. greater kudu) have small, grazer-sized salivary glands. Resting (non-feeding or ruminating) saliva flow rates of mule deer (browser) and domestic sheep and cattle (grazers) were not significantly different from each other. Ruminal liquid flow rates were not different between feeding types. Robbins *et al.* (1995) concluded that many of Hofmann's nutritional and physiological interpretations of anatomical differences amongst ruminants were not supportable.

Valderrabano *et al.* (1996) examined browsing ability and utilization by sheep and goats of *Atriplex halimus* bushes and they found that volume of bushes consumed by goats was higher than that consumed by ewes and the values appear to be associated with the mean size of twigs eaten (4.58 vs. 2.72mm). Goats make much greater use of browse than sheep. They have special mouth parts, including a split upper lip, and are more selective than sheep as they search for a variety of feeds (Devendra and Burns, 1983; Devendra, 1990). Sheep tend to make less use of these feeds because of their grazing habits and because of the fact that both species are often herded together for feeding (Devendra, 1995). Aldosari (1996) compared desert sheep and goats in the utilization of some forages and concluded that goats utilize poor-quality roughage better than sheep. Genin *et al.* (1994) investigated diet selection and utilization by llama and sheep in rangelands of Bolivia, and found that sheep consumed more soft herbs and grasses than llamas (25-45% vs. 8-25%). Dawson and Ellis (1996) studied the diets of euros (hill kangaroos), sheep and feral goats, in a hilly, shrubland area of southern Australia, and they found that sheep consumed much shrub (*A. vesicaria*) in dry conditions, though grass (*Eragrostis spp.* and *Aristida spp.)* was important in wetter conditions.

Devendra (1995) reviewed the comparative feeding behaviour and digestive physiology of goats and sheep and found that sheep make less use of browse than goats and also they are less selective than goats in the search for variety in feeds. Sheep make less use of browse because of their grazing habits. Goats are more tolerant of tannins than sheep. Goats secrete saliva more than sheep.

2.3.2 Factors affecting browse intake

There are several factors affecting browse intake including, the quality and quantity of the available browse, animal species, the livewight of animals, and whether the browse is used alone or with other feed. In addition, the presence of toxic compounds in the browse can affect its intake. Devendra (1995) reviewed the composition and nutritive value of browse legumes, and stated that the voluntary intake of browse depends on the nutritive value.

El Aouini and Sarson (1976) working with sheep on a purely browse diet in the Maquis of Northern Tunisia, found that intake of browse was closely related to the liveweight of the animals. It was found that cattle, sheep and goats consumed up to 3, 3.8 and 6.0 % respectively of their body weight in dry matter daily.

Leng (1986) pointed out that requirements differ according to whether browse is being used alone or as a diet supplement.

Sarson and Salmon (1978) examined the relationship between maintenance needs of cattle, sheep, and goats and browse intake per 100 kg live weight. The analysis showed that browse alone could not meet the maintenance requirements of cattle. It could, however, ensure maintenance of sheep, but did not allow for production.

In Australia, Wilson *et al.* (1975) used oesophageal fistula to study the food preferences of captive feral goats compared with sheep at three grazing pressures, and they found that goats tended to select diets with appreciably higher nitrogen contents than did sheep. Woodward *et al.* (1995) studied intake and digestibility for sheep and goats consuming *Acacia brevispica* and *Sesbania sesban*, and they concluded that sheep had lower refusals of browse and higher intake rates than goats.

The use of feeds from trees and shrubs is not without problems. Many of them contain substances that are harmful to animal health. Little is known about the effects of these on the animal body both in the short and long term (Devendra, 1993). For example, mimosine found in *Leucaena* (a non-protein amino acid) has chronic goitrogenic effects in mammals (Lowry, 1990). Similarly, fluoroacetic acid is a secondary compound in certain species of *Acacia, Oxylobium, and Gastrolobium,* (Lowry, 1990). Fluoroacetate has been associated with death of livestock in areas of Australia

(Everist, 1974). Tannins (phenolic compound) present in several species can prevent protein breakdown in the rumen (Driedger and Hartifield, 1972). They have adverse effects on intake and digestibility at high levels (above 10% leaf dry weight) but are tolerated at up to 5% (Barry and Duncan, 1984). The adverse effects of toxic substances can be avoided by preventing animals from entering new areas containing unknown plant types. They should also be prevented from over-feeding on tree leaves of unknown nutritive value. They should not feed on plant parts containing toxins at levels above known and recommended maximum intakes.

2.3.3 Nutritive value of browse

Ivory (1990) reviewed the nutritive value of browse species as livestock feed and noted that there is extreme variability in the nutritive value of common shrub and tree species. This variation is due to the greatly varying inherent nutritive values between species as well as the variation found within species because of the difference in plant parts, the age of tissue, and the soil and climate in which the plant is growing. The nutritive value of forage is a function of its digestibility, chemical (mineral) composition, and presence of toxins or antinutritive factors.

Considerable variation in proximate analysis and digestibility have been recorded for tree species used for animal feeding (Gohl, 1981; Bulo *et al.*, 1985; Brewbaker, 1986; Vercoe, 1987; Goodchild and McMeniman, 1987; Little *et al.*, 1989; Rekhate and Honmode, 1995; Atiq-ur-Rehman, 1996). For example, Vercoe (1987) found that *in vitro* dry matter digestibility (IVDMD) of some *Acacias* tree species varied from 16.9 to 66.9% and crude protein from 8.6 to 22.6%. Bulo *et al.* (1985) found that *in vitro* dry matter digestibility (IVDMD) of leaf and edible stems of 12 shrub or tree legumes varied from 36 to 63% and 35 to 58%, respectively; crude protein varied from 11 to 31% and 9 to 18%, respectively. Brewbaker (1986) listed a wide range of crude protein contents (7-33%) and Little *et al.* (1989) found a range in crude protein of 10-29% for N tree legume species. Devendra (1993) listed approximate forage crude protein content percentages for some trees and shrubs in different countries, and the highest percentage was found in *Cajanus cajan* species. Fruits and pods of leguminous species can also have a high protein content (10 -20%) (Brewbaker, 1986; Goodchild and McMeniman, 1987). Generally, pods have a lower crude protein content but a higher organic matter digestibility than leaves (Ivory, 1990). Regarding the effect of season on the protein content of tree or leaves, Panjaitan (1988) found that the crude protein content of leaves of tree legumes grown at four sites in Indonesia varied from 23 to 29% in the wet season and from 19 to 29% in the dry season.

Regarding the minerals content of browse Vercoe (1987) analyzed the foliage of 23 species of trees used for livestock feeding or browsing in Australia. Most of them were leguminous species and considerable variation between their minerals contents was found (P, 0.005-0.18%; K, 0.14-1.78%; Ca, 0.29-3.52%; S, 0.21-1.13; Na, <0.01%-0.41%; Mg, 0.21-0.62%; Cu, 4-152ppm; Zn, 22-123ppm). Brewbaker (1986) found that all species satisfied the minimum animal requirements for Ca (0.18%); however, each species tested was found to have low concentrations of at least one essential element for animal growth. The most generally deficient element was P; it was below the estimated requirements for sheep and cattle in 86% of species tested.

2.3.4 Palatability of browse

Browse plants range in palatability from being completely inedible to being so palatable that they do not survive browsing pressure. There is no single plant characteristic that has been found to be highly correlated with palatability and intake potential. Attempts have been made to classify species according to their palatability, for example Le Houerou (1980) compiled a list of species and their relative palatability. While plants have a variable degree of palatability, palatability itself is related to the alternative foods available and the assessment of palatability and intake will differ between environments and accessible vegetation types. Within plants palatability may vary with seasonal changes in the chemistry of the plant (Cook, 1972). Even those plants with a very low palatability can become very important in adverse conditions. Palatability also depends on the relative abundance of the species and the botanical composition of the grazing/browse available. Kaitho *et al.* (1996) defined a palatability index which was related to species, dry matter content, intake, and amount offered. Using this index 40 multipurpose trees were grouped into 4 groups. Tree species such as *Leucaena leucocephala* and *Sesbania sesban* which are known to have good nutritive value had high palatability. In the same classification group, there were less well known species such as *Acacia venosa*. Other species, for example *Flemingia macrophylla* had poor palatability. *Gliricidia sepium* although used by farmers, had medium palatability.

2.3.5 Agronomy of browse shrubs and trees

This topic was reviewed in detail by Ivory (1990) and Humphreys (1995). Ivory (1990) noted that there are many desirable agronomic characteristics of shrubs and trees that are relevant to their potential as animal feed. The most desirable agronomic characteristics of a shrub or a tree species is that it is easily and reliably established; it exhibits a good competitive ability against weeds (particularly during establishment); it remains highly productive under repeated cutting or grazing and browsing; it should be well adapted to the particular climatic and edaphic features of the environment; it should require no or little fertilizer; it should be resistant to local pests and diseases; it should have adequate seed production or be reliably vegetatively propagated.

Leguminous trees have been used for planting; since they do not require large inputs of nitrogen fertilizer to sustain high levels of production under repeated cutting (Humphreys, 1995). An additional advantage of leguminous species is their high protein content, which is generally the most deficient component of an animal's diet (Ivory, 1990).

The most widely used tree species in grazing systems is *Leucaena* (Jones and Bray, 1982). *Gliricidia* has also been used for dairy production (Chadhokar and Lecamwasam, 1982;

Chadhokar, 1983b) and also it has been used for large and small ruminants in many part of the humid tropics (Coates, 1995). Thus, tree species must tolerate complete defoliation and damage from grazing animals as well as sustain rapid rates of regrowth from numerous growing points on the remaining stems following grazing. It is generally used as a high protein supplement to low quality basal feeds such as straws and other crop residues for increased weight gain and milk production in cattle and buffalo (Chadhokar, 1983a) and can be used as a substitute for more costly concentrate supplements in milking cows (Chadhokar, 1983b). For low quality feeds, *G. sepium* protein is most effectively used when fed at about 30% level (Simons and Stewart, 1994).

2.4 SUPPLEMENTARY FEED

Supplementary feed can come in the form of feed blocks, grains, fluids or extruded feeds which contain energy, protein or minerals (Lynch et. al, 1992). It can also come in the form of forage to supplying specific nutrients to supplement what is provided by a poor quality forage. Chadhokar (1983), for example, stated that some browse species can be used as sources of protein supplement for animals fed low quality basal feeds such as straws. Manyuchi *et al.* (1994) demonstrated that high quality forage supplements increased the intake of poor quality forage when the poor quality forage was offered as a basal diet to sheep.

Concentrate is a feed that is high in nitrogen-free extract and total digestible nutrients and low in crude fiber (less than 18% CF) and it may be either poor or rich in protein (Campbell and lasley, 1985). It includes cereal grains, soybean-oil meal, cottonseed meal, and by-products of the milling industry, such as corn gluten and wheat barn, those feed sources taken from a plant origin and some concentrate nutrients that can be extracted from an animal origin especially protein and minerals (e.g. fish meal, meat meal and blood meal). It is fed to sheep when their basal diet is in poor quality (e.g. energy deficiency) or when there are shortages in their feed (Hunter and Siebert, 1982). Also its used in pregnancy to avoid any nutrients deficiency (Pattinson *et al.*, 1998), and also it used for creep feeding to supply protein to avoid its deficiency and to obtain better growth rate (Chadwick, 1995).

Supplementary feeds have an effect on grazing time. For example, Holder (1962) found that feeding supplements to grazing animals reduce their grazing time, particularly when a concentrate ration is used. For example, Goetsch (1998) studied the effect of supplemental grain maize ((0, 0.5 and

1.0% body weight on DM basis) on intake, and on the grazing behaviour of Dorset ewes. Their results showed that grazing time decreased when the concentrate level increased. Similarly, Ewbank *et al.* (1994) found that increasing concentrate level (0, 0.7, 1.4 and 2.1 kg of concentrate/day) with milking ewes will reduce silage intake (0.876, 0.867, 0.694 and 0.633 kg/day respectively).

The time when the supplement is offered also affects the intake of forage. For example, Carro *et al.* (1994) found that intake of hay and total organic matter for sheep (12 adult wethers) was affected by the time at which concentrate was offered in relation to forage feeding. They found that the daily pattern of hay intake was not changed when concentrate was offered at 09.30 h compared with feeding hay alone, but concentrate given at 16.00 h resulted in a lower hay intake.

2.5 TECHNIQUES AND METHODS USED TO STUDY FEEDING BEHAVIOUR

2.5.1 Observation of feeding behaviour

The feeding behaviour of sheep can be monitored visually, noting at regular intervals whether or not each animals is eating, ruminating, standing, etc. Or by using video-recording. The visual method can be used for small group of animals, whereas the video-recording method can be used for both small or large group of animals and also it can be used either out-doors in the natural environment or in-doors.

2.5.2 Techniques used to study feeding behaviour under controlled condition

There are many techniques used to study eating behaviour under controlled conditions. Ortega-Reyes and Provenza (1993) used an artificial frame technique with video-recording to investigate the effect of experience and age on the development of foraging skills in goats browsing blackbrush. They used artificial frame technique to train goats to eat older growth twigs from blackbrush plants. They placed 4-6 branches in a wooden frame for each goat. They analyzed the video tapes to find out the total number of browsing attempts and also to find out the percentage of browsing attempts that were successful. Meuret (1988) used a cage technique to study browsing behaviour in goats. The goats were placed in large, comfortable cages, designed to suit their behaviour, and in front of the cages, leafy branches were clamped 3 by 3 in a tree-like structure, which allowed goats to select and browse from the offered forage in conditions as close as possible to those on rangeland.

They found that browsing behaviour in cages was similar to that measured on rangeland. And also they found that his technique using lactating goats and branches cut by hand in the forest, appears to be a reliable way of assessing actual use of tree and shrub foliage for goat production. Roguet *et al.* (1998) developed a mothed (test apparatus) to study feeding station (FS) behaviour of grazing ewes (Romanov X Limousin dry ewes). The test apparatus consisted of a rectangular pen with openings in one of the long sides through which the sheep could extend its head to graze.
Flores *et al.* (1989a) placing four plants (hycrest crested wheatgrass and serviceberry) growing in pots in a holes at regular intervals in a 2.5 x 2.5m plot to examine visually the effect of experience on the foraging skill of lambs.

2.5.3 Techniques used to study feed preferences or selection

Operant conditioning is a technique used to examine animal thought and motivation (Wood-Gush, 1993) and also it can show how much 'work' or energy an animal is willing to expend to receive the reward of food (Chalkley, 1997). Kilgour *et al.* (1991) reported that the operant procedure can be used in two ways; to study an animal's perceptual abilities and to assess their needs and/or preferences. Evaluation of "needs" provides an objective assessment that can be linked to management and welfare issues (Kilgour *et al.*, 1984; Nicol, 1994).

Also mazes can be used as a technique for studying eating behaviour, as they have been successfully used to test the feed preferences of an animal species. For example, Hosoi *et al.* (1995) conducted two experiments to examine the foraging behaviour of sheep and goats using a T-maze. In one experiment, animals were given two free choices in the maze. In each case, selection of either arm resulted in their obtaining high quality feed, a situation classified as a 'win'. A losing possibility was added in a second experiment by introducing low-quality feed into one arm of the maze.

Obstacles technique (e.g. weighted door) can also be used in preference experiments to gauge the strength or magnitude of an animal's preference for one feed or environment rather than another. For example, Chalkley (1997) used a weighted door as a measure of motivation in chickens, and in sheep (Aden, 1997). Also Cooper and Mason (1997) used the same technique to examine the behavioural priorities of mink.

2.5.4 Automatic techniques used to provide and measure feed intake

Wangsness *et al.* (1976) used a light beam and photocell to record the length of meals (feeding period) in sheep. The technique detected when a sheep had its head in the feeder and employed this to move a new container of food into the feeding area automatically if at least 20 min had elapsed since the previous meal. This technique has also been used to study the feeding behaviour of growing cattle (Chase *et al.*, 1976).

Suzuki *et al.* (1969) used continuous automatic recording of the weight of a food container. The duration of a meal is signalled by frequent oscillations in the weight of a container as it is disturbed by the animal's head. The weight of food eaten during that meal is the difference between the weights before and after the meal.

Electronic recognition allows a feed-dispensing system to recognize an animal's identity and to record the amount of food eaten by each individual (Forbes, 1995). Such systems are available commercially for the recording and/or control of concentrate allowance to individual dairy cows kept in groups (out-of-parlour dispensers; Broster *et al.*, 1982). This system cannot be used to dispense long roughages but if measurement of individual intake of hay or silage is required and animals cannot be fed individually then it is possible to use a marker dilution technique in which each animal is dosed by mouth with a known amount of an inert material. Chromic oxide has often been used, either given as a pellet or incorporated in a palatable feed (Forbes, 1995).

2.6 CONCLUSION

The conclusions drawn from the literature review are as follws:

1- sheep feeding is a complex process and the decision as to which food the sheep should consume, at what quantities and at what times is not a simple one because it depends on several factors including species specific, food specific (e.g. quality and quantity of forages, and whether the forages are provided alone or with supplement) and system of rearing or production .

2- Intake of feed depends on many factors including availability, palatability, acceptability, accessibility, experiences and preferences of the available feed. The presence of deleterious (toxic) substances can also limit the intake of food.

3- In the tropics, incorporation of tree and shrub fodders into sheep feeding systems is very important. This is because food is one of the major inputs into a sheep production system and inadequate feeding is usually considerd as a major factor determining the level of sheep production. Shrubs and tree fodders provide protein, vitamins and mineral elements which are lacking in grassland pastures during the dry and/or cold season and can be used as supplementary feed.

4- Supplementary feed can increase or decrease the intake and time spent on eating basal diet and this depends upon the quality and quantity of the available forages and on the quantity of supplementary feed offered.

5- There is information available on nutritional values and agronomy of browse species. There is also information about grazing behaviour in different animal species but less detailed information about browsing behaviour.

6- Sheep are intermediate-feeder. They are mainly grazers, but can depend on browse in some periods.

CHAPTER 3

PRELIMINARY STUDY TO INVESTIGATE THE USE OF HIGH-LEVEL FEEDERS TO EXAMINE THE FORAGING BEHAVIOUR OF SHEEP

EXPERIMENT 1

3.1 INTRODUCTION

The foraging behaviour of animals can be investigated using video-cameras or visual recording. For example, Ortega-Reyes and Provenza (1993) used video-recording to investigate the effect of experience and age on the development of foraging skills in goats browsing blackbrush. They analyzed the video tapes to find out the total number of browsing attempts and also to find out the percentage of browsing attempts that were successful. These authors also quantified the number of twigs ingested by breaking or chewing and the percentage success of breaking and chewing. Morgart (1990) used binoculars to observe the foraging behaviour of Desert Bighorn sheep in Arizona, a technique which has been used widely to observe behaviour in many wild and domestic species.

The foraging behaviour of housed sheep can also be observed using a technique such as that used by Ortega-

Reyes and Provenza (1993). They used an artificial frame technique to study goats eating older growth twigs from blackbrush plants. They placed 4-6 branches in a wooden frame for each goat. The frame was constructed by attaching (with screws) one wooden board (2″×6″×6′ inches) vertically to two wooden boards (2″×12″×2′ inches) placed horizontally on the ground as a base of support. A third wooden board (2″×6″×6′ inches) was not secured, but was free to move. Plant material was secured with metal clamps between the free wooden board and the wooden board that was attached to the base (Provenza, personal communication). Meuret (1988) used a cage technique to study browsing behaviour in goats. The goats were placed in large, comfortable cages, designed to suit the behaviour of goats, and in front of the cages, leafy branches were clamped 3 X 3 in a tree-like structure, which allowed goats to select and browse from the offered forage in conditions as close as possible to those on rangeland.

In this study the use of a specifically designed High-level feeder (HLF) as a source of forage was evaluated in in-door and out-door (grazing) experiments.

3.2 MATERIALS AND METHODS

3.2.1 Experiments

Experiment 1a:

Adaptation

On the first day of the adaptation period animals were adapted to the environment of the pen for 2 hours and provided with hay and straw on feeders. The HLF was present but without any browse materials. On the second day the animals were adapted to eating ivy and sycamore from the HLF once a day and to foraging hay from a side feeder for 2 hours. In the third day the animals were adapted to eating ivy and sycamore from the HLF and to foraging straw from a side feeder for 2 hours. On the fourth day the animals were adapted to eating ivy and sycamore from the HLF to eat concentrate from a side feeder for 2 hours. The animals of Cambridge and Welsh Mountain ewes were kept grazing together outside before and after the observations. The hypothesis of this experiment was described in Table 1.2.

Experiment

This experiment was conducted in-doors with four treatments, each having a HLF (Section 3.2.3) containing a mixture of Ivy and Sycamore. The experiment was conducted over four days. Each treatment was conducted in each day with two hours of observations without replications of treatments. The treatments were:

1- High-level feeder only.

2- High-level feeder + Straw .

3- High-level feeder + Hay.

4- High-level feeder + Concentrate.

The branches placed in the high-level feeders for foraging were collected daily from a woodland area on the College Farm, University of Wales, Bangor. The two types of tree branches that were used in the high-level feeder during foraging were Ivy and Sycamore. Branches of these species were used because they are commonly foraged by sheep and were available in reasonable abundance at the farm where the experiment was conducted. The experiment was conducted in October 1995. Branches of Sycamore and Ivy were placed so as to hang upward on the square weldmesh of the basket of the high-level feeders, to allow ewes to forage from them as if they were foraging or browsing from a tree.

In Treatments 2 and 3 the animals also had access to hay and straw *ad libitum* from the side feeders. The feeders (baskets) were supported on the side of the pen. The measurements of the hay and straw feeder trough were, top measurement 47cm × 47cm, height was 50cm and the base measurement was 39cm × 15cm. The concentrate intake in Treatment 4 was restricted to 2kg fed from a metal rectangular-shape trough placed on the floor inside the pen, fed once per day at the beginning of the recording period. The concentrate contained protein 18%, oil 2.5%, fibre 13%, ash 8%, vitamin A 10000iu/kg, vitamin D3 2000iu/kg, vitamin E 20iu/kg and sodium selenite & selenium 0.35mg/kg, and the ingredients are shown in Appendix 1. The concentrate was made specifically for sheep by a commercial company (Frankland Feed Ltd.).

Experiment 1b:

Adaptation

The same animals of Cambridge and Welsh Mountain ewes that used in the in-door experiment were used in out-door experiment and they were kept in the same observation plot grazing together before and after observation. The animals were provided with ivy and sycamore on the high-level feeders and provided twice a day one time in the morning and one time in the after noon and repeated three times.

Experiment

This experiment was conducted outside in a grazing situation for one day without replication and was designed purely to observe whether the sheep showed interest in eating ivy and sycamore from high-level feeders when grazing was available. The sward height during grazing was between 2cm to 3cm. The high-level feeder contained Ivy and Sycamore as described for Experiment 1a.

3.2.2 Animals and pens

Eight dry ewes (four Cambridge and four Welsh Mountain) were selected randomly from animals aged 3-4 years from flocks at the College Farm, University of Wales, Bangor. In the in-door experiment, the ewes were kept in a pen (8.5 m × 6 m). The same animals were used in the out-door experiment where the ewes were kept in a grazing area (37m × 25m); the grazing area was predominatly perennial ryegrass and white clover .

3.2.3 Design of the High-Level Feeder (HLF)

A high-level feeder was designed to simulate as closely as possible a tree of medium height (from 100cm to 130cm). The HLF presented animals with feed at above head height. The basket containing feed was mounted onto a metal rod corresponding to the trunk of a tree. The HLF allowed feed to be presented in a defined way, in terms of type and quality. So the HLF can be used as an artificial tree (AT), or as a feeder for hay and straw when foraging behaviour and selection are to be examined. When animals ate feed from the HLF, the term given to this action was "eating or foraging".

The high-level feeders were made from metal and are illustrated in Figure 1 (page 50). It consisted of a pipe rod, 112cm high and 7.5cm in diameter (1); this rod was perforated with several holes, the distance between the holes was 7.5cm (2); to adjust the height of the cone shaped basket. The basket was 50cm × 50cm (3) and made from 7cm square weldmesh. Tree branches or Ivy were located in this basket. The HLF was fixed in the ground by a wheel (4) which was made from metal. The height of tree during observations was 130cm from the ground to the top of the basket.

3.2.4 Observations

3.2.4.1 In-door observations

The activities of all ewes were recorded every five minutes for a total of two hours per day for each treatment (10.00 to 12.00 h). Six categories of activity were observed in this study, eating ivy and sycamore from the HLF, eating of concentrate supplement, hay and straw from the side-feeder, standing, ruminating, lying and walking.

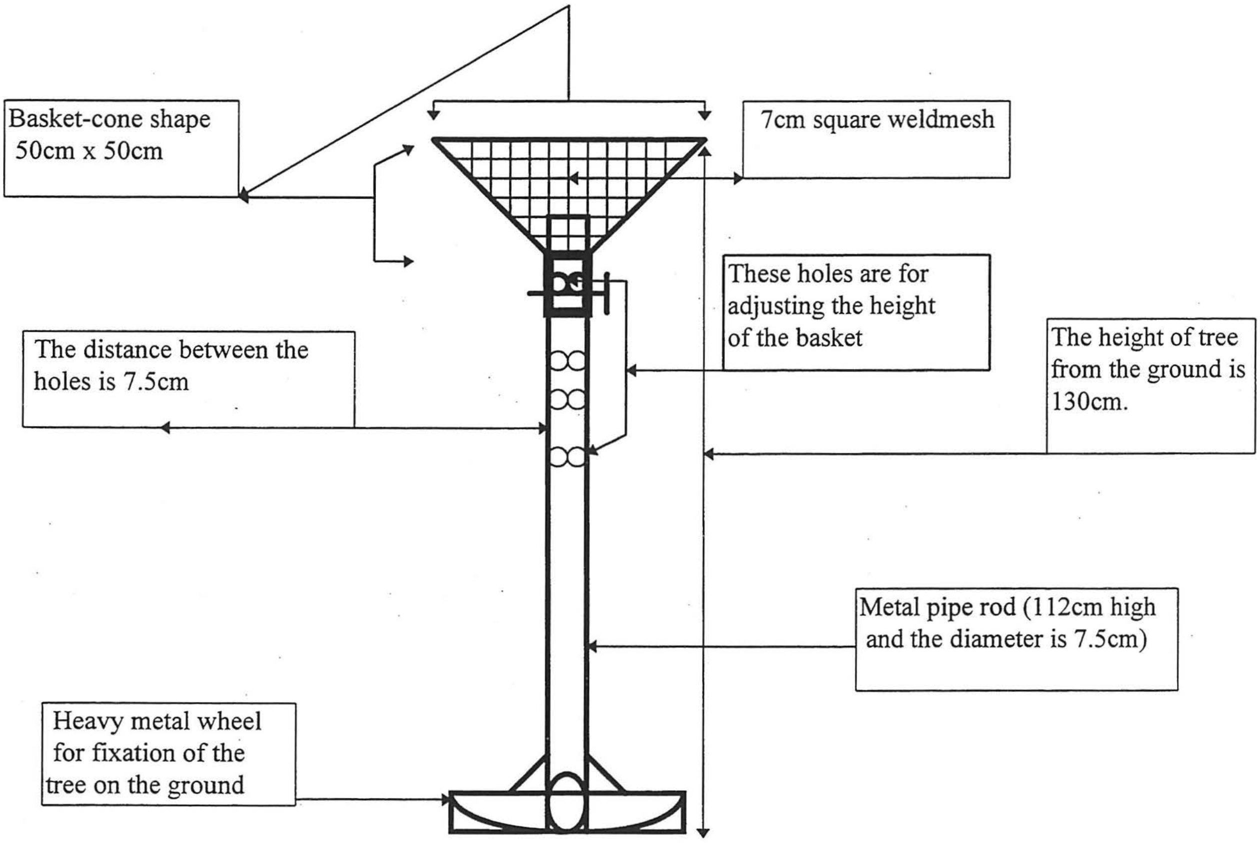

Figure 1. Design of the high-level feeder

Browsing:

The sheep ate browse by picking or biting in a standing position and sometimes stood on their hind legs as shown in (Figure 2a), moving their head towards the branches of the HLF.

Standing:

Including standing while urinating, defecating, ruminating or looking.

Lying:

Sheep were lying in lateral recumbency-resting, sleeping or ruminating.

Walking:

Walking or running, with head up, did not include steps taken while grazing.

The observations of these activities were taken from a window which was located in the second floor of a barn adjacent to the experimental pen.

3.2.4.2 Out-door observation (grazing)

The activities of all ewes were recorded every five minutes, and the observation times were (10.00 to 12.00 h and from 14.00 to 16.00 h). The behaviour categories observed were the same as those observed in the in-door experiment with the addition of times spent grazing. Animals were observed from a point located away from the plot using binoculars to avoid disturbing the animals.

3.2.5 Statistical analysis

The time spent by ewes performing the activities were calculated from the real-time recordings. The average time spent in each individual behaviour was calculated for each ewe as follows:

$$TS = TI \times 5 \qquad \text{----------} \quad (1)$$

Where **TS** = Time spent on each behaviour activity (minutes).

TI = Total incidence of each behaviour for all sheep.

5= The recording interval (behaviour was recorded for each animal every 5 minutes).

The average percentage time spent in each individual behaviour was calculated as follows:

$$T = \frac{TA \times 100}{TL} \qquad \text{----------} \quad (2)$$

Where **T** = Percentage (%) time spent on each behaviour activity.

TA = Average time spent on each behaviour activity.

TL = Total Length of the recording period (minutes).

T was calculated separately for each ewe and for each activity.

Two statistical procedures were used, namely, chisquare and analysis of variance (ANOVA). ANOVA was used to examine the effect of treatments on individual behaviours. Chisquare examined the effect of treatments on the distribution of time accross all behaviours. Percentage time spent by treatments and activities was analyzed by chisquare for each breed and for both breeds combined. The analysis was completed using the MINITAB statistical package (Minitab, 1994).

Prior to ANOVA data for each behaviour were checked for normality. For the indoor experiment browsing activity was not adujsted because the data were normally distributed, however the other behaviour activities were adjusted using a square root transformation. For the out-door experiment data were not adjusted because they were normally distributed. For the indoor experiment the ANOVA examined the effect on behaviour of breed and treatment and using ewes within breeds as random factors. For the out-door experiment the effect of breed only was examined.

3.3 RESULTS

3.3.1 In-door experiment

Generally Cambridge ewes spent more time eating ivy and sycamore from the HLF than did Welsh Mountain ewes. This was observed on all treatments except on the concentrate treatment in which the Welsh Mountain ewes spent more time eating ivy and sycamore from the HLF than Cambridge ewes did (49.2% and 45.8%, respectively). The time spent eating ivy and sycamore from the HLF showed significant difference between treatments ($P<0.05$). The ewes spent more time eating ivy and sycamore on the concentrate and straw treatments than they did on the other treatments. and also the time spent eating hay, straw and concentrate supplement differed between treatments ($P<0.001$) with more time spent eating hay and concentrate than spent eating straw.

3.3.1.1 The difference between treatments for Cambridge ewes in the in-door experiment.

Treatments had significant effects on the overall behaviour of Cambridge ewes (chisquare statistic-$P<0.05$). Generally, provision of hay, straw and concentrate supplement to Cambridge ewes led to an increase in the time spent eating ivy and sycamore from the HLF (40.8%-45.8%). Provision of hay led to an increase in the time spent ruminating (20.8%) compared to the other treatments. Also provision of hay increased the time spent standing and ruminating rather than standing only compared to the HLF only and HLF + straw treatments. Provision of concentrate markedly affected the behaviour patterns of Cambridge ewes. They spent more time eating ivy and sycamore from the HLF, lying and standing when concentrates were available and less time ruminating (Table 3.1).

3.3.1.2 The difference between treatments for Welsh Mountain ewes in the in-door experiment.

Treatments had significant effects on the overall behaviour of Welsh Mountain ewes (chisquare statistic- $P<0.05$). Generally, Welsh Mountain ewes showed interest both in eating ivy and sycamore from the HLF and eating hay, straw and concentrate supplement. On the HLF only, AT + straw and HLF + hay treatments Welsh Mountain ewes spent most of their time eating ivy and sycamore from the HLF (24%, 27% and 20%, respectively) and standing (49%, 51% and 34%, respectively).

Table 3.1. Percentage (%) and mean time (minute) spent by different breeds in different activities for the in-door experiment.

Treatment	Breed *	Eating ivy & sycamore	Lying	Ruminate	Stand.	Walk	Eating**
HLF only	Camb.%	37.5	5.2	16.7	31.3	9.3	------
	WM. %	24.1	7.5	3.3	49.1	16	------
	ALL%	**30.8**	**6.3**	**10**	**40.2**	**12.7**	------
	ALL time*	**36.9**	**1.4**	**11.9**	**6.6**	**3.8**	------
HLF +Straw	Camb.%	40.8	9.3	12.4	37.5	00.0	00.0
	WM.%	27.0	6.2	9.6	51.0	5.2	1.0
	ALL %	**33.9**	**7.8**	**11**	**44.2**	**2.6**	**0.5**
	ALL time*	**40.6**	**2.02**	**13.1**	**7.1**	**1.04**	**0.3**
HLF +Hay	Camb.%	40.8	00.0	20.8	13.4	1.0	24.1
	WM.%	20	2.0	17.8	34	3.3	22.9
	ALL%	**30.4**	**1.0**	**19.3**	**23.7**	**2.1**	**23.5**
	ALL time*	**36.3**	**0.6**	**23.1**	**4.8**	**1.1**	**4.8**
HLF + Concentrate	Camb.%	45.8	11.6	00.0	13.5	6.2	22.9
	WM. %	49.2	1.0	11.7	8.2	15.8	14.1
	ALL %	**47.5**	**6.3**	**5.9**	**10.9**	**11.0**	**18.5**
	ALL time*	**56.9**	**1.6**	**6.9**	**3.3**	**3.3**	**4.7**
P-Value for treatments across both breeds		0.013	0.397	0.024	<0.001	<0.001	<0.001

(Breed *) Camb.% = Percentage time spent by Cambridge; WM.%= Percentage time spent by Welsh Mountain ewes. ALL % = Percentage of time spent by both breed.
(**) Eating Straw, Hay or Concentrate on Treatments 2, 3 and 4 respectively. ALL time*=The means of times (minutes) spent by both breeds. The data of eating ivy & sycamore and ruminating activities were not adujsted because the data were normally distributed. The other behaviour activities were adjusted using a square root transformation.

Provision of concentrate increased the time spent eating ivy and sycamore from the HLF (49%) and decreased the time spent standing (8%) and lying (1%) compared with the other treatments (Table 3.1). On the HLF + hay treatment, time spent eating hay (22.9%) was greater than the time spent eating ivy and sycamore from the HLF (20%) compared with that of the other treatments (Table 3.1).

3.3.1.3 The difference between treatments for both breeds combined in the in-door experiment.

Treatments had significant effects on the overall behaviour of ewes across both breeds (chisquare statistic-$P<0.05$). There were significant differences in the time spent eating ivy and sycamore from the HLF between treatments ($P< 0.05$). The ewes spent more time eating ivy and sycamore on the concentrate and straw treatments than they did on the other treatments.

The results of behaviour activities of both breeds on the HLF only and HLF + straw treatments were similar except that the animals walked less when straw was available. Provision of hay did not alter the time spent eating ivy and sycamore from the high-level feeders but the animals spent more time standing and ruminating rather than standing only compared to the HLF only and HLF + straw treatments. The times spent eating hay by both breeds (23.5%) was more than the time spent eating straw (0.5%) as shown in Table 3.1. Provision of concentrate markedly affected the behaviour patterns of the animals. Eating of ivy and sycamore time increased whilst standing time decreased.

3.3.1.4 The difference between breeds and between ewes within breeds in the in-doors experiment.

Generally Table 3.2 shows that there were no significant differences between the behaviour of ewes within breed except on eating ivy and sycamore from the HLF, ruminating and standing which showed significance differences between ewes within breed ($P<0.05$ and $P<0.001$ respectively).

Also Table 3.2 shows that times spent eating ivy and sycamore by Cambridge ewes was greater ($P= 0.007$) than the time spent by Welsh Mountain ewes (49min. and 36min. respectively). The times spent eating hay, straw and concentrate supplement did not differ between breeds ($P>0.05$).

The times spent standing and walking by Welsh Mountain ewes (6.0min. and 3.1min. respectively) were greater than that observed for Cambridge ewes (4.8min. and 1.5min. respectively). Cambridge ewes spent more time lying and ruminating than did Welsh Mountain ewes as shown in Table 3.2.

Table 3.2. The means and probabilities for times (minute) spent on the various behaviour activities by Cambridge and Welsh Mountain ewes in the in-door experiment.

Breed	Eating ivy & sycamore	Stand.	Ruminating	Lying	Walk	Eating**
Cambridge	49.4	4.8	15.0	1.7	1.5	2.4
Welsh	35.9	6.0	12.5	1.3	3.1	2.4
P-Value for individual ewes within breed	**<0.001**	**<0.001**	**0.004**	**0.101**	**0.215**	**0.545**
P-Value for different between breeds	**0.007**	**0.014**	**0.478**	**0.429**	**0.001**	**0.318**

(**) Eating Straw, Hay or Concentrate.

The data for eating ivy and sycamore activity were not adujsted because the data were normally distributed. The other behaviour activities were adjusted using a square root transformation.

3.3.2 Outdoor experiment.

Generally both breeds showed interest in eating ivy and sycamore from the HLF while at pasture. The animals spent most of their times grazing, eating ivy and sycamore and ruminating (94min, 61min. and 38.8min. respectively) compared to the other behaviour activities as shown in Table 3.3. Cambridge ewes spent more time eating ivy and sycamore from the HLF ($P<0.05$) than did Welsh Mountain ewes (74min. and 49min. respectively). Welsh Mountain ewes spent more time grazing ($P<0.05$) than Cambridge ewes.

Table 3.3. Percentage (%) and mean time (minute) spent by Cambridge and Welsh Mountain ewes in different activities for the out-door experiment (grazing environment).

Breed *[1]	Eating ivy & sycamore	Lying	Rumminating	Stand.	Walk	Grazing
Camb.%	30.3	10.9	25.5	6.2	5.3	21.8
Cambridge mean time	73.8	26.3	61.3	15	11.3	52.5
WM. %	20.3	8.3	6.8	6.7	6.7	56.2
Welsh ewe mean time	48.75	3.75	16.3	16.3	16.3	135
ALL%	**25.3**	**9.6**	**12.7**	**6.5**	**6**	**39.0**
ALL time*[2]	**61.3**	**15**	**38.8**	**15.6**	**13.8**	**93.8**
P-Value for the effect of breed	**0.027**	**0.002**	**0.007**	**0.829**	**0.304**	**0.001**

(Breed *[1]) Camb.% = Percentage time spent by Cambridge; WM.%= Percentage time spent by Welsh Mountain ewes. ALL % = Percentage of time spent by both breed.

ALL time*[2]=The means of times (minutes) spent by both breeds.

3.4 DISCUSSION

The experiments investigated the use of a high-level feeder (HLF) to observe foraging behaviour of sheep in an in-door and out-door environment. Animals spent 30%-48% of their time eating ivy and sycamore from the HLF in the in-door environment and 25% in the grazing environment. These percentages suggest that if grass is available then ewes spend less time eating from the HLF. However, the results also demonstrate that sheep will eat ivy and sycamore from the HLF both in-doors and in a grazing environment. Meuret (1988) examined browsing behaviour in goats using cages and found that browsing behaviour in cages was similar to that measured on rangeland. This supports the use of the HLF technique to examine browsing behaviour both in-doors and out-doors because Meuret (1988) found that there were no differences between the behaviour of animal in an in-door experiment and on rangeland. Additionally, in present study, ewes showed similar interest in eating from the HLF in both the in-door and out-door experiments. This supports the use of the HLF in further in-door experiments.

The results showed that Cambridge ewes spent more time eating ivy and sycamore than did Welsh Mountain ewes. This is probably due to the larger size and weight of the Cambridge which competed and prevented Welsh Mountain ewes from eating ivy and sycamore. Demment and Van Soest (1985) found that large ruminants might be less selective and foraged more than small ruminants because larger animals require higher daily dry matter intake. A further study is required to determine the exact reason why Cambridge ewes ate ivy and sycamore for longer than Welsh Mountain, since in this experiment there were no treatments that allowed a comparison of Welsh alone with Cambridge+Welsh Mountain.

The narrow muzzle and cone-shape of their heads allowed ewes to squeeze their heads between the branches in the basket of the high-level feeders to select the small leaves of ivy and sycamore. The observed behaviour pattern of ewes during eating ivy and sycamore from the HLF was moving their head forward and downward (jerking movement of the head) and then cutting leaves using all parts of their mouths (lips, tongue, and teeth). They ate leaves and stems from the HLF. Also it was observed that some of the Cambridge ewes were standing in their hind legs to reach over hanging leaves. These observations suggest that ewes ate from the HLF in a manner similar to a real tree.

The high-level feeder technique provides opportunities to investigate the foraging behaviour of animals and their intake of specific forage or browse species. Studying these topics in desert or rangeland conditions is difficult and expensive. The high-level feeder technique could therefore play an important role in the studying of animal foraging behaviour, forage selectivity, preferences and forage intake. For example, selection of species by animals can be examined by using several high-level feeders, each HLF having different forage or browse species.

During eating of ivy and sycamore by ewes from the HLF, it was observed that animals sometimes pulled out the leaves of the branches very hard and this lead to branches falling on the ground. This wastage is hard to incorporate into calculations to estimate intake and is a disadvantage of the technique. For small-leaved browse species the HLF basket could be modified by using wire mesh with smaller holes. The losses were minimal for the type of browse (Ivy/ Sycamore) examined in this study.

The conclusion drawn from these experiments is that the high-level feeder technique can be used to simulate foraging from a tree since the behaviour of ewes during eating ivy and sycamore from the HLF was similar to that observed when they eat from real tree. It was observed (Alshami, unpublished) that when sheep graze in open areas, when they find trees they went to the trees and ate from them. Their eating behaviour was generally similar to that observed when they ate from the HLF. It is interesting to consider how sheep perceive the HLF. It is likely that the most important driving force for sheep is food consumption and whether that food is on the HLF or on real trees they attempt to eat from them. Sheep may consider both the HLF and a real tree as objects that contain food. The HLF technique therefore, provides a method to investigate the foraging behaviour of sheep in both in-door and grazing environments. The technique was applied in a series of experiments as described in Table 1.2.

Figure 2a. Ewe standing on its hind legs to reach ivy from the HLF (Photographed by S. AL-Shami).

Figure 2b. Sheep eating ivy from the HLF in a grazing environment (Photographed by S. AL-Shami).

CHAPTER 4

THE EFFECT OF ALTERNATIVE FEED SOURCES ON THE BEHAVIOUR OF WELSH MOUNTAIN AND CAMBRIDGE EWES GIVEN ACCESS TO IVY ON A HIGH-LEVEL FEEDER

EXPERIMENT 2

4.1 INTRODUCTION

Forage from trees and shrubs, in browsing or cut-and-carry systems, normally represents a component of the total feed provided to livestock, with grazed pastures, supplementary forage, concentrates or by-products making up the remainder. Use of browse as a feed for animals can improve feed intake of low quality feed. Norton and Poppi (1995) noted that with low quality hays/straws, supplementation with browse from leguminous trees results in an increased digestion and feed intake. In other situations, where browse is the basal diet, concentrate supplementation can reduce browse\forage intake (Ewbank *et al.*, 1994). The impact of browse on the intake of poorer forage or of higher quality supplements on browse intake depends on a variety of factors including feed characteristics and the type and productive state of animals. During growth and lactation, for example, direct replacement by browse species of concentrate feed may reduce dietary energy supply and animal performance may be adversely affected. Wong *et al.* (1987) studied milk production in *Sahiwal x Friesian* cows grazing *Leucaena-Brachiaria decumbens* pasture and given concentrate supplementation. They found that supplementation increased milk production and growth rate. The impact of supplementation on browse intake is also associated with changes in behaviour and feed utilisation. Landau *et al.* (1993) studied the effects of two levels of concentrate supplementation on dairy goats browsing Mediterranean scrubland, and found that animals on the high level of concentrate had reduced grazing time. Foraging behaviour and intake are also affected by animal species. Dulphy *et al.* (1990) compared feed intake, feeding activities (such as time spent eating daily and number of meals daily) and ruminating-chewing activities in adult Texel wether sheep, non-lactating Limousin ewes, non-lactating Alpine goats, crossbred steers and lactating Holstein cows. They were fed on maize silage, early or late hay and grass silage alone or with 30% concentrate. They found that there were species variation on time spent eating and rumination, and also they found that animals respond to diet changes.

Differences between breeds with regard to browsing or feeding behaviour are not well documented. For example, Komwihangilo (1994) investigated the behaviour of sheep under stall feeding conditions, and suggested that differences might exist in feeding behaviour between breeds of the same species and recommended further study.

The aim of this experiment was to investigate the effect of the availability of alternative feed sources on the eating behaviour of Welsh Mountain and Cambridge ewes given access to ivy on a high-level feeder (HLF). The hypothesis of this experiment was described in Table 1.2.

4.2 MATERIALS AND METHODS

4.2.1 Adaptation

The experiment was carried out at the end of November 1995. The animals of both breeds were adapted together in an in-door pen (8.5m × 6m) three hours per day for six days (the first three day were in the morning (09.00-12.00 h) and the last three days were in the after noon (13.00-16.00 h). On the first day of adaptation the animals had access to ivy from the HLF without any additional feed. On the second day of adaptation the animals had access to ivy from HLF once in morning and were also provided with 2kg concentrate as a supplement. On the third day the animals had access to ivy from the HLF and also they were provided with hay *ad libitum* from a side-feeder. The same procedure were repeated for a further three days but in the afternoon. Before and after the adaptation and observation periods the animals of each breed were kept grazing out-side in separate flocks.

4.2.2 Animals and experimental design.

A randomised complete block design was used to conduct an in-door experiment using three treatments [ivy only (I), concentrate + ivy (C), hay + ivy (H)], using weeks as a blocking factor with each treatment conducted in a day using three days per week. Treatments were allocated at random to days. Eight dry ewes, four Cambridge and four Welsh Mountain (WM), were selected randomly at age 2-6 years and 5 years old for Cambridge and WM ewes respectively from a flock at the College Farm, University of Wales, Bangor. Prior to the experiment the weight of each animal was recorded.

4.2.3 Treatments

Three treatments were used:-

Treatment 1: Ivy only (I). Animals had *ad libitum* access to ivy from the HLF (3 trees) without any additional feeds were provided. The design of high-level feeder (HLF) was as described in Section 3.2.3.

Treatment 2: Concentrate supplement + ivy. Animals had *ad libitum* access to ivy from the HLF (3 trees) and 2kg concentrates was fed as a supplement, and it was provided once at the beginning of the observation period. The concentrate allowance was limited to 2kg, being an upper limit beyond which digestive problems can result. The concentrate was described in Section 3.2.1.

Treatment 3: Hay + ivy. Animals had *ad libitum* access to hay located on wire feeders at a side of the pen (side-feeder). Two types of side feeders (small and large) were used. The measurements of the small feeder were, top measurement 47cm × 47cm, height 50cm and base measurement 39cm × 15cm. The measurements of the large feeder were, top measurement 53cm × 53cm, height 107cm and the base measurement 45cm × 23cm. Sheep had *ad libitum* access to ivy from the HLF (3 trees).

4.2.4 Feed intake of ivy, hay and concentrate supplement

The weights of ivy branches and hay and concentrate supplement were recorded before and after feeding. Feed intake was calculated as the difference between quantity of feed offered and quantity of feed refused.

4.2.5 Observations

The activities of all ewes were scored every five minutes for six hours of observations per treatment (from 9.00 to

12.00 h and from 13.00 to 16.00 h). The categories of activity were as described in Section 3.2.4.1.

4.2.6 Measurements of leaf area

Twenty-thirty branches were selected at random from walls around fields of the College Farm and weighed. One hundred leaves were removed at random from the branches and weighed and their area measured using an automatic area meter (Model AAM-7, Hayashi Denkoh Co.LTD). Leaf areas were measured weekly.

4.2.7 Proximate analysis for Ivy

Ivy leaves were collected as described in Section 4.2.5. Proximate analysis (moisture, DM, CP, CF, crude fat and ash) were carried out for these samples.

4.2.8 Statistical Analysis

The time spent by ewes performing the activities were calculated from the real-time recordings. The average and percentage time spent in each individual behaviour were calculated using the formulae described in Section 3.2.5. The results of percentage time spent by treatments and activities was analysed by Chi-square analysis for each breed and for both breeds combined. The analysis was completed using the Minitab statistical package (Minitab, 1994).

Prior to ANOVA, data for each behaviour were checked for normality. Data of behaviour activities were adjusted using a square root transformation because the data were not normally distributed. Adjusted behaviour activities were analysed by ANOVA to determine the effect of breed and treatments using a model that included treatments, breeds and replications (week) as fixed effects and ewes within breed as a random effects. Comparable models were also used to examine the effect of treatments on ivy and hay and concentrate supplement intake.

4.3 RESULTS

Table 4.1 shows the number of animals, mean weight (kg), and standard deviation for each breed. The mean weight of Cambridge ewes was higher than the weight of Welsh Mountain ewes (67.3kg and 39.5kg, respectively).

Table 4.1. Number of animals, mean weight (kg), and standard deviation for each breed.

Breed	Number of animals	Mean weight (kg)	Standard deviation (kg)
Cambridge	4	67.3	11.76
Welsh Mountain	4	39.5	4.65

4.3.1 The difference between breeds in the times spent on various behaviour activities.

Both breeds showed interest in eating ivy from the HLF, but Cambridge ewes spent more time eating ivy from the HLF than did Welsh Mountain ewes ($P<0.001$) as shown in Table 4.2. The times spent eating ivy, ruminating and eating hay and concentrate supplement by Cambridge ewes (9.7 min., 11.3min., and 4.6min., respectively) were greater than the times spent by Welsh Mountain ewes (6.4min., 8.02min., and

3.5min., respectively). In contrast, Welsh Mountain ewes spent more time standing, lying and walking than did Cambridge ewes as shown in Table 4.2.

Table 4.2. The means of the times (minutes) spent on the various behaviour activities by Cambridge and Welsh Mountain ewes (mean across treatments).

Breed	Eating ivy	Stand.	Rumuminating	Lying	Walk	Eating**
Cambridge	9.77	8.02	11.3	5.50	5.86	4.69
Welsh	6.44	9.38	8.02	9.84	7.06	3.50
P-value	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.002**	**<0.001**

(**) Eating Hay and Concentrate supplement.

4.3.2 The difference between individual ewes within breeds and also the difference between treatments across both breeds and also the difference between replicates.

Generally, the results show that there were significant differences between all the behaviour activities of individual ewes within breeds except the time spent on eating hay and concentrate supplement which showed no significant difference (P>0.05) as shown in the first P-value of Table 4.3. Also the results show that there were no significant differences between replicates in the time spent on various behaviour activities (P>0.05) as shown in the third P-value of Table 4.3.

In this experiment the chi-square analysis revealed significant differences between the times spent on various behaviour activities in the different treatments ($P<0.05$). On all treatments both breeds spent most of their time eating ivy from the HLF, lying and standing. The percentage time spent eating ivy by both breeds on the ivy only treatment was greater ($P<0.05$) than on the concentrates + ivy and hay + ivy treatments (24%, 20%, 17%, respectively) as shown in Table 4.3. The time spent lying on the ivy only and concentrate + ivy treatments was greater than the time spent on this behaviour when hay was provided (22%, 26% and 14%, respectively). Both breeds ruminated more on the hay + ivy treatment (23.5%) than they did on the concentrate + ivy (10.5%) and ivy only treatments (15.5%). Walking decreased when hay and concentrate supplement was available.

4.3.2.1 Behaviour of Cambridge ewes

Cambridge ewes showed good interest in eating ivy from the HLF and spent most of their time (26%-31.3%) eating ivy from the HLF compared to the other activities. Chi-square analysis revealed significant differences between the behaviour activities of Cambridge ewes across treatments

(P<0.05). Provision of hay and concentrate supplement markedly affected the behaviour pattern.

Table 4.3. Percentage (%), means and probabilities for the time (minute) spent by different breeds in different activities for each treatment.

Treatment	Breed *1	Eating ivy	Lying	Ruminating	Stand	Walk	Eating**
Ivy only	Camb.%	31.3	14	19.9	22.4	12.0	-------
	WM. %	16.5	30.1	11.1	25.7	16.3	-------
	ALL%	**23.9**	**22.0**	**15.5**	**24.1**	**14.1**	-------
	ALLtime*2	**8.9**	**8.4**	**9.6**	**9.1**	**6.9**	-------
Concentrate supplement + Ivy	Camb.%	26.3	16.2	12.5	21.9	11.5	11.2
	WM.%	13.3	34.8	9.3	21.9	12.0	8.5
	ALL %	**19.8**	**25.5**	**10.9**	**21.9**	**11.8**	**9.8**
	ALLtime*2	**7.8**	**8.6**	**7.6**	**8.6**	**6.4**	**5.8**
Hay + Ivy	Camb.%	26.0	5.6	30.2	12.9	7.6	17.3
	WM.%	8.6	22.1	16.8	29.6	14.6	7.9
	ALL%	**17.3**	**13.8**	**23.5**	**21.2**	**11.1**	**12.6**
	ALL time*2	**7.4**	**6.06**	**11.8**	**8.45**	**6.03**	**6.47**
1-P-value for between indiv within breeds	different idual ewes	<0.001	<0.001	0.007	<0.001	0.042	0.152
2-P-Value for of different	activities treatments	0.041	0.001	<0.001	0.001	0.074	<0.001
3-P-value for between repli	different cates	0.798	0.060	0.988	0.099	0.390	0.858

(Breed *1) Camb.% = Percentage time spent by Cambridge; WM.%= Percentage time spent by Welsh Mountain. (**) Eating either hay or concentrate supplement. ALL % = Percentage of time spent by both breed. ALL time*2=The means of times (minutes) spent by both breeds. (The means of times for the all behaviour activities were adjusted using square root transformation.

The time spent eating ivy decreased when hay and concentrate supplement were provided. On these treatments ewes spent 26.3% and 26.0% (concentrate and hay respectively) eating ivy from the HLF, whereas in the ivy only treatment they spent 31%. On the ivy only treatment Cambridge ewes spent most of their time eating ivy and standing (31.3% and 22.4%

respectively) compared to the hay + ivy and concentrate + ivy treatments. The provision of hay to Cambridge ewes affected their behaviour patterns, decreasing the time spent eating ivy, lying, walking and standing (26%, 6%, 8% and 13% respectively) and increasing the time spent ruminating and eating of hay (30.2% and 17% respectively) compared to other treatments (Table 4.3).

4.3.2.2 Behaviour of Welsh Mountain ewes

Welsh Mountain ewes spent more time eating ivy from the HLF when there were no hay and concentrate supplement provided to them (17%). Also the chi-square analysis for the percentage times spent by Welsh Mountain ewes on the various activities reflects that there were significant effects of treatment on distribution of behaviour activities of Welsh Mountain ewes. The time spent by Welsh Mountain ewes lying, standing and walking was greater than the time spent eating ivy and on other activities. Provision of hay and concentrate supplement to Welsh Mountain ewes affected their behaviour, decreasing time spent eating ivy from HLF and increasing lying and standing time. On the concentrate + ivy and ivy only treatments ewes spent more time lying than they did on the hay + ivy treatment (35%, 30% and 22% respectively). On the hay + ivy treatment ewes spent more time ruminating than they did on the other treatments (16.8%).

4.3.3 Feed intake of ivy, hay and concentrate supplement.

Table 4.4 shows ivy, hay and concentrate supplement intakes and residues for each treatment. The intake of browse (ivy) was significantly affected by treatments (P<0.05), which increased by 1kg when there was no hay and concentrate supplement available to ewes. The intake of hay and concentrate supplement showed no significant difference between treatments as shown in Table 4.4.

Table 4.4. The means of ivy, hay and concentrate supplement fresh weight intake and residue.

Treatment	Weight of ivy leaves and Branches (kg)		Concentrate and hay weight (kg)		Intake (kg per day)	
	Before	Residual	Before	Residual	ivy	H or Conc.*
ivy only	8	4.6	------	-------	3.4	-----
Concentrate + ivy	8	5.8	2hay	0	2.2	2 Conc.
Hay + ivy	8	5.6	4Conc.	2.3	2.4	1.7 hay
P-value					0.025	0.184

H or Conc.*= Eating Hay or Concentrate supplement.

4.3.4 Ivy composition

Ivy contained 56.4% dry matter, 24.8% crude protein, 21.3% Ash and 37.2% crude fibre (Appendix 2).

4.3.5 The weight of ivy materials and measurements of leaf area

Table 4.5 shows the weight of branches and leaves and the leaf area measurements for each week. Approximately 5.3kg branches + leaves were used, of which 1.4kg was leaves.

Table 4.5. Mean weight (branches and leaves) and the leaf area measurements and leaf weights.

WEEK	Number of branches/kg fresh weight	Branches & Leaf Weight kg	Means branch length (cm)	Leaf weight kg	Leaf area measurement per 100 leaves cm^2
1	5.0	5	70	1.37	1540
2	4.2	7	69	1.42	1580
3	5.0	4	75	1.26	1460
Means	4.7	5.3	71.3	1.35	1526

4.4 DISCUSSION

In this experiment sheep showed interest in eating ivy from the high-level feeder (HLF) and spent 17% to 24% of their time on this activity. The results of this experiment also showed that when ivy was provided alone the time spent eating ivy from the HLF was greater ($P<0.05$) than when other feeds were also provided (24% eating ivy in ivy only, 20% in concentrates + ivy, 17% in hay+ ivy). This indicates that the provision of additional feeds reduced the time spent eating ivy from the HLF. The results also showed that type of additional feed can have an affect on the time spent eating ivy from the HLF. Provision of concentrate did not have such a large impact on time spent eating ivy from the HLF as hay did. This is probably due to the fact that the quantity of concentrate was limited in this study. This fact confirms what was discussed in the literature review (Section 2.4), that time spent eating from a basal diet is decreased by providing concentrate (Ewbank *et al.*, 1994 and Goetsch, 1998).

Provision of hay to ewes reduced the time spent eating ivy from the HLF but not significantly. This may indicate that ewes preferred to eat ivy or alternatively due to the differences in the nature of harvesting (eating method) hay and ivy. Papachristou *et al.* (1992) investigated the effect of forage resource on goats feeding time. They used three pasture types, namely, (A) 53% brush and 31% herbage, (B) 60% brush and 21% herbage and (C) 66% brush and 11% herbage cover. They found differences in the grazing time due to the larger bites from shrubs (23%) than from herbaceous species. The Papachristou *et al.* (1992) study agreed with my experiment from the point that type of forage has an affect on eating method and on the time spent eating such forages.

The time spent ruminating increased in the hay and decreased in the concentrate supplement treatment. Fariani *et al.* (1994) studied the effect of protein and/or energy supplementation on rumination behavior of sheep (one supplemented and the other not supplented) receiving ammonia-treated rice straw as a basal diet and they found that time spent ruminating was shorter in supplemented than unsupplemented sheep, confirming the effect of concentrate observed in the present experiment.

The results showed that there were breed differences in all behaviour activities ($P<0.002$). The variations observed between breeds in the behaviour activities during eating from the HLF probably depends on the body size (weight) of animal, because the Cambridge ewes were larger than Welsh Mountain ewes. It was observed that Cambridge ewes prevented Welsh mountain ewes eating ivy from the HLF by not allowing enough space for them to eat ivy from the HLF and sometimes by pushing them with their heads. Cambridge ewes also started eating ivy from the HLF before the Welsh Mountain ewes. EL Aouini and Sarson (1976) working with sheep on a purely browse diet in the maquis of northern Tunisia, found that intake of browse is closely related to the live weight of the animals and found that sheep can consume up to 3.8% of its body weight in dry matter daily. This work confirms the suggestion that because of higher live weight, Cambridge ewe spent more time at the HLF than Welsh Mountain ewe.

Variations between individual ewes in their ability to stand on their hind legs was observed. During observations, some Cambridge ewes stood on their hind legs to reach overhanging ivy leaves on the HLF. This behaviour was seen only in some of the Cambridge ewes. In contrast, Welsh Mountain ewes reached the overhanging leaves of the HLF by jumping on their fore legs (Figures 2a and 2b). This difference in behaviour (standing on the hind legs or jumping) is probably due to the size of animal relative to the HLF.

The conclusions drawn from this experiment are that sheep ate ivy from the HLF with behaviour patterns similar to those observed when sheep browse from a tree. Some aspects of their behaviour was affected by the availability of other feed sources. The provision of hay and concentrate supplement did not significantly reduce the intake of ivy but ewes tended to spend less time eating ivy from the HLF when hay and concentrate supplement were available. The results also indicated that there were differences in behaviour between Cambridge and Welsh Mountain ewes. This aspect is investigated in more detail in Chapter 5.

CHAPTER 5

INTERACTION BETWEEN BREEDS AND ALTERNATIVE FEED SOURCES ON THE BEHAVIOUR OF SHEEP GIVEN ACCESS TO IVY ON A HIGH-LEVEL FEEDER IN A GRAZING ENVIRONMENT

EXPERIMENT 3

5.1 INTRODUCTION

Providing animals with sources of feeds in addition to their basal diet can influence their behaviour. The experiment described in Chapter 4 indicated that hay and concentrate supplement tended to decrease the time spent eating ivy from the HLF. Reports in the literature have shown that concentrate supplement can decrease the intake of a basal diet. Ewbank *et al.* (1994) studied the effect of concentrate level on performance of dairy sheep offered grass silage *ad libitum* and concluded that increasing concentrate level with milking ewes will reduce silage intake. Similarly Patterson *et al.* (1997) found that feeding concentrates within a complete diet

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A summary of some results from this Chapter was published in the BSAS Winter Meeting in 1998 (Appendix 9).

depressed the intake of silage by 0.15 proportionately in cows. It has also been found that supplementation can affect the behaviour pattern of grazing herbivores and affect forage utilization (Murden *et al.*, 1993).

Whilst there are reports of differences between species in feeding/grazing behaviour, there are fewer references to breed differences. The species differences include differences in selectivity and height of canopy grazed, with sheep, for example grazing more selectivity than cattle and grazing lower parts of grass swards than goats (Gong *et al.*, 1996 a&b; Dumont *et al.*, 1995; Devendra, 1995; Forbes, 1995; Abaye *et al.*, 1994; Norton *et al.*, 1990; Gatenby, 1986; Griffiths, 1966). Senn *et al.* (1995) examined three breeds of lactating cows (Holstein-Friesian=HF, Simmental=SI and Jersey=JER) fed on hay, maize silage (MS) and grass silage (GS) *ad libitum*. They found breed differences and circadian (dark and light) changes in the feeding behaviour of lactating cows selecting from 3 different feedstuffs.

Chapters 3 and 4 showed that there were differeneces between sheep breeds (Welsh Mountain and Cambridge) in the time spent eating ivy from the HLF in an in-door experiment. The present experiment investigated the extent to which the behaviour of Welsh Mountain ewes (a small breed) was affected by the presence of Cambridge ewes (large breed) in a grazing environment. The hypothesis of this experiment was described in Table 1.2.

5.2 MATERIALS AND METHODS

5.2.1 Adaptation

The experiment was carried out from March 1996. The animals were adapted in two grazing pens (37m×25m for each pen) for 7 days. In the first day of adaptation period Welsh Mountain and Cambridge ewes were provided together with 0.5kg concentrates per ewe, provided once a day at the beginning of observations, and without any ivy on the HLF for 2 hours in the morning. In the afternoon of the first day of the adaptation period Welsh Mountain and Cambridge ewes had access to hay *ad libitum* from the feeder. On the morning of the second day of the adaptation period the Welsh Mountain ewes had access to 0.5kg concentrates per ewe, provided once a day at the beginning of observations, and also to ivy from the HLF for two hours. In the afternoon of the second day Welsh Mountain and Cambridge ewes had access to hay *ad libitum* from a feeder and also to ivy from the HLF for two hours. On the morning of the third day Welsh Mountain ewes had access to eating hay *ad libitum* from a feeder and also to ivy from the HLF for 2 hours. In the afternoon of the same day the

Welsh Mountain and Cambridge ewes had access to 0.5kg concentrates per ewe, provided once a day at the beginning of observations, and also to ivy from the HLF for 2 hours. The procedures described for the second and third day of the adaptation periods were repeated another two times.

5.2.2 Animals and experimental design.

A randomised complete block experiment was conducted in a grazing area (37m×25m) using four treatments. Each treatment was conducted over one day with each cycle of four treatments being conducted weekly with week as the blocking factor. Treatments were allocated at random to days within weeks. Eight dry ewes (four Cambridge and four Welsh Mountain (WM) ewes) were selected randomly at age 1-2 years old from flocks at the College Farm University of Wales, Bangor.

Feed intake and measurements of leaf area were as described for Experiment 2 (Sections 4.2.3 and 4.2.5 respectively).

5.2.3 Treatments

Four treatments were used in this experiment.

Treatment 1: Welsh Mountain ewes + concentrate supplement (WOC). The animals had access to 0.5kg concentrates per ewe per day, provided once a day at the beginning of observations. On this treatment the animals also had access to grazing pasture (Perennial ryegrass-white clover 2-4cm) and to eating ivy from HLF (the design of the HLF was as described in Section 3.2.3).

Treatment 2: Welsh Mountain ewes + hay (WOH). The animals had access to hay from side-feeders (troughs), the type of feeder was "large" and its measurements were as described in Section 4.2.2. The animals also had access to grazing pasture and to eating ivy from the high-level feeders.

Treatment 3: Welsh Mountain ewes + Cambridge ewes + concentrate supplement (WCC). The animals had access to 0.5kg concentrates per ewe per day, provided once a day at the beginning of observations. On this treatment the animals also had access to grazing pasture and to eating ivy from the high-level feeders.

Treatment 4: Welsh Mountain ewes + Cambridge ewes + hay (WCH). The animals had access to hay from side-feeders (troughs). The animals also had access to grazing pasture and to eating ivy from the high-level feeders.

The weights of ivy, hay and concentrate supplement were recorded before and after feeding in each treatment for three weeks. Table 5.4 shows the mean weights. The ingredients of the concentrate was as described in Section 3.2.1.

5.2.4 Observations

The activities of all ewes were observed every five minutes for six hours per treatment using binoculars (from 9.00 to 12.00 h and from 13.00 to 16.00 h). The categories of activity were as described in Section 3.2.4.2.

5.2.5 Statistical Analysis

The time spent by ewes performing the activities were calculated from the real-time recordings. The average and percentage time spent in each individual behaviour was calculated using the formulae described in Section 3.2.5. The results of percentage time spent by treatments and activities were analysed by Chi-square, to see the effect of treatments on the distribution of observations (% time) across all behaviours.

Prior to ANOVA data for each behaviour were checked for normality. Data of all behaviour activities were adjusted using square root transformation except for grazing, ruminating, walking and eating behaviour which were not adjusted because they were normally distributed.

Adjusted behaviour activities were analysed by ANOVA using the MINITAB statistical package (1994) to determined the difference between breeds and between treatments using a model that included treatments, replicates and breeds as fixed effects and ewes within breed as a random effect. The interactions between treatments (feeds) and breeds was also included. To examine if there was a difference between the Welsh Mountain ewes when eating alone and when they were eating with Cambridge ewes a model was used that included ewes and treatments. ANOVA was also used for the ivy, hay and concentrate supplement intake to determine whether there were any differences between treatments in term of feed intake.

5.3 RESULTS

A non-significant chisquare statistic revealed that the overall distribution of time by behaviour was not significantly affected by treatments.

The means, probabilities and percentage times spent by ewes performing various activities are shown in Table 5.1. There were no significant difference between breeds, between treatments and between replicates in time spent eating ivy from the HLF ($P>0.05$). The animals spent 18%-22% of their time eating ivy from the HLF. Also the results show that there were no significant differences between the behaviour activities of individual ewes within both breeds ($P>0.05$) as shown in the first P-value of Table 5.1. The results also show that there were significant differences between the replicates on the time spent on most behaviour activities ($P<0.05$) except on the eating ivy from the HLF, eating hay and concentrate supplement and walking which showed no significant differences between replicates (Table 5.1).

5.3.1 The difference between the behaviour of Welsh Mountain ewes when eating alone and when they were eating with Cambridge ewes.

As shown in Table 5.1 there was no significant difference between the behaviour of Welsh Mountain ewes when they were alone and when they were with Cambridge ewes (P>0.05), except that Welsh Mountain ewes spent less time standing when alone than when they were with Cambridge ewes (P<0.05) as shown in Table 5.1.

The provision of hay and concentrate supplement did not generally affect the behaviour of Welsh Mountain ewes (P>0.05), except that the Welsh Mountain ewes spent more time standing (17%) when hay was available (Table 5.1).

When they were by themselves Welsh Mountain ewes spent more time eating concentrate than eating hay (47.5min. and 22.08min., respectively). But when they were with Cambridge ewes, the time spent eating concentrate decreased whereas the time eating hay increased. Welsh Mountain ewes also spent more time standing when they were with Cambridge ewes than when they were alone as shown in Table 5.1.

The behaviour of Cambridge ewes was not generally affected by treatments, except that they spent more time eating concentrate supplement than they did hay ($P<0.001$)as shown in Table 5.1.

5.3.2 The difference between the behaviour activities of both breeds

Table 5.2 shows that there were no significant difference between breeds in the times spent on various behaviour activities ($P>0.05$).

The interactions between the feeds and breeds showed that there were no significant effects on the behaviour activities of ewes except that the times spent standing and eating of hay and concentrate supplement were affected by this interaction ($P<0.05$). When both breeds were eating ivy together they spent more time standing when the hay was available than if concentrate was available. When both breeds were together ewes spent more time eating concentrate 11% than eating hay (6.4%) as shown in Table 5.1.

Table 5.1. The effects of breed, hay and concentrate supplement feed on behaviour of ewes.

Treatments	Breed *	Eating ivy	Lying	Ruminate	Stand	Walk	Grazing	Eating**
Welsh only + Concentrate	Welsh ewes%	21.6	10.4	10.6	7.9	9.5	27.4	13.2
	Mean time	**8.8**	**5.7**	**38.3**	**5.3**	**34.2**	**98.8**	**47.5**
Welsh+Cambridge + Concentrate	Camb.%	19.4	10.4	10.4	9.5	8.4	29.9	11.7
	WM.%	17.5	15.4	11.1	8.7	7.9	28.2	10.8
	ALL%	**18.4**	**12.9**	**11.2**	**9.1**	**8.1**	**29**	**11.2**
	All Mean time	**8.1**	**6.3**	**40.4**	**5.6**	**29.6**	**104.8**	**40.6**
Welsh only + Hay Supplement	Welsh ewes %	20.6	10.1	10.5	17	10.1	21.7	6.1
	Mean time	**8.6**	**6.1**	**37.9**	**7.7**	**36.3**	**78.3**	**22.1**
Welsh+Cambridge + Hay supplement	Camb.%	23.5	9.1	10.8	9.6	9.9	32.5	4.4
	WM. %	19.9	13.4	11.5	9.7	8.1	28.6	8.5
	ALL %	**21.7**	**11.2**	**11.1**	**9.6**	**9**	**30.5**	**6.4**
	All Mean time	**8.8**	**6.2**	**39.6**	**5.9**	**32.5**	**110.2**	**23.3**
1- P-value for differen between individual ewes of both breeds		0.680	0.620	0.807	0.955	0.212	0.410	0.750
2- P-Values for different between treatments of Welsh ewes only		0.108	0.322	0.082	<u><0.001</u>	0.263	0.227	<u><0.001</u>
3- P-Values for differen between treatments of Cambridge ewes only		0.115	0.415	0.720	0.927	0.106	0.240	<u><0.001</u>
5- P-Value for different between breeds		0.615	0.741	0.833	0.133	0.105	0.268	0.553
6- P-values for Feed*Breed		0.560	0.997	0.556	<u>0.019</u>	0.233	0.650	<u><0.001</u>
7-P-value for the different between replicates		0.097	<0.001	<0.001	<0.001	0.384	<0.001	0.244

(*) Camb. = Cambridge; WM.= Welsh Mountain. (**) Eating either supplement (Concentrate or Hay).
ALL % = Percentage of time spent by both breeds. ALL mean time=The means of times (minutes) spent by both breeds. (The means of times for the all behaviour activities data were adjusted using square root transformation except for the data of grazing, ruminating, walking and eating activity data were not adjusted because their data were normally distributed.

5.3.3 Measurements and weight of leaf area

Table 5.2 shows the weight of branches and leaves and leaf area measurements for leaves of ivy plant for each collected week. There was 0.25 kg leaves per kg branches. According to the leaf measurements for each week there was a relationship between branch length and leaf area measurement. As branch length increased the leaf area measurement increased.

Table 5.2. Mean weight (branches and leaves) and the leaf area measurements and leaf weights.

WEEK	Number of branches/kg fresh weight	Branches & Leaf Weight kg	Means branch length (cm)	Leaf weight (kg)	Leaf area measurement for hundred leaves cm^2
1	4	5	79	1.29	1497
2	4.5	4	71	1.09	1453
3	3.5	6	78	1.38	1541
Means	4.0	5	76	1.25	1497

5.3.4 Ivy, hay and concentrate supplement intake

Table 5.3 shows the mean weight of ivy plant and hay and concentrate before and after feeding. There were significant differences between treatments in ivy, hay and concentrate intake ($P<0.05$). Table 5.3 also shows that there were similar ivy intakes for the Welsh

Mountain ewes for the concentrate and hay treatments (1.3kg). If Welsh Mountain ewes were eating alone they had a higher ivy intake than if they were eating with Cambridge ewes.

Table 5.3. The means of browse and supplements intake and residues.

Treatment	weight of ivy leaves and branches (kg)		weight of hay & concentrate (kg)		Intake/Ewe (kg)	
	Before	Residual	Before	Residual	Ivy	H & Conc.*
Welsh+Concentrate	6.1	4.8	2 Conc.	0	0.325	0.5 Conc.
Welsh+Camb.+Conc	8.3	6.2	4 Conc.	0	0.262	0.5 Conc.
Welsh+Hay	5.3	4	3 Hay	2.1	0.325	0.225 Hay
Welsh+Camb.+Hay	8.6	6.7	5.3 Hay	4	0.237	0.162 Hay
P-value					0.033	0.001

H & Conc.*= Eating Concentrate supplement or Hay.
Camb.=Cambridge; Conc.=Concentrate.

5.4 DISCUSSION

The experiment conducted in Chapter 4 showed that there were differences in eating behaviour between Cambridge and Welsh Mountain ewes offered feed from a HLF. However, the experiment in Chapter 4 did not include treatments to allow comparisons between the breeds alone and in mixed groups. The current experiment was conducted to further examine the differences between breeds using treatments that had Welsh Mountain alone and Welsh Mountain + Cambridge ewes.

The results of this Chapter showed that sheep ate from the HLF when in a grazing environment, spending from 18-22% of their time eating ivy from the HLF when hay and concentrate supplement were also available. The results showed that sheep spent more time grazing (29-31%) than eating ivy from the HLF (18-22%). This confirms the classification of sheep as intermediate feeders (i.e. they are naturally grazers but can become browsers depending on their surroundings). This was described in

Section 2.3.1 based on Pratt and Gwynne (1977), Devendra (1995), Meuret (1997) and Mysterud (1998).

Differences between species in feeding/grazing behaviour and interactions between species were described in the literature review (Section 2.2) but few reports have described breed differences. Some reports have discussed differences between breeds in performance and diet selection. For example, Revesado *et al.* (1994) studied diet selection by two breeds of sheep (Churro and Merino) and found differences between the breed in terms of diet selection. They found that proportion of leaves in the diet was significantly lower in July in Merino sheep, but there was no significant difference between months in Churro sheep. Similarly, Noble *et al.* (1993) noted differences among breeds of chickens in terms of diet selection. They found that White Leghorn chicks displayed dietary preferences whereas the White Plymouth Rock breed did not display dietary preferences.

In this study having a mixed breed group (Welsh Mountain ewes + Cambridge ewes) did not markedly affect the eating behaviour of Welsh Mountain ewes but in the presence of Cambridge ewes they ate less hay and stood and ruminated for longer, without decreasing grazing time as they did when they could eat hay without competition from Cambridge ewes.

The results showed that there were no differences ($P>0.05$) in grazing time per ewe Welsh Mountain ewes grazed alone compared to when Cambridge ewes joined them. This suggests that there was no breed difference in grazing time, and that there was no competition between individuals during grazing since each ewe had sufficient grazing space.

Time spent eating ivy was not affected by mixed-breed groups but the intake of ivy was. When the 4 Welsh Mountain ewes were alone, ivy intake per ewe was greater (0.33kg/ewe) than when they were with Cambridge ewes (0.26kg/ewe) (Table 5.3). The reduction in intake per ewe could be explained in several ways: (1) A breed effect that is mainly due to body size of ewes, i.e. larger ewes eat more and they are more competitive than smaller ones; (2) A breed effect that is unrelated to weight, due for example to behaviour e.g aggressive behaviour; (3) A numbers effect, i.e. in a large group the intake per ewe might be lower than in a small group.

It was observed that ewes ate mainly leaves and sometimes twigs. Assuming that ewes ate only leaves, then the estimation of leaf intake can be calculated from Table 5.2 and Table 5.3. Ewes ate about 23% (817.2g) - 24% (1257.6g) of the total ivy leaves available in both situations, i.e when the 4 Welsh Mountain ewes were eating alone and when the 4 Cambridge ewes joined them. This suggests that intake of leaves was not limited by quality available. However, the number of HLFs in relation to the number of ewes might have been a limiting factor. Two HLFs were used in each treatment and may have forced ewes to compete with each other to eat from the HLF resulting in a decrease in ivy intake per ewe.

It was also observed that individual ewes of both breeds, Welsh Mountain ewes 1 and 3 and Cambridge ewes 1, 2 and 3 spent more time eating ivy than the other sheep. This indicates that size of ewe might have affected ivy intake since these individuals were heavier than other ewes. Hohenboken *et al.* (1995) studied breed and nutritional effects and interactions on energy intake of cows, and they found that although there were no differences between breeds in their efficiency of feed utilization, the cows of a larger breed ate more than cows of a smaller one.

It was observed in both treatments that ewes that had larger size started eating from the HLF before smaller size individuals. When both breeds were together Cambridge ewes started eating ivy from HLF before Welsh Mountain ewes. It was observed in the first quarter of the observation period that when smaller sized ewes wanted to eat from the HLF the larger size ewes did not allow enough space for them. When the larger size ewes stopped eating ivy from HLF they grazed or ruminated, then smaller size ewes went to eat from the HLF. It is likely that these ewes had to search harder for ivy leaves because all leaves that were easily accessible at the front of branches had been eaten by the larger ewes. This suggests that all ewes irrespective of size had equal opportunity in terms of time to eat from the HLF but the smaller ewes ate less ivy because they had to search for leaves during eating from the HLF. This probably explains why the time spent eating from the HLF was unaffected by mixed-breed grazing but ivy intake per ewe was less in the larger group. Hall *et al.* (1997) did two experiments to study feeding behaviour in sheep, one with a heterogeneous flock (28.6 to 93.2 kg body weight) and the other with a more homogeneous flock (32.4 to 46.6 kg) by offering concentrate and hay *ad libitum* separately. They found that competition between individual sheep was less in the homogeneous flocks than in the heterogeneous flock.

The conclusions drawn from this chapter are that there was no breed effect on the time spent grazing or eating from a HLF. A reduced intake per ewe in the mixed-breed treatment grazing was the result of competition between ewes particularly related to size and the increase in numbers of ewes eating together.

CHAPTER 6

THE EFFECT OF FORAGE QUALITY ON THE BEHAVIOUR OF WELSH MOUNTAIN EWES WHEN THE SOURCES ARE AVAILABLE SEPARATELY ON A HIGH-LEVEL FEEDER

EXPERIMENT 4

6.1 INTRODUCTION

Feed intake and selection are affected by the quality of available feeds and by the animal species that are eating those feeds (Poppi and Norton, 1995; Alcaide *et al.*, 1997 and Bartolome *et al.*, 1998) and by sward height and types of vegetation in a grazing area (Staaland *et al.*, 1995; Penning *et al.*, 1997; Bakker *et al.*, 1998 and Prache *et al.*, 1998). Norton *et al.* (1990) compared cattle, sheep and goats in terms of selection for grass or legume and leaf or stem. Goats showed the greatest discrimination against stem and were more similar to cattle in diet selection than sheep. Goats had a high preference for legume leaf because it was located at the top of a sward whereas sheep had less preference because they grazed at the bottom of the sward. Genin *et al.* (1994) investigated diet selection and utilization by llama and sheep in rangelands of Bolivia, and found that llamas consumed more coarse bunchgrasses than sheep, while sheep consumed more soft herbs and grasses than llamas. Staaland *et al.* (1995) found that reindeer and goats had more diverse feed selection than sheep who fed mainly on grasses and forbs. Dumont and Petit (1995) measured the choices of heifers and ewes between a poor quality hay offered *ad libitum*, and a good quality hay offered in limited quantities. Ewes had a higher preference for good forage than heifers and tried to maintain good forage consumption when the reward level decreased.

Sheep can discriminate between feeds of different quality when different sources are available to them. Arnold (1966) suggested that sheep can use smell, taste and tacticle stimuli to discriminate between different plant species. Forbes (1995) stated that sheep discriminate between feed sources on the basis of visual or taste cues. Narjisse *et al.* (1997) also found that sheep and goats used taste and odour to decide whether they will eat available food.

Edwards *et al.* (1997) found that sheep formed associations between cues and rewards and distinguished between the cues by sight and smell. The ability to discriminate between feeds prior to eating them suggests that the preferences exhibited by sheep given a choice between species do not simply arise because of a need to sample both species. Edwards *et al.* (1994) concluded that sheep can discriminate between feed items on a spacial scale and scale of aggregation and that diet selection may be modified by starvation.

In this experiment a high-level feeder (HLF) was used as a feeder to investigate the effects of different feed sources (ivy, hay and straw as representative of good, medium and poor quality forages, respectively) on the behaviour of Welsh Mountain ewes. The hypothesis of this experiment was described in Table 1.2.

6.2 MATERIALS AND METHODS

6.2.1 Adaptation

The experiment was carried out on August 1996. Prior to the experiment the animals were adapted to eating the different types of forages (ivy, hay and straw) that located on the HLF in an in-door pen (5.5m × 5.5m) for 10 days. On the first day of the adaptation period the animals had access to 2kg concentrate and hay *ad libitum* from side-feeders and without any forages on the HLF for 3 hours in the morning. On the second day of adaptation the animals had access to ivy from the HLF, and also they had access to hay and 2kg concentrate from side-feeders for 3 hours in the morning. On the third day the animals had access to hay from the HLF and also had access to hay and 2kg concentrate from side-feeders for 3 hours in the morning. On the fourth day the animals had access to straw from the HLF and also had access to hay and concentrate from side-feeders for 3 hours in the morning. The same procedures were repeated for another four days but in the afternoon. In the last two days the four treatments were repeated, one treatment in the morning and the other in the afternoon. Before and after the adaptation and observation periods the animals were kept out-door grazing together.

6.2.2 Animals, experimental design and treatments.

A randomised complete block experiment was conducted in an in-door pen (5.5m × 5.5m) using four treatments. 1. Good quality forage (Ivy); 2. Medium quality forage (Hay); 3. Poor quality forage (Wheat straw); 4. No forage on the high-level feeders. In each treatment the animals had access to eating ivy and eating hay and straw *ad libitum* from the high-level feeders (Section 3.2.3). Animals also had *ad libitum* access to hay with 2kg concentrate as a supplement in all treatments. In Treatment 2, the hay was removed from the hay troughs in the final replication because animals had shown no interest in eating hay from the troughs in previous replicates. The concentrates were as described in Section 3.2.1. Each treatment was conducted over one day with each cycle of four treatments being conducted weekly with week as a blocking factor. Treatments were allocated at random to days within weeks. Eight dry Welsh Mountain ewes (4 years old) were selected randomly from flocks at the College Farm, University of Wales Bangor.

6.2.3 Forages intake, measurements of leaf area and observations

Ivy, hay, straw and concentrate supplement intake were measured as described Section 4.2.2. The techniques used to measure leaf area were as described in Section 4.2.5 and the observations of behaviour were as described Section 4.2.4.

6.2.4 Statistical analysis

The time spent by ewes performing the activities were calculated from the real-time recordings. The average and percentage time spent in each individual behaviour activity was calculated using the formulae described in Section 3.2.5. The results of percentage time spent by treatments and activities was analysed by Chisquare for each treatment to examine the effect of treatment on the distribution of observations (% time) across all behaviours. The analysis was completed using the Minitab statistical package (Minitab, 1994).

Prior to ANOVA data for each behaviour were checked for normality. Data of behaviour activities were adjusted using a square root transformation where the data were not normally distributed. Standing and ruminating were not adjusted because their data were normally distributed. Adjusted behaviour activities data were analysed by ANOVA to see if there was a difference between treatments in the time spent on individual behaviours using treatments and replicates as fixed factor and ewes as random factor.

6.3 RESULTS

Percentage and mean times spent by ewes performing various activities are shown in Table 6.1. The distribution of time by behaviour was affected by treatments (chi-square statistic significant at P<0.05).

Table 6.1. The effect of forage quality on the behaviour of Welsh Mountain ewes (Mean time in minutes).

Treatment	Statistic	Eating from HLF	Lying	Ruminating	Stand	Walk	Eating (**)	
							Conc	Hay
Good quality forage (Ivy)	%	18.8	17.2	26.9	18.1	10.4	5.2	3.5
	Mean time	67.5	7.3	96.5	65.2	37.4	18.5	12.5
Medium quality forage (Hay)	%	9.3	26.5	22.9	19.7	14.5	7.1	0
	Mean time	33.2	95.6	82.3	71	52	25.6	0
Poor quality forage (Straw)	%	0.1	13.8	27.7	20.1	14.6	9.0	14.7
	Mean time	0.20	6.8	99.8	72.2	52.7	32.2	52.9
No forage on the HLF	%	0	18.5	29.0	19.1	14.8	6.3	12.3
	Mean time	0	7.9	104.2	68.9	53.7	22.5	44.1
P-value for treatments		<0.001	<0.001	0.040	0.572	<0.001	<0.001	<0.001
P-value for the different between the replicates		0.744	0.014	0.277	0.105	0.009	0.304	0.015
P-value for the different between the individual ewes activities		0.926	0.001	<0.001	<0.001	<0.001	0.037	0.956

(**) Eating either Concentrate supplement or Hay from the side-feeder.

The mean times spent eating from the HLF differed significantly between treatments (P<0.001), whereas not significantly differences between individual ewes and between replicates (P=0.926 and P=0.744 respectively) as shown in Table 6.1. Eating hay from the feeder showed significant difference between replicates and between treatments (P<0.05 and P<0.001 respectively), whereas there was no significant difference between individual ewes (P>0.05).

Generally ewes spent more time eating when forage quality was good (18.8%), less at medium (9.3%) and very little (0.1%) if poor quality forage was available. Ewes spent more time ruminating when straw was available (27.7%) than when hay was provided as medium quality forage (22.9%).

The times spent lying and walking differed significantly between treatments, between replicates and between individual ewes (P<0.001, P<0.014 and P<0.001 respectively). When medium quality forage was available, ewes spent more time lying (26.5%) than they did on the other treatments (Table 6.1). Animals spent less time walking when good quality forage was available (10%) compared with the other two treatments.

The times spent eating concentrates and hay also differed significantly between treatments (P<0.001). When there was poor quality forage available on the high-level feeders, the animals spent more time eating concentrate (9%) and hay (14.7%) (Table 6.1). But when there was no forage available ewes spent a large proportion of time ruminating (29%). Also the results show that there was significant difference between time spent by individual ewes eating concentrate ($P<0.05$), whereas there was no significant differences between time spent by individual ewes eating hay ($P>0.05$) as shown in Table 6.1.

Table 6.2 shows that the weight of branches and leaves and the leaf area measurements for each week. There were 0.6kg leaves per kg branch.

Table 6.2. Mean weight (branches and leaves) and the leaves area measurements (100 leaves) and leaves weight.

WEEK	Number of branches/kg total fresh weight	Branches & Leaf fresh Weight kg	Mean branch length (cm)	Leaf Weight kg	Leaf area measurement per 100 leaves cm^2
1	8.0	3	63	1.52	2833
2	7.5	4	64	2.65	2399
3	7.0	5	66	3.02	2569
Means	7.5	4	64.3	2.40	2600.3

The mean of forages (ivy, hay and straw) and supplement intakes for each treatment are presented in Table 6.3. The mean intake of ivy (2.1kg) was greater than intakes of hay and straw (0.9kg and 0kg, respectively). On the poor forage (straw) and no-forage treatments, intake of supplements were greater (3.3kg and 3.2kg, respectively) than on the good and medium quality forage treatments (3kg and 2kg, respectively).

Table 6.3. The fresh weights of forage and concentrate supplement intake and residues.

Treatments	forage weight (kg)		Weight of hay and concentrate (kg)		Intake (kg)	
	Before	Residual	Before	Residual	foraging from the HLF	Hay & Conc.*
Good quality forage (Ivy)	6.3	4.2	2.0 Conc. 3.0 Hay	0.0 Conc. 2.0 Hay	2.1	3.0
Medium quality forage (Hay)	3.0	2.1	2.0 Conc. 0	0.0 Conc. 0.0	1.0	2.0
Poor quality forage (Straw)	3.0	3	2.0 Conc. 3.0 Hay	0.0 Conc. 1.7 Hay	0.0	3.3
No forage on the HLF	0.0	0.0	2.0 Conc. 3.0 Hay	0.0 Conc. 1.8 Hay	0.0	3.2
P-value					0.006	0.009

Hay & Conc.*= Hay & Concentrate supplements.
Conc.=Concentrate

6.4 DISCUSSION

The experiment showed that intake and time spent eating forage by Welsh Mountain sheep depended on the quality of available forage. This conclusion is based on intake and precentage time spent eating forages of different quality from a HLF. Ewes spent progressively less time eating ivy, hay and straw from a HLF(19%, 9% and 0.06% respectively, Table 6.1). Intake of ivy was also greater than intakes of hay and straw (2.1kg, 0.9kg and 0kg respectively). It was observed in the experiment that ewes firstly went to the HLF and examined the forage material. They then started to eat, or went to examine the side-feeder. This indicates that the behaviour of sheep is affected by the availability of forages of different types and also that ewes choose from those feeds available to them. It was observed that when hay was available in a side-feeder with ivy on the HLF the ewes ate and spent more time eating ivy from the HLF (2.1kg and 19% respectively) than hay from the side-feeder (1kg and 3.5%). Plumb (1991) found that bison and cattle consumed forage classes in order of availability but also found that they exhibited selection for higher quality forages. The factors that affect feed selection were described in detail in Section 2.1.2. Two main factors control diet selection. These are, (1) external factors including, palatability of feeds, the chemical composition of the available feeds, forages availability and food flavour. (2) Animal factors include, starvation e.g. Dumont *et al.* (1995) found that efficiency of feed selection by animals decreased when they were starved; species and requirement of animal for a nutrients. The basic method of feed selection was reviewed by Lynch *et al.* (1992). When an animal starts eating the coginitive systems (sight, smell, touch and taste) produce stimuli to recognise and assess the palatability of the available feeds which result in diet selection. The consequences of having eaten a food can be positive or negative (Lynch *et al.*, 1992). If the post-ingestive consequences is positive, this will result in an increase in intake, and it can be inferred that the animals preferred ivy to hay and straw. The literature showed that an animal species preferred a specific type of feed because of its flavour (Provenza *et al.*, 1995 and Ralphs *et al.*, 1995), or because the feed meets the requirement of an animals for some nutrients (for example, rats, Tepper and Kanarek, 1989; chickens, Cumming 1989; pigs, Kyriazakis *et al.*, 1990; sheep, Burritt and Provenza, 1991; Cooper *et al.*, 1995 and Provenza, *et al.*, 1994). Forbes (1995) stated that animals are sensitive to a number of nutrients and can make appropriate choice according to how they feel. So it can be concluded that animals will select or prefer a specific type of food due to their body requirement for a specific nutrients and\or for flavour of the food.

It was found that the sheep did not eat straw. When it was available in the HLF, they ate only hay and concentrate from the side-feeders. This indicates that in the presence of other feeds they did not choose straw although it is known (Kaitho *et al.*, 1997; Antongiovanni *et al.*, 1998; Khandaker *et al.*, 1998 and Rasool *et al.*, 1998) that sheep can eat it and it is used as a forage source. This is probably due to the fact that ewes had better feeds available and also that their nutrient requirements could be satisfied by the range of feeds available during the period of observation and by grazing at other times. Dumont and Petit (1995) studied the effect of starvation on the preferences of sheep by offering a poor and a good quality hay. They found that sheep were less reluctant to feed on poor forage when starved. It has also been found that the physical form of straw can affect intake. Kenney and Black (1984) found that when the straw was offered to sheep alone and the length was reduced from 30 to 10 mm the rate of eating increased from 5.5 to 12.4 g/minute. In the present experiment the length of straw was long.

When hay was available both in the trough and in the high-level feeder, it was observed that ewes only ate hay located in the HLF. This result was unexpected since the type of feed was the same in both locations. This suggests that type of feeder and its location might have an effect on the forage intake and behaviour of ewes. When hay was available on the HLF and in the side-feeder, the ewes chose only the hay located on a HLF located at the center of the pen. This result will be investigated in more detail in Chapter 7.

The conclusions drawn from this experiment are that the type of forage available affected the eating behaviour of ewes and that time spent eating depended on the forage type with ewes choosing higher quality forages. Eating forage other than browse (e.g. hay) from the HLF indicates that the high-level feeder can be used as a feeder to examine selection of forages. The selection of forages is discussed further in more detail in Chapter 8 when forages were available simultaneously.

CHAPTER 7

THE EFFECTS OF LOCATION OF FORAGE ON THE BEHAVIOUR OF SHEEP WHEN MEDIUM QUALITY FORAGE IS AVAILABLE IN A HIGH-LEVEL FEEDER AND SIDE-FEEDER

EXPERIMENT 5

7.1 INTRODUCTION

Selection of feeds by sheep from different locations is affected by the availability and quality of preferred forage in a particular area (Samuel *et al.*, 1980; Bailey, 1988 and Scott *et al.*, 1995). Presence of supplemental feed in the preferred foraging location can also affect foraging from a preferred area because it has been noticed that when grain was absent, there was no difference in use of any particular area in the pasture (Roath and Krueger, 1982; Senft *et al.*, 1985; Lawrence and Wood-Gush, 1988 and Stuth, 1991). Also it has been found that choice of forage from a preferred locations is affected by social interactions amongst sheep when they are foraging within the same environmental area, i.e. by formation of sub groups, each group eating and selecting their choice forage from their preferred locations (Wilson and Emmans, 1979; Squires, 1981 and Scott *et al.*, 1995). Also differences between animal species in preferred grazing area have been noted. Sheehy and Vavra (1996) found that cattle preferred foraging plant communities located at medium distance from the forest edge and on moderate elevation. Elk preferred foraging areas near the forest edge at higher elevations. Such preferences for location are difficult to interpret given the strong association between plant species and location, in relation for example to altitude. Similarly, Hosoi *et al.* (1995) conducted two experiments to examine the foraging behaviour of sheep and goats using a T-maze. They found that there were differences between sheep and goats in selection from the feed located on the arms of a T-maze. Goats responded by increasing the frequency of shifting to the second free choice, particularly when the first choice was a losing one. Sheep did not respond to this possibility with a measurable change in behaviour.

Animals can learn to identify the position or location of preferred food. Forbes (1995) noted that in addition to features such as colour, shape and brightness, animals can also learn the position of the food if its position is consistent between exposures. Research by Gillingham and Bunnel (1989) offered three foods (apples, dairy pellets and alfalfa) to deer in a small enclosure. They found that deer can know where the location or position of preferred food (apples) even when the food positions were changed, demonstrating a memory of successful paths to food. Also Provenza (1994) found that prior-experience of animals to eating from locations that contain preferred forage had an effect on the foraging and selection of food from a particular area. Research by Scott *et al.* (1995) showed that lambs spent more time in the area containing their preferred food when that food was available to them before. During observations in Experiment 4, it was observed that when hay was available both in a high-level feeder and in a side-feeder, animals ate from the HLF but not from a side-feeder. An experiment was designed to confirm this result using a wider range of relevent treatments. Location in this study was represented by placing forage on a HLF (located at the centre of the pen) and on a feeder (located at a similar height at the side of the pen).

7.2 MATERIALS AND METHODS

7.2.1 Adaptation

The experiment was conducted on 16 of October 1996. Prior to the experiment, the animals were adapted to the animal house and to eating from the high-level feeders for six days, 3 hours per day (in the first three days the adaptation was in the morning and in the last three days it was in the afternoon) in an in-door pen (5.5m×5.5m). On the first day of the adaptation period the animals were adapted to the house and to the first treatment [No hay on the HLF (No forage) + Concentrate + Hay on the side-feeder (NFCH)]. On the second day of adaptation period the ewes were adapted to the second treatment [Hay on the HLF (Forage) + Concentrate + No hay on the side-feeder (FCNH)]. On the third day of adaptation the ewes were adapted to the third treatment [Hay on the high-level feeder + Concentrate + Hay on the side-feeder (FCH)]. The same methods were repeated one time again. Before and after adaptation and observation periods the ewes were kept out-door grazing together.

7.2.2 Animals, experimental design and treatments.

A randomised complete block experiment was conducted in an in-door pen (5.5m×5.5m), using three treatments. 1. No hay on the high-level feeder (No Forage) + Concentrate + Hay on the side-feeder (NFCH); 2. Hay on the high-level feeder (Forage) + Concentrate + No hay on the side-feeder (FCNH); 3. Hay on the high-level feeder + Concentrate + Hay on the side-feeder (FCH). Concentrate was fed as 2kg per treatment as a supplement at the beginning of the observation period. The ingredients of the concentrate were as described in Section 3.2.1. Each treatment was conducted over one day with each cycle of three treatments being conducted weekly with week as a blocking factor. Treatments were allocated at random to days within weeks. Eight dry Welsh Mountain ewes (4 years old) were selected randomly from flocks at College Farm, University of Wales, Bangor.

Food intake and refusals from the high-level feeders and from the side-feeders were recorded before and after each treatment.

The design of the high-level feeders was as described in Section 3.2.3. Observations were as described in Section 3.2.4.1 The construction of the hay side-feeder was similar to the basket of the high-level feeder. The measurements of the hay side-feeder were, top measurement 53cm × 53cm, height 107cm and the base measurement 45cm × 23cm.

7.2.3 Statistical Analysis

The time spent by ewes performing the activities were calculated from the real-time recordings. The average and percentage time spent in each individual behaviour was calculated using the formulae described in Section 3.2.5. Percentage time spent by treatments and activities was analysed by Chisquare to examine the effect of treatment on the distribution of observations (% time) across all behaviours. Prior to ANOVA data for each behaviour were checked for normality, and then the analysis was completed using the Minitab statistical package (1994) to examine the effect of treatments on individual behaviour using treatments and replicates as fixed factor and ewes as random factor.

Also ANOVA was also used to examine whether there were differences between treatments in term of feed intake.

7.3 RESULTS

The distribution of time by behaviour activites was not affected by treatments (chisquare statistic $P>0.05$). Percentages and mean times spent by Welsh Mountain ewes (minutes) performing various activities for each treatment are shown in Table 7.1. The table shows that there were no significant effects of treatments on most behaviours except for eating of hay from the side-feeder and from the high-level feeder ($P<0.001$), ruminating and walking ($P<0.05$). And also the results show that there were no significant differences between the replicates on the all behaviour activities of ewes ($P>0.05$) except on the eating of concentrate showed significant difference between the replicates ($P<0.05$) as shown in Table 7.1. Also the results show that there were significant differences between the ewes in most behaviour activities ($P<0.05$) except for eating of hay from the side-feeder and from the high-level feeder and eating of concentrate which showed no significant differences between individual ewes ($P>0.05$). The animals spent more time eating hay from the side-feeders when there was no hay available on the high-level feeders, whereas if there was hay on the high-level feeders the ewes ignored the hay that was present in the side-feeders. Providing hay in the side-feeder had no effect on time spent at the high-level feeder. In treatment FCH ewes spent no time eating hay from side-feeders but spent 8% of their time eating hay from high-level feeders.

Table 7.1. The effect of location of hay on the behaviour of Welsh Mountain ewes (Mean time in minutes)

Treatment		Hay on the HLF	Hay on the side-feeder	Stand.	Ruminating	lying	Walk	Conc.
(1)No hay on the HLF	%	NA	5.3	21.6	24.5	27.4	15.3	5.5
+Concentrate+Hay on the side-feeder	Means time	NA	19.1	78.1	88.7	98.7	55.2	20
(2)Hay on the HLF	%	6.4	NA	21.9	28.4	24.3	13.4	5.1
+Concentrate + No ha on the side-feeder	Means time	23.3	NA	79.1	103.7	87.6	48.3	18.5
(3)Hay on the HLF	%	6.2	0.0	18.9	32.5	25.7	10.9	5.2
+ Concentrate+Hay on the side-feeder	Means time	22.4	0.0	68.1	118.1	92.7	39.3	18.9
P-value for treatm ents		<0.001	< 0.001	0.072	0.005	0.369	0.001	0.585
P-value for the diff rent between replicates		0.113	0.667	0.459	0.510	0.526	0.535	0.011
P-value for the different between ewes		0.797	0.403	< 0.00	0.009	<0.001	0.007	0.166

NA= None available

In treatments FCH ewes spent 32.5% of their time ruminating, a greater proportion of time than on the other treatments. In contrast, the time spent walking activity (11%) in this treatment was less than in the other treatments as shown in Table 7.1. It is noteworthy that in the absence of hay in the HLF, ewes spent almost as much time eating hay from the side-feeder as they did foraging in the other treatments.

Table 7.2 shows the mean of foraging hay from the HLF and from the side-feeder and concentrate supplement intake and residues. There were significant differences between treatments in both hay intake from the side-feeder and concentrate supplement and hay intake from the HLF ($P<0.05$). Ewes ate 0.63 and 0.76kg hay from the HLF without and with hay available in the side-feeder, respectively. They ate slightly less hay (0.53kg) when hay was available in the side-feeder only.

Table 7.2. The means fresh weights of hay from the HLF and from side-feeder and concentrate supplement intake and residues.

Treatment	Weight Hay on the HLF (kg)		Weight of hay & concentrate (kg)		Intake (kg)	
	Before	Residual	Before	Residual	Foraging hay from the HLF	hay & concentrate from side-feeder
(1) No hay on the HLF+ Concentrate + Hay on the side-feeder	NA	NA	2.0 Conc. 2.0 Hay	0.0Conc. 1.47 Hay	NA	2.0 Conc. 0.53 hay
(2) Hay on the HLF + Concentrate + No hay on the side-feeder	2.0	1.37	2.0 Conc. NA Hay	0.0Conc. NA Hay	0.63	2.0 Conc. NA Hay
(3) Hay on the HLF + Concentrate + Hay on the side-feeder	2.0	1.24	2.0 Conc. 2.0 Hay	0.0Conc. 2.0 Hay	0.76	2.0 Conc. 0.0 Hay
Probability					0.002	0.006

NA= None Available

7.4 DISCUSSION

The results of Chapter 6 showed that when hay was available in both a HLF and feeder at the side of the pen ewes ate exclusively from the HLF. In the present experiment the treatments were designed to examine this behaviour in more detail by comparing behaviour in situations when hay was available from either/or both a HLF and side feeder.

There are many references showing that animals display a preference for certain locations during grazing. For example, El Aich *et al.* (1989) and Scott *et al.* (1995) found that sheep preferred to graze from locations that contained their preferred plant species. Similarly, Samuel *et al.* (1980) found that choice of foraging location was affected by forage quality. Cattle also exhibit preference for location during grazing for example, Bailey (1988) studied the characteristics of spatial memory and foraging behaviour of cattle and Bailey and Sims (1998) used an 8-arm radial maze to determine the strength of the association between food quality and spatial locations in steers. Both these studies found that cattle had the ability to discriminate between the types of food present within their foraging area and associated those types of food with their locations. Distel *et al.* (1995) found that time spent grazing from a preferred location was affected by vegetation type, height, density and herbage mass. Cosgrove *et al.* (1996) found that cattle displayed preference for white clover and its location during grazing different types of grasses, and their preferences affected by the season. Similarly, Guevara *et al.* (1996) found that cattle exhibited preference for some types of plant species during grazing in rangeland of Argentina.

There are also references in the literature demonstrating preference for location in "housed" animals. In pigs, for example, Jones *et al.* (1996) found that pigs preferred to rest, sit, feed and forage more in unpolluted than polluted compartments that accessible to them. Feeder and drinker locations also affect the choice of sows farrowing site (Haskell and Hutson, 1994). They prefer to farrow in areas that had feeders and drinkers.

Deer also display dietary preferences and have an ability to associate preferred food with its location. Gillingham and Bunnell (1989) offered three foods (apples, dairy pellets and alfalfa) to deer in a small enclosure. Initially, apples were preferred to dairy pellets or alfalfa and when the foods were placed separately 5 meters apart the deer searched for apples. When these were depleted a second food was accepted. When the food positions were changed, the animals search paths were at first similar to those used successful before the foods were moved, demonstrating a memory of successful paths to food.

Choice of foraging location can also be affected by the location of supplemental feeds, i.e. animals prefer to forage from areas that are located around the source of supplementary feed (Roath and Krueger 1982; Senft *et al.*, 1985; Lawrences and Wood-Gush, 1988 and Stuth, 1991).

The results of the present experiment indicate that if there was hay available in the high-level feeder then ewes did not eat hay from the side-feeder. However, when there was no hay in the high-level feeder ewes spent as much time at the side-feeder as they did by the high-level feeder. This indicates that ewes were capable of choosing between the sources of hay, but they would eat from either source if there was no alternative available to them.

There are several possible explanations for the result and these include accessibility, safety and shape.

(1) The first possible explanation is that the ewes may have preferred eating from HLF due to its accessibility at the centre of the pen. Location at the centre of the pen may have given the ewes more freedom in terms of movement since they could move all around the HLF to select forage. In the case of the side-feeder animals could only use one side of the feeder because they could not reach the back. The HLF, located at the centre of the pen also allowed more animals to eat from it at the same time compared to the side-feeder. Where different types of maze for studying feed location have been used the results suggest that animals display prefererences for locations, for example Hosoi *et al.* (1995) found that animals prefered to eat at a lateral location in a T-maze (i.e the two arms of the maze were located laterally),

and suggested that they preferred that location because the food was easily accessible.

(2) The second possible explanation is that ewes might have preferred to eat from the HLF due to safety. It was observed that when individual ewes ate from the side feeder it moved and the hurdles sometimes moved. When other individuals went to eat from the side-feeder they may have been disturbed by the movement. Hutson (1985) found that disturbance affected the routine movement of sheep.

(3) The third possible explanation is that the ewes may have preferred eating from the HLF due to the way in which hay was presented in the HLF. The HLF was designed so that feed could be presented in a form similar to a real tree (Section 3.2.3). The HLF was designed to look like a tree having a rod in the middle similar to the trunk of a real tree, and with an inverted pyramidal shape basket into which forage could be placed. In contrast, the side-feeder had a rectangular shape basket; it was wide at the top and narrow at the bottom.

The conclusion drawn from this experiment is that ewes display a preference for eating hay from a HLF located at the centre of the pen compared to a side-feeder. However, in the absence of hay in the HLF they ate from a side-feeder. Accordingly, it is difficult to determining whether a combination of the above explanations are correct (i.e. 1, 2 or 3) or one of them, because these reasons were not strong enough to prevent ewes eating from a side-feeder if no food was available in HLF. So the drive to eat was stronger than other possible reasons for not choosing the side-feeder.

CHAPTER 8

SELECTION BY SHEEP OF FORAGES AVAILABLE SIMULTANEOUSLY ON THE HIGH-LEVEL FEEDERS

EXPERIMENT 6

8.1 INTRODUCTION

Many authors have reported experiments that demonstrate feed selection. These include experiments with sheep (Gorgulu *et al.*, 1996; Matejovsky and Sanson, 1995; Penning *et al.*, 1995; Provenza *et al.*, 1995, 1993; Revesado *et al.*, 1994; Scott *et al.*, 1996; Staaland *et al.*, 1995; Villalba and Provenza, 1997); deer (Duncan *et al.*, 1994); goats (Barroso *et al.*, 1995; Papachristou and Nastis, 1993); elk (Wood *et al.*, 1995); and cattle (Dumont *et al.*, 1995; Olivo *et al.*, 1994).

Feed selection by sheep depends on the animal's requirements, the quality and quantity of available food, and the ability to differentiate between feeds. Lynch *et al.* (1992) noted that diet selection in sheep is based on sheep making a decision concerning what plant species, individual plants and parts of plants to eat. Gorgulu *et al.* (1996) found that Awassi lambs, given choices among feed ingredients, could select diets that met their nutrient requirements depending on stage of maturity. Penning *et al.* (1995) found that lactating ewes grazing clover had higher daily DM intakes than those grazing ryegrass. Ramirez *et al.* (1995) studied forage selection by sheep on a buffelgrass-shrub range, and found that buffelgrass was preferred by lambs during all months, comprising 85% of the total diet with shrubs at 14%. Sheep have the ability to select components from a single food offerred to them. Forbes (1995), Black and Kenney (1984) and Bhargava *et al.* (1988) noted that when grass or hay is offered in the long, unchopped form animals have the opportunity to select between stem and leaf, and also noted that the proportion of leaf selected by sheep increases with amount of straw offered.

Experiment 4 showed that ewes spent more time eating ivy than hay and straw when these forages were available at separate time on a HLF. The aim of this experiment was to examine whether the same behaviour is observed when the three same sources of forage were available simultaneously on separate high-level feeders.

8.2 MATERIALS AND METHODS

8.2.1 Adaptation

The experiment was conducted on 20 of November 1996. Prior to the experiment, the animals were adapted to the animal house and to eating from the high-level feeders for six days, 3 hours per day (in the first three days the adaptation was in the morning and in the last three days it was in the afternoon) in an in-door pen (5.5m×5.5m). On the first day of adaptation period the animals were adapted to the first treatment [to eating ivy (good quality forage)from the HLF for three hours in the morning]. On the second day of adaptation period the ewes were adapted to the second treatment [to foraging hay (medium quality forage) from the HLF for three hours in the morning]. On the third day of adaptation periods the ewes were adapted to the third treatment [to foraging wheat straw (poor quality forage) from the HLF for three hours in the morning]. The same procedure were repeated for a further three days but in the afternoon. Before and after the adaptation period the animals will be kept together grazing outside(the grazing area was predominatly by perennial reygrass and white clover).

8.2.2 Animals, experimental design and treatments.

The experiment was conducted in an in-door pen (5.5m × 5.5m), using three types of forages on the high-level feeders. 1. Ivy (good quality forage); 2. Hay (medium quality forage); 3. Wheat straw (poor quality forage). Each type of forage was located on a separate high-level feeder (HLF) and the animals had *ad libitum* access to the forage that located on the HLF.

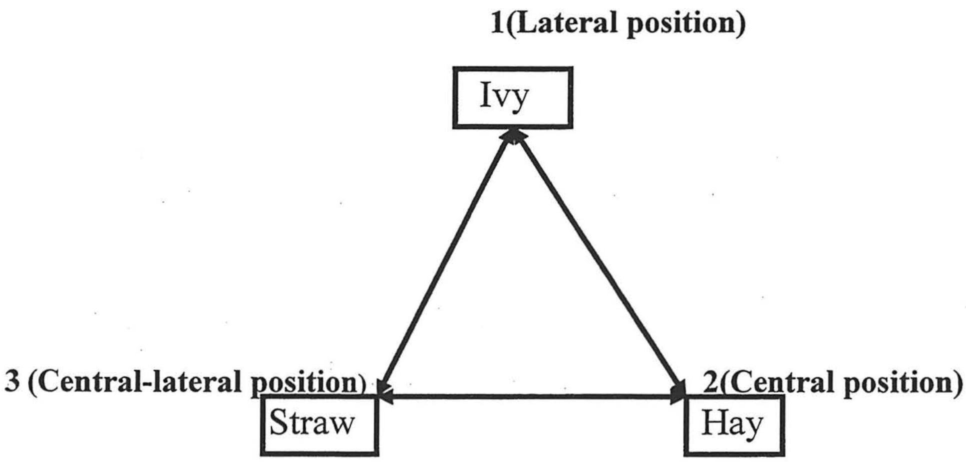
The experiment was repeated three times, and at each time, the location of each forage type was changed by rotating position as shown in Figure 8.1. This was done to prevent any forage being continually favoured by animals because of position in the pen, e.g. proximity to external wall or door. The animals had access to 2kg concentrate as a supplement, provided to them one hour before starting the observations. The ingredients of the concentrate were as described in Section 3.2.1. Eight dry Welsh Mountain ewes (4 years old) were selected randomly from flocks at College Farm University of Wales, Bangor. The weight of food intake and residues from the high-level feeders were recorded before and after feeding.

The design of the high-level feeder was as described in Chapter 3 (Section 3.2.3). The observations were as described in Section 3.2.4.2.

8.2.3 Statistical analysis

The time spent by ewes performing the activities were calculated from the real-time recordings. The average and percentage time spent in each individual behaviour was calculated using the formulae described in Section 3.2.5. Prior to ANOVA data for each behaviour were checked for normality, and then the data of the behaviour activities were analysed by ANOVA using the Minitab statistical package (Minitab, 1994) to examine the effect of treatments on individual behaviours, with replicates as fixed factor and ewes as random affect. ANOVA was also used to examine if there were effects of treatments on forage intake.

Figoure 8.1 The locations of forage in replicate 1



The forage sources were rotated from position 1 to 3 for the 3 replicates.

8.3 RESULTS

Table 8.1 shows mean and percentage times spent by Welsh Mountain ewes in various behaviour activities. Generally, behaviours of ewes were not significantly different between the replicates and also between the ewes except for lying activity which differed significantly between ewes (P<0.05). Ewes spent most of their time ruminating, lying and standing (28%, 22.2% and 21.2% respectively).

Table 8.1. Means (minute) and percentage (%) time for each behaviour and probabilities for the effect of replicate.

Behaviour	Mean	%	Probability for difference between ewes	Probability for difference between replicates
Standing	76.6	21.2	0.099	0.145
Ruminating	101.1	28	0.424	0.069
Lying	80.2	22.2	0.024	0.935
Walking	45.0	12.5	0.301	0.442

Table 8.2 shows the times spent by ewes eating the different feed sources. Ewes selected forage in the order ivy > hay > straw spending 15% of their time eating ivy and very little time eating hay and straw

(0.8% and 0% respectively). Ewes consumed 2.1kg ivy, 0.3kg hay with no detectable straw intake.

Table 8.2. Time (minute) spent eating ivy, hay and straw and their fresh intake.

Forage type	Mean	% time	Forage weight Before kg	Forage weight Residual kg	Forage Intake kg
Ivy	53.7	14.9	6	3.9	2.1
Hay	3.0	0.8	1	0.7	0.3
Straw	0.0	0.0	1	1	0.0
P-value for forage intake					≤0.001

8.4 DISCUSSION

In Chapter 6 ewes displayed a preferences for one type of forage (ivy) more than the other available forages (hay and straw) when those feeds were available to them on the HLFs separately. In the present experiment the same feeds were used but they were presented to ewes simultaneously on the HLFs. The results show that ewes displayed a preference for one type of forage (ivy) more than the other forages. Ewes selected ivy > hay > straw, spending 15% of their time eating ivy and very little time eating hay and straw (0.8% and 0%, respectively). Intake of ivy was also greater than that of hay and straw (2.1kg, 0.3kg and 0kg, respectively). This indicates that ewes have the ability to select from different types of forages available to them simultaneously on the HLFs. Several reasons why ewes preferred a specific type of forage (ivy) more than the other available forages were dicussed in Chapter 6. These included, brightness, for example Bazely and Ensor (1989) noted that sheep may use this characteristic to discriminate between plant species. Shape could be another reason since ivy had distinct leaves. Prache *et al.* (1998) found that grazing time and selection of pastures were higher on swards that had high green leaf mass. Sheep preferred to eat leaves more than the other component of a plant, for example, Black and Kenney (1984) gave sheep unchopped barley straw and hay and found that sheep selected the leaves more than stems. Additionally, ewes may have expressed a preference for ivy due to its nutrient content. The literature shows that animals of different species have the ability to select their diet from a free choice of two or more types of foods available to them in order to make up a balanced diet, for example, in birds (Forbes and Shariatmadari, 1994; Uzu *et al.*, 1993; Forbes, 1995), pig (Kyriazakis *et al.*, 1990; Bradford and Gous, 1991) and sheep (Glimp, 1971; Cropper *et al.*, 1985, 1986; Hou *et al.*, 1991 a&b; Gorgulu *et al.*, 1996; Hills *et al.*, 1998). Gorgulu *et al.* (1996) examined diet selection in Awassi lambs and found that when lambs were given choice among feed ingredients, they could select diets that met their nutrient requirements according to their stage of maturity. Animals may select one type of food more than the others due to their experiences of foraging from that particular food early in life. Provenza (1994) stated that experience affects food selection. Nolte *et al.* (1990) and Nolte and Provenza (1992) found that lambs consume more of foods they had been exposed to early in life.

Flores *et al.* (1989a) found that lambs with experience of foraging on the shrub serviceberry prehended serviceberry more successfully and thus had higher intake rates per unit time than inexperienced lambs. Forage selection is also affected by post-ingestive-consequences, i.e. if the post-ingestive-consequences are positive then animals will eat those feeds in preference to others available (Provenza, 1995). They will avoid foods that are toxic as a result of negative post-ingestive-consequences (Provenza *et al.*, 1993).

The experiment described in Chapter 6 and the present experiment found that sheep preferred ivy. It was observed in the current experiment that ewes investigated the available forages by smelling them, and it is known that sheep can use smell to discriminate between forages of different qualities (Arnold, 1966; Forbes 1995; Edwards *et al.*, 1997; and Narjisse *et al.*, 1997). Another possible reason why ewes preferred ivy is due to their prior experience of eating ivy. The ewes used in the experiment had access to ivy from walls around fields at the College Farm, and this prior-foraging experience may have influenced their preferences as displayed in the current experiment.

The present experiment also indicates that the high level-feeder is a suitable and useful in-door technique to study diet selection by sheep to determine their preferences. Determination of domestic animals preferences and need is usually with choice tests or operant conditioning techniques (Hughes, 1976; Dawkins, 1981; Faure, 1985, 1986, 1991; Dawkins and Beardsley, 1986; Lagadic and Faure, 1987; Faure and Lagadic, 1989). In the present study the HLF technique was proved as a useful choice test in sheep.

It can be concluded that Welsh Mountain ewes have the ability to select their diet from different types of forage available to them simultaneously. It is likely that they preferred ivy for a variety of reasons including its leafy shape, smell and taste and their prior foraging experience. Additionally, the HLF is an useful tool when selection and preference of a forages need to be study in sheep.

CHAPTER 9

THE EXTENT TO WHICH SHEEP WILL OVERCOME AN OBSTACLE IN ORDER TO EAT FROM A HIGH-LEVEL FEEDER

EXPERIMENT 7

9.1 INTRODUCTION

Dawkins (1983) stated that operant conditioning techniques can be used to assess motivation and to find out how hard animals are prepared to 'work' to gain access to food or to avoid something. Kilgour *et al.* (1991) mentioned that the operant precedure can be used in two ways; to study animal perceptual abilities and to assess their needs and/or preferences. For example, mazes have been successfully used to test the feed preferences of different animal species. For example, Grandin *et al.* (1994) used a Y-maze in a cattle experiment; Pollard *et al.* (1994) used a Y-maze for red deer and Hosoi *et al.* (1995) used a T-maze in goat and sheep work.

Obstacles can also be introduced into preference and need experiments to gauge the strength or magnitude of an animal's preference for one feed or environment rather than another. For example, Nicol (1986), Cooper and Appleby (1994) and Chalkley (1997) used a weighted door as an obstacle to measure the motivation or need in chickens. Similarly, Cooper and Mason (1997) used the same technique to examine the behavioural priorities of mink in a closed economy. Jackson *et al.* (1999) used an operant crate and a weighted push-door technique to measure feeding motivation in sheep.

Such techniques are useful tools to investigate the preferences of animals and to determine how much they are willing to work to obtain food. Understanding such factors are important from the management and welfare point of view.

The aim of this experiment was to examine the extent to which sheep will overcome an obstacle (weighted door) in order to eat ivy from a high-level feeder and concentrate from a feeder, to see how much the ewes are willing to work to obtain food. The technique was a modification of a method described by Aden (1997).

9.2 MATERIALS AND METHODS

9.2.1 Animals and Pen

The experiment was conducted in an in-door (3m×9m) pen. The pen was divided into two parts, the first part was a 'holding pen' (3m×3m) used for holding the animals before they were released for observations. The next section was the 'experimental pen' (3m×6m). This pen was divided into two parts A and B, pen A (3m×3m) and pen B (3m×3m) separated by a one-way gate. The gate was attached to a weight. The weight was held by a rope, one end of which was attached to the door. The door of the pen was not completely closed, but was left open (12cm gap), the need for a gap was noted by Aden (1997) who found that in the absence of a gap sheep had difficulties opening the one-way door. Aden (1997) found that a weight of 15kg represented an obstacle that sheep could overcome. The high-level feeder (HLF) and concentrate trough were located in pen B. Four dry Cambridge ewes (4 years old) were selected randomly from a flock at College Farm University of Wales, Bangor for this study.

9.2.2 Experimental design and Treatments

A randomised complete block experiment was conducted with four treatments, namely, 1. Concentrate + 0kg on door; 2. Ivy (HLF) + 0kg on door; 3. Concentrate + 15kg on door; 4. Ivy (HLF) + 15kg on door. Each treatment was repeated four times at random within four blocks (replicates) of treatments. The ewes were released randomly within each treatment run and the time taken to reach the high-level feeder or concentrate was recorded for each ewe starting from the door of pen B. The maximum time allowed was 30sec. Before conducting the experiment the animals were adapted to the pens and treatments for two weeks. At the beginning of the adaptation period, the animals had access to concentrate (limited amount) and ivy located in the high-level feeder without using a weight (0kg) to close the door. They were adapted gradually to open the weighted-door starting from 5kg till they were able to open 15kg (by increasing 5kg each day) for the remainder of the first week of the adaptation period.

The design of the high-level feeder was as described in Section 3.2.3. The ivy was located on the high-level feeder as if the ewes eating a browse materials from a tree.

9.2.3 Statistical analysis

The times taken to reach the feeds (high-level feeder (ivy) and concentrate) were analysed by ANOVA using a model that included the ewes as a random factor and replicates, feed, weight and the interaction between feed and weight as fixed factors.

9.3 RESULTS

During the experiment it was observed that the animals used many tactics to open the door including their foot or by sticking their head between the bars of the door and the wall of the pen. Once they got their head between the bars, they then continued to push the door with their shoulders and body. It was also observed that one of the ewes always opened the door before the others, and presumably acted as a leader for the group.

Table 9.1 shows that there was a significant difference ($P<0.001$) between the times taken to overcome the 0kg weight(13 sec.) and the 15kg weight (24 sec.). The ewes took almost twice as much time to reach the feed when the door was weighted.

When there was no weight on the door, the ewes took more time to open the gate when ivy (23.2 seconds) was available than when concentrate was available (3.5 seconds). There was no significant interaction between type of feed and weight ($P>0.05$).

Table 9.1. The mean time (seconds) taken by ewes to reach feeds with and without a weight on the one-way door.

Feed	**Weight**		**Mean for feed**	**Probability for effect of feed**
	0kg	**15kg**		
1- Concentrate	3.5	10.8	**7.1**	<0.001
2- Ivy	23.2	37.8	**30.5**	
Mean for weight	**13.4**	**24.3**		
Probability for effect of weight	**<0.001**			
Probability for interaction between weight and feed	**0.188**			

The times taken by individual ewes to overcome the obstacles and to reach the feeds (Table 9.2) showed that there were significant differences between them (P<0.001). The time taken by ewe 1 was consistently shorter than others ewes, taking on average 9 sec. to reach the feed.

Table 9.2. Time (seconds) taken by individual ewes to reach feed.

Ewe number	Mean time
1	8.9
2	24.6
3	14.9
4	26.9
P-Value	<0.001

9.4 DISCUSSION

Sheep have to expend energy (i.e. work) in order to obtain food in the natural environment. If the food is in short supply they have to work harder to obtain it. For example, the "obstacle" in a grazing environment of animals in an arid environment may be lack of grass due to drought, and in this situation the animals must work to search for their food. Sherwin and Nicol (1995) classified the task or work required by an animal to gain access to a resource into various types. (1) The instrumental approach requires an animal to learn to activate some mechanism such as a lever or running wheel (e.g. Roper, 1973; Collier *et al.*, 1990; Matthews and Ladewig, 1994). (2) The homeostatic-competition approach requires an animal to expose itself to an environment which challenges homeostatic processes e.g. warm or cold ambient temperature (e.g. Johnson and Cabanac, 1982a&b; Cabanac and Johnson, 1983). (3) The "natural" obstacle approach requires an animal to overcome a barrier such as a narrow gap (Nicol, 1986; Cooper and Appleby, 1993).

The results of the current experiment showed that ewes overcame an obstacle in order to obtain food. The significant difference that occurred between the times spent to open the unweighted door and to open the weighted door indicates that ewes in both situations expended energy to gain access to a food but the degree of expending energy varied depending on the type of obstacle that was present. This result supports the findings of Aden (1997) who found that animals took more time to open a 15 kg weighted-door than an 8kg one, and this indicates that animals are motivated to work to gain access to a resource.

Sheep took less time ($P<0.05$) to reach concentrate than ivy on the HLF (7 sec. and 31 sec., respectively). This suggests that ewes discriminated between types of available feeds by eyesight. Because it was observed during observations that when the ewes saw the concentrate feeder present in the pen they moved faster through the obstacle than when they saw ivy on a HLF. This indicates that ewes have the ability to learn to associate a preferred feed with its feeder. Edwards *et al.* (1996 and 1997) examined the ability of sheep to form spatial associations between 2 cues (each patch of feed reward had a turf of perennial ryegrass, or white clover, associated with it as a cue) and 2 feed rewards patches (placed in plastic bowls containing preferred, cereal pellets, or non-preferred, lucerne pellets feed). They found that sheep formed associations between cues and rewards and distinguished between the cues by sight or smell. It was also stated that the ability to form "flexible associations between cues and feed is an important mechanism, acting independently of memory of spatial locations", that would help sheep select diets that are better than the average in spatially and temporally complex feed environments. The observation in the present experiment showed that ewes went faster to eat from one type of feed (i.e. concentrate) than they did from another (i.e. ivy), also indicates that ewes might have the ability to take a decision to work harder in order to move faster to preferred feeds. Barnard (1983) and Forbes (1995) stated that when an animal wants to perform any activity from the routine daily activities there must be a decision making process to determine which activity to perform at any given time. Examples that demonstrate that sheep have the ability to take a decision, include searching for food or survival, selection of diet component from different types of feeds available to them (Hou *et al.*, 1991a) and reactions to "predators" e.g. fox. The decision by animals to eat or to move faster to a food source is affected by hunger and by prior-experience.

(1) Hunger

If animals are hungry they will move faster to the available food. For example Petherick *et al.* (1992) trained hens to run down a 14.4 m alley for food after being deprived. They found that the speed of running was significantly increased by deprivation. Similarly, Jackson *et al.* (1999) used an operant crate and a push-door technique to measure feeding motivation in sheep after 0h, 6h, 12h, 18h and 24h without food. They found that sheep went quicker through the push-door to reach their food when the period of food deprivation increased. Also they found that deprived sheep spent less time pushing the door than non-deprived one.

(2) Prior-experience

If an animal has prior-experience of a food it will eat faster from it. For example, Flores *et al.* (1989a) found that sheep used to eating grass had a higher biting rate for grass than those experienced in harvesting shrubs. Similarly, Ortega-Reyes and Provenza (1993) found that goats with experience of browsing blackbrush ate faster than goats without experience of this forage.

The results showed that there were significant differences between individuals in the times taken to reach the food sources. Some individuals did not go through in the maximum time allowed (i.e 30 sec.). These differences were probably due to body size and the capability of individual ewes to push the obstacle. It was observed that ewes that had smaller body size took more time to overcome the obstacle. This result agrees with the result of Aden (1997). Studman (1991) also found that the ability of a sheep to go through a barrier is a function of the size of the gap, the force that the animal can apply and the size of the sheep. The sheep will succeed if it can apply enough force to allow it to produce a large gap to escape from that barrier.

So it can be concluded that both the HLF and obstacle techniques are useful techniques when the degree of preferences for feeds is to be studied. It can also be used to test if an animal species are willing to work to obtain particular foods. It can also be concluded that sheep have the ability to take a decision to work harder in order to move faster to preferred feeds.

CHAPTER 10

THE EFFECT OF PRIOR-FORAGING EXPERIENCE ON THE FORAGING BEHAVIOUR OF EWES GIVEN ACCESS TO IVY

EXPERIMENT 8

10.1 INTRODUCTION

Forage utilization has been shown to be affected by experiences of the animals with regard to the available foods. Provenza and Balph (1987) reviewed the foraging behaviour in ruminants (that included food learning and recognition, foraging skills and foraging efficiency). They found that dietary habits are not fixed genetically, but are modified by experience. They noted that food learning may help to adapt herbivore animals to the available forages within their environment. For example, Flores *et al.* (1989b) found that the lambs with experience foraging on the shrub Serviceberry (*Amelanchie alnifolia*) prehended Serviceberry more successfully and thus had higher intake rates per unit time than inexperienced lambs or lambs experienced in foraging only on grass. Similarly Ortega-Reyes and Provenza (1993) studied the foraging skills in goats and they found that foraging skills improved with foraging experience (e.g. the foraging skills of the animal were improved by repeating foraging experience). Provenza and Balph (1987) studied diet learning by domestic ruminants and they found that sheep that had no experience with two generally unpalatable plant species ate much less of them than sheep with experience.

The objective of this study was to examine whether there is an effect of prior-feeding experience on selection of feed from alternative sources.

10.2 MATERIALS AND METHODS

10.2.1 Adaptation

Two groups of animals were adapted on separate plots. They were a high-level feeder group (HLF) (4 mature, dry Welsh Mountain ewes) and floor group (F) (4 mature, dry Welsh Mountain ewes). These animals were selected randomly from flocks at the College Farm University of Wales, Bangor. Their ages were 5 to 6 years old. The HLF group were adapted to eat ivy located on the high-level feeders for 5 days, and fed once a day. The F group were adapted to eat ivy located on the floor for 5 days, and fed once per day. Both groups were provided with concentrate at 0.5 kg per ewe during the adaptation period and during the experiment, but before the recording of behaviour began.

10.2.2 Treatments and Method

10.2.2.1 Treatments

The experiment was conducted in an in-door pen (5.5m × 5.5m) using two treatments namely:

1- The high-level feeder trained group (HLF): They had access to ivy located on the high-level feeder and on the floor.

2- The floor trained group (F): They had access to ivy located on the floor and on the high-level feeder.

10.2.2.2 Method

Before and after observations the animals were kept grazing outside (the grazing area was predominatly perennial reygrass and white clover). Each treatment was repeated three times. The weights of ivy intake and residues for each location were recorded before and after the observation period. The observation period was 3 hours at 5 minutes intervals from 10.00 h to 13.00 h. The observations of the activities were as described in Section 3.2.4.2.

Dry matter digestibility (DMD), modified acid detergent fiber (MADF), crude protein (CP) and ME were estimated. The samples of ivy plant components from 2 chapters were mixed and a representative sample for each component was taken for the chemical analysis because the ivy species were the same and it was taken from one location.

The sample for ivy evaluation was taken randomly from 3kg freshly collected daily from College Farm. The 1kg was isolated from the 3kg and the other 2kg were located in AT and floor (1kg per location).

Ivy leaves and twigs, branches and flowers were separated from the 1kg and the weight for each part was taken and then those parts were dried for 4 days (the weight of sample was taken after two days and after that it was taken each day to compare it with the other days until constant weight was obtained) at 105°C; after that the dry weight for each part was taken to calculate the DM%. This was done for each replicate. The samples were kept for the ivy evaluation.

10.2.2.2.1 Chemical analysis

The chemical analysis are described in Appendix 6-8.

10.2.2.2.2 Estimation of the metabolisable energy (ME) of ivy plant components

The ME was estimated from the MADF and IVD of ivy plant components based on the equations for fresh grass, hay and straw (AFRC, 1995). The equations that were used are as follows:

<u>Fresh grass *</u>
ME=16.20-0.0185[MADF]
ME=-0.46+0.0170[IVD]

<u>Hay*</u>
ME=15.86-0.0189[MADF]
ME=2.67+0.0110[IVD]

<u>Straw*</u>
ME=0.53+0.0142[IVD]

These equations were used in the absence of an equation specifically for ivy and were thought to reflect the range of characteristics of ivy components including leaves and branches. The ME was estimated by applying all the above equations for each component of ivy plant (leaves, branches, twigs and flower), after that the range and mean of ME value for each component of ivy plant was calculated.

10.2.2.2.3 Calculation of ivy DM intake:

A 1kg sample was taken randomly from approximately 3kg of fresh material. The leaves, twigs, branches and flowers of the sample were separated. The fresh weight of each component was taken. The components were dried for 4 days (the weight of sample was taken after two days and after that it was taken each day to compare it with the other days until it reached a constant weight) at 105°C.

At the end of the observation period the refusals of ivy plant from the HLF and the floor were weighed. The leaves, twigs, branches and flower were separated from the refusals, and then they were dried at 105°C for 4 days. The dry weight for each component was determined.

10.2.2.2.4 Estimated metabolisable energy (ME) requirement of ewes

The estimated maintenance ME requirement for ewes excluding activity was calculated as:-

$$\mathbf{ME\ (MJ/day)} = 0.23 \times (W/1.08)^{0.75} \times \frac{1}{0.72} \longleftarrow \text{(AFRC,1995)}$$

10.2.2.2.5 Statistical Analysis

The time spent by ewes performing the activities were calculated from the real-time recordings. The average and percentage time spent in each individual behaviour was calculated using the formulae described in Section 3.2.5. The data of the behaviour activities were analysed by ANOVA using the Minitab statistical package (1994) to examine the effect of browse locations on individual behaviours, with groups as a fixed effect and ewes within group as a random factor.

ANOVA was also used to examine the effects of browse locations on intake and to see if there were interactions between group and locations, with groups and locations as a fixed effects.

10.3 RESULTS

10.3.1 The difference in behaviour between the HLF and floor groups

The results show that there were significant differences between the HLF-trained and floor-trained groups in the time spent eating ivy from the HLF and floor (P<0.05). The HLF-trained group spent more time eating ivy from the HLF than the floor-trained group (15.5% and 10.5% respectively). The floor-trained group spent more time eating ivy from the floor than the HLF-trained group (16.4% and 3.2% respectively).

The results of Table 10.1 show that animals trained to eat from a specific location or source they still eating from the other location.

There were no significant differences between the HLF-trained and floor-trained groups on the time spent standing, ruminating, lying or wlaking (P>0.05).

The results of Table 10.1 also show that there were significant differences between individual ewes in the time spent eating ivy from HLF (P<0.05). However, there were no significant differences between individual ewes of either groups on the time spent eating ivy from the floor (P>0.05).

10.3.2 Interaction between group and location

There was a signficant interaction between group and location (P<0.05) and this indicated that the ewes that were trained to eat ivy from the HLF spent more time eating from the HLF than they did from the floor. Conversely, the floor-trained group spent more time eating ivy from the floor than they did from HLF as shown in Table 10.1. This indicates that training increased the time spent eating on the location that the ewes are accustom to eating from it and not prevent the ewes from eating from the sources or location which they are not accustom to it.

10.3.3 DM intake of ivy

Dry matter percentage, DM offered and DM intake and residue are presented in Table 10.2. 1kg fresh weight of ivy plant had from 107.3-108.3g DM weight leaves, 11-14g DM weight twigs, 247-252.7g DM weight branches and 9.3-10.3g DM weight flower. The overall DM % of ivy plant from 37.8-38.4%.

The highest proportion of the DM intake by ewes was leaves, which they consumed about 82-86% leaves and the rest of percentage was the other components of ivy plant which they eating twigs, young green branches and flower when all the leaves of a branches were eaten.

There was a signficant interaction between group and location (P<0.05) on the ivy intake, and this indicated that ewes that were trained to eat ivy from the HLF ate more from the HLF than they did from the floor. Conversely, the floor-trained group ate more ivy from the floor than they did on HLF as shown in Table 10.2.

The results of the DM intake for the floor-trained group indicates that ewes ate more ivy from both HLF and floor than HLF-trained group did (P<0.05). The overall dry matter intake (DMI) of the floor-trained group from the HLF was 70.6 g/4 ewes (17.7g DM/ewe) and from the floor was 81.3 g/4 ewes (20.3g DM/ewe), whereas for the HLF-trained group the overall DMI of ivy from the HLF was 64.7 g/4 ewes (16.2g DM/ewe) and from the floor was 29.6 g/4 ewes (7.4g DM/ewe) (Table 10.2).

Table 10.1. The times (minutes) spent on various behaviour activities by Welsh Mountain ewes and ivy fresh weight intake.

		Eating ivy from HLF	Eating ivy from floor	Stand.	Ruminating	Lying	Walk	Ivy intake from HLF (fresh Weight) kg	Ivy intake from floor (fresh weight kg
HLF-group	mean	27.9	5.8	45.8	20.4	50.4	29.6	0.185	0.054
	%	15.5	3.2	25.5	11.3	28	16.5		
Floor-group	mean	18.8	29.6	31.3	24.2	55.0	21.2	0.190	0.228
	%	10.5	16.4	17.4	13.4	30.5	11.8		
P-value for ewes within (gro up)		0.010	0.871	0.252	0.853	0.90	0.896		
P-value for group		0.019	0.001	0.085	0.558	0.68	0.185	0.008	
P-value for location								0.105	
P-value for group* location								0.011	

Table 10.2. Ivy DM intake and residue for HLF and floor groups

Day-group		Ivy plant					Total DM % of ivy plant
		Leaf	Twig	Branch	Flower	**Total**	
HLF group	Distribution (%) of total DM by component	28.7	2.9	65.6	2.8		**37.8%**
	DM offered (g)	108.3	11	247	10.3		
	DM residues from the HLF (g) DM residues from the floor(g)	52.6 84	6 10.3	247 245	6.3 7.7		
	DM intake from the HLF (g) Percentage of DM intake %	55.7 86.1%	5 7.7%	0 0%	4 6.2%	64.7g	
	DM intake from the floor (g) Percentage of DM intake %	24.3 82.1%	0.7 2.4%	2 6.8%	2.6 8.8%	29.6g	
floor group	Distribution (%) of total DM by component	28.0	3.6	65.9	2.4		**38.4%**
	DM offered (g)	107.8	14	252.7	9.3		
	DM residues from the HLF(g) DM residues from the floor(g)	48.7 39	6.3 7	251 252	6.7 4		
	DM intake from the HLF(g) Percentage of DM intake %	58.6 83.0%	7.7 10.9%	1.7 2.4%	2.6 3.7%	70.6g	
	DM intake from the floor(g) Percentage of DM intake %	68.3 84.0%	7 8.6%	0.7 0.9%	5.3 6.5%	81.3g	

10.3.4 Chemical composition and IVDMD of ivy plant

The estimation of metabolisable energy (ME) of ivy plant components are presented in Table 10.3.

Table 10.3. estimation of metabolisable energy (ME) of ivy plant components

Equations adopted for estimation of ME (MJ/KG DM)	Leaves MJ/KG DM	Twigs MJ/KG DM	Flower MJ/KG DM	Branches MJ/KG DM
Fresh grass *				
ME=16.20-0.0185[MADF]	10.5	10.4	12.1	6.3
ME=-0.46+0.0170[IVD]	10.2	11.4	10.8	4.8
Hay*				
ME=15.86-0.0189[MADF]	10.1	9.9	11.6	5.8
ME=2.67+0.0110[IVD]	9.3	10.0	9.7	5.8
Straw*				
ME=0.53+0.0142[IVD]	9.1	10.0	9.6	4.6
ME (MJ/KG DM) range*	9.1-10.5	9.9-11.4	9.6-12.1	4.6-6.3
mean	9.8	10.3	10.8	5.5

*= The sources of equations was AFRC (1995).

The percentages of IVDMD, MADF%, CP% and ME for ivy plant components are presented in Table 10.4. The results shows that IVDMD % of twigs, flower and leaves of ivy plant were higher than that of branches (66.9%, 63.6%, 60% and 28.5% respectively). The results also show that CP% of flowers, leaves and twigs were higher than CP% branches (16.2%, 12.6%, 4.8% and 3.7% respectively), whereas their MAD fiber contents were lower than that of branches (22.3%, 30.7%, 31.3% and 53.4% respectively). The ME of flowers, leaves and twigs were also higher than branches (10.8 MJ/Kg DM, 9.8 MJ/Kg DM, 10.3 MJ/Kg DM and 5.5 MJ/Kg DM respectively) as shown in Table 10.4.

Table 10.4. Chemical composition and % of IVDMD of ivy plant

	Leaves	Twigs	Flower	Branches	Total	
Distribution (%) of total DM by component	28.4	3.2	2.6	65.8		
IVDMD %	60.0	66.9	63.6	28.5		
SEM*	0.115	0.176	0.145	0.333		
Ash-free MADF %	30.7	31.3	22.3	53.4		
SEM*	0.361	0.233	0.260	0.233		
Crude protein % (CP)	12.6	4.8	16.2	3.7		
SEM*	0.012	0.038	0.023	0.020		
ME (MJ/KG DM) range*	9.1-10.2	9.9-11.4	9.6-12.1	4.6-6.3		
mean	9.8	10.3	10.8	5.5		
ME requirement per ewe (MJ/day) for HLF-group	**4.499**					
ME intake *(MJ)* from the HLF/3 hours period	0.55	0.055	0.044	0	**0.1621/ewe**	**0.6486/4 ewes**
ME intake *(MJ)* from the floor/3 hours period	0.238	0.0076	0.0283	0.011	**0.0712/ewe**	**0.2849/4 ewes**
ME requirement per ewe (MJ/day) for floor-group	**4.471**					
ME intake *(MJ)* from the HLF/3 hours period	0.57	0.0839	0.0283	0.00935	**0.1729/ewe**	**0.6915/4 ewes**
ME intake *(MJ)* from the floor/3 hours period	0.669	0.0763	0.0577	0.00385	**0.2017/ewe**	**0.8069/4 ewes**

SEM*=Standar error mean. **range***= The range was according to the equation used (IVDMD & MADF equations for fresh grass, hay and straw) __

10.3.4.1 ME intake from ivy

The overall ME intake for floor group from the HLF was 0.1729 MJ/ewe and from the floor was 0.2017 MJ/ewe, whereas for the HLF-group the overall ME intake of ivy from the HLF was 0.1621 MJ/ewe and from the floor was 0.0712 MJ/ewe as shown in Table 10.4. This results indicated that the ME intake for HLF-group and floor-group still do not meet the requirement of ewes, because the ME requirement per ewe per day is 4.499 MJ/ewe/day and 4.471 MJ/ewe/day for HLF and floor group respectively as shown in Table 10.4. As there was no significant difference between the weights of ewes of the two groups ($P<0.05$) (36.8kg for HLF-group and 36.5kg for F-group), the overall mean ME requirement per ewe per day was 4.48 MJ/ewe/day.

Figure 10.1 shows the number of ewes eating ivy from the HLF and floor by HLF-trained group. The ewes start eating ivy from the HLF, also the Figure 10.1 shows that the number of ewes eating ivy from the HLF were more than that from the floor. Eating ivy from the HLF by HLF-trained group was active at the beginning of the observation period and then it started to decrease and then it returned active again at the end of observation period. Also at the middle of observation period the ewes took a rest period and then returned to eating ivy from both locations.

Figure 10.2 shows the number of ewes eating ivy from the floor and HLF by floor-trained group. The ewes start eating ivy from the floor, also Figure 10.2 shows that the number of ewes eating ivy from the floor was more than that from the HLF. The eating of ivy from the floor was more active than that from the HLF, and then the eating from both locations started to decrease.

Figure 10.1 Number of ewes (sum of 3 replicates) eating ivy from HLF and floor of the HLF-group

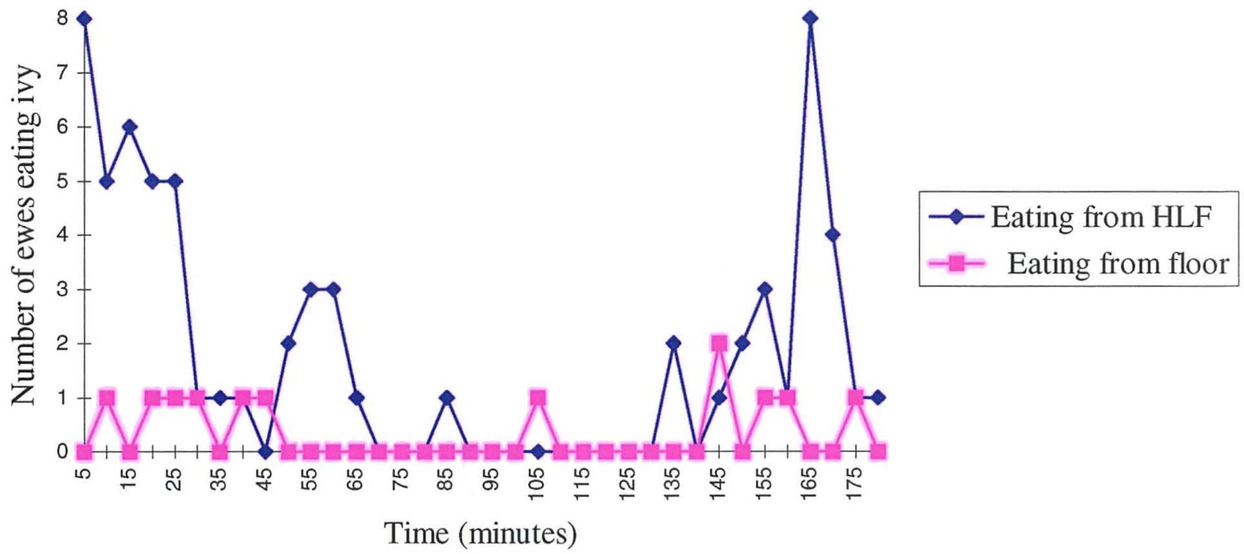
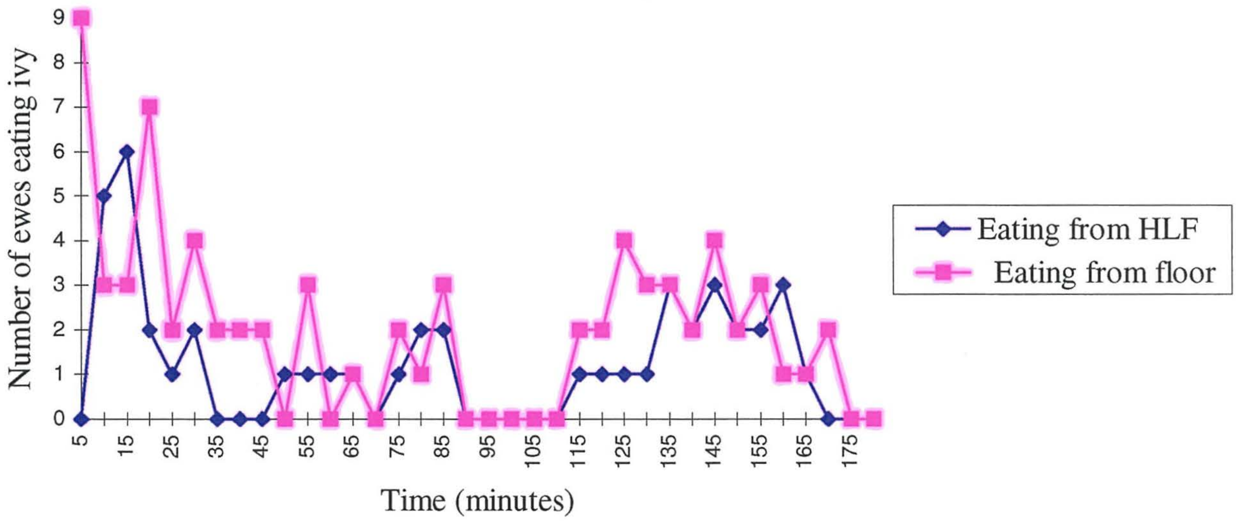


Figure 10.2 Number of ewes (sum of 3 replicate) eating ivy from HLF and floor of the F-group



10.4 DISCUSSION

The aim of this experiment was to examine whether there was an effect of prior-feeding experience on selection of feed from alternative sources. The literature shows that prior-foraging experience affects diet selection and intake in sheep (Arnold and Maller, 1977; Lobato *et al.*, 1980; Keogh and Lynch, 1982; Lynch *et al.*, 1983; Green *et al.*, 1984; Flores *et al.*, 1989a; Provenza *et al.*, 1993; Provenza, 1994; Scott *et al.*, 1995) and goats (Provenza and Malechek, 1986; Provenza *et al.*, 1990, Ortega and Provenza, 1993). For example, Provenza and Balph (1987, 1988 and 1990) and Provenza *et al.* (1988) found that unexperienced animals spent more time foraging but ingested less forage compared to experienced ones.

The results of this chapter show that prior-foraging experience or training increased the time spent eating ivy from the source that sheep had been trained to eat from. The results also show that animals trained to eat from a specific location or source still ate from other available sources. This agrees with the findings of Provenza and Balph (1987) who concluded that livestock that have had an experience of foraging from a specific location utilized more forage from that location than from an unfamiliar one.

Time spent eating ivy from the HLF was affected by individual ewes within the group. It was observed that some ewes did not allow space for the other ewes to eat ivy, indicating that there was a competition effect between individual ewes.

The results also indicated that although the time spent eating ivy from the HLF by the HLF-trained group was more than the time spent eating ivy from HLF by the floor-trained group, the floor-trained group ate more ivy from both the HLF and floor than did the HLF-trained group. This suggests that time spent eating increased without an increase in ivy intake. This was probably due to an increase in the time spent searching for younger leaves rather than eating. For example, Sibbald and Shellard (1998) found that grazing time of sheep increased without an increase in herbage intake due to an increase in time spent searching for preferred grass species rather than ingestive behaviour.

The preference of ewes for ivy leaves more than the other components may reflect their greater digestibility and CP content. Barroso *et al.* (1995) studied the factors that influence food selection and found that plants were preferred when *in vitro* DM digestibility and CP increased.

The average ME provided by ivy per ewe during the experiment (i.e. 3 hours) was 0.3 MJ (0.1 MJ/ewe/h). This indicates that the ME intake did not meet the daily requirement of ewes. The ME requirement per ewe per day was estimated to be 4.5 MJ/ewe/day. In order to meet the daily maintenance requirement ewes would have to eat ivy for longer and considerabley increase their intake. In the current experiment ivy provided only a small fraction of the daily requirement, with the remainder from grazing and concentrate. In contrast Sarson and Salmon (1978) found that browse provided alone to sheep could meet their maintenance requirements.

The conclusions that can be drawn from this experiment are that prior-feeding experience or training increased the time spent eating ivy from the sources that sheep were accustomed or experienced to eating from. However, animals trained to eat from specific locations or sources still ate from the other sources available. This suggests that drive to eat by ewes can overcome prior-training/experience.

CHAPTER 11

THE EFFECT OF FORAGE LOCATIONS ON THE FORAGING BEHAVIOUR OF SHEEP WHEN GOOD QUALITY FORAGE IS AVAILABLE

EXPERIMENT 9

11.1 INTRODUCTION

Animals can learn to identify the position or location of preferred food. Forbes (1995) noted that in addition to features such as colour, shape and brightness, animals can also learn the position of the food if its position is consistent between exposures. Gillingham and Bunnel (1989) offered three foods (apples, dairy pellets and alfalfa) to deer in a small enclosure. They found that deer preferred apples more than the others even when the position of the foods were changed or placed separately 5 meter apart the deer searched for apples. However, they found that deer demonstrated a memory of successful paths to preferred food. Selection of foraging locations by sheep was also affected by dietary ingredients and flavour of the forages found in the preferred locations (Scott and Provenza, 1998).

The selection of foods is affected by the animal species eating these foods and also by the quality of the available foods. For example, Hosoi *et al.* (1995) conducted experiments to examine the foraging behaviour of sheep and goats using a T-maze apparatus. They found both animals species eating from both arms of the maze when good quality feed was presented on these arms, but when low quality food was introduced into one arm of the maze, they found that goats were more selective than sheep.

It was observed in Experiment 5 (Chapter 7) that when hay (medium quality forage) was available to ewes at two locations (HLF and side-feeder), ewes ate hay from the side-feeders when there was no hay available on the high-level feeders (HLF), whereas if there was hay on the high-level feeders the ewes ignored the hay that was present in the side-feeders. The objective of this study was to investigate the effect of different locations of forage in the behaviour of ewes when a high-quality forage (ivy) was available.

11.2 MATERIALS AND METHODS

11.2.1 Adaptation

The animals were adapted in an in-door pen for three hours in the afternoon each day for 6 days. On the first day of adaptation the animals were adapted to eat ivy from the HLF for three hours in the afternoon, and on the second day they were given ivy located on the floor for three hours in the afternoon, on the third day they were adapted to eat ivy that was located on a hurdle at the side of the pen for three hours. The same procedure was repeated for a further three days. Before and after the adaptation period the animals were kept together grazing outside(the grazing area was predominatly perennial reygrass and white clover). The animals were provided with concentrate 0.5 kg per ewe during the adaptation period and during the experiment but before the recording began.

11.2.2 Treatments and Method

11.2.2.1 Treatments

Eight mature and dry Welsh Mountain ewes were selected randomly from flocks at College Farm University of Wales, Bangor. The experiment was conducted in an in-door pen (5.5m × 5.5m), using three locations for the feed (ivy) 1. eating ivy from the high-level feeders (HLF); 2. eating ivy from a floor (F); 3. eating ivy from a hurdle at the side of the pen (H). The animals had access to feed from the three locations at the same time.

11.2.2.2 Method

The experiment was repeated three times. The weight of browse or ivy intake and residues for each location was recorded before and after feeding.

11.2.2.2.1 Observations

The observation was 3 hours at 5 minutes interval per day on the afternoon. The observations of the activities were as described in Section 3.2.4.2.

11.2.2.2.2 Ivy intake and ivy sampling for chemical analysis

The weight of ivy was recorded before and after feeding. for each locations. Total ivy intake was calculated as the difference between quantity of ivy offered and quantity of ivy refused.

The sample for ivy DM analysis was taken randomly from 8kg freshly collected daily from College Farm. 2kg were isolated from the 8kg and the other 6kg were located in HLF, hurdle and floor (2kg per location).

Ivy leaves and twigs, branches and flowers were separated and the weight for each part was taken and then those parts were dried for 4 days at 105^{o}C after that the dry weight for each part was taken to calculate the DM%, and this was done for each replicate (Table 11.4). Due to the ivy plant was taken from one locations and from one species in this chapter and in Chapter 10, so the samples of this chapter were kept with the samples of Chapter 10 for evaluation of ivy plant. The chemical analyses that carried out for ivy plant were, MADF, IVDMD, CP and estimation of ME; methods of measurements are described in Chapter 10.

11.2.2.2.2.1 Estimation of ivy dry matter (DM) intake and ME requirement for ewes.

DM intake of ivy component =

$$\frac{\text{\% of contribution of component to ivy DM}}{100} \times \text{Total DM intake}$$

The percentage of contribution was based on results obtained in Chapter 10. The above formula was used in this experiment (Chapter 11) because this experiment was done before the experiment in Chapter 10, and the idea for the calculation of ivy intake came when the experiment of chapter 11 was already completed.

The estimated maintenance ME requirement for ewes were as described in Section 10.2.2.2.4.

11.2.2.2.3 Statistical Analysis

The time spent by ewes performing the activities were calculated from the real-time recordings. The average and percentage time spent in each individual behaviour was calculated using the formulae described in Section 3.2.5. The data of the behaviour activities were analysed by ANOVA using the Minitab statistical package (Minitab,

1994) to examine the effect of browse location on individual behaviours, with replication snd locations as fixed factors and ewes as a random factor.

ANOVA was also used to examine the effects of browse locations on intake with replication and locations as fixed factors.

11.3 RESULTS

Table 11.1 shows the mean and percentage time spent by Welsh Mountain ewes in various behaviour activities. The ewes spent most of their time standing and lying (28% and 25% respectively).

Table 11.1. Means (minutes) and percentage (%) time for each behaviour.

Behaviour	Mean	%
Standing	50.6	28.1
Ruminating	18.1	10.0
Lying	44.2	24.5
Walking	26.4	14.7

The results of Table 11.2 shows that ewes ate ivy from the different locations in the order hurdle > HLF > floor spending 20% of their time eating ivy from the hurdle, 13% from HLF and less time from floor 8%. Ivy intake by ewes from the hurdle was more than that from HLF and floor.

Table 11.2. Mean time spent (minutes) eating ivy from different locations and ivy intake (fresh weight).

forage locations	Mean time	% time	ivy weight kg		ivy Intake kg
			Before	Residual	
Hurdle	20.2	11.2	2	1.455	0.544
HLF	12.9	7.2	2	1.623	0.376
Floor	7.5	4.2	2	1.812	0.188
P-value for ivy intake					0.037

Table 11.3 shows that there were significant differences in the time spent eating ivy from the hurdle and HLF between individual ewes (P<0.05), whereas there was no difference between individual ewes (P>0.05) in the time spent eating ivy from the floor. The results also show that there was a significant difference between individual ewes in the total time spent eating ivy (P<0.001). During observations it was observed that some ewes did not allow space for the other ewes to eat browse or ivy. This probably indicates that there was competition effect between individual ewes.

Table 11.3. Means of time spent (minutes) eating ivy from each location by individual ewes and their probability and weights of ewes.

Ewe number	Floor	Hurdle	HLF	Total	Weights of animals at the begning of experiment
1	11.6	16.6	23.3	51.5	43
2	6.6	16.6	10.0	33.2	33
3	10.0	15.0	5.0	30.0	43
4	**3.3**	**48.3**	**31.6**	**83.2**	**47**
5	3.3	18.3	5.0	26.6	45
6	11.6	16.6	13.3	41.5	43
7	6.6	20.0	8.3	34.9	41
8	6.6	10.0	6.6	23.2	38
Probability for the different between individual ewes on time spent eating of ivy	0.321	<u>0.006</u>	<u>0.014</u>	<u><0.001</u>	

Figure 11.1 shows that eating ivy by ewes during observation was intermittent and they took two rest periods between the eating periods. The eating was active at the beginning, middle and at the end of observation periods. The ewes ate ivy in sequence starting from the hurdle and then they went to the HLF and when they finshed from these two locations they started eating ivy from the floor.

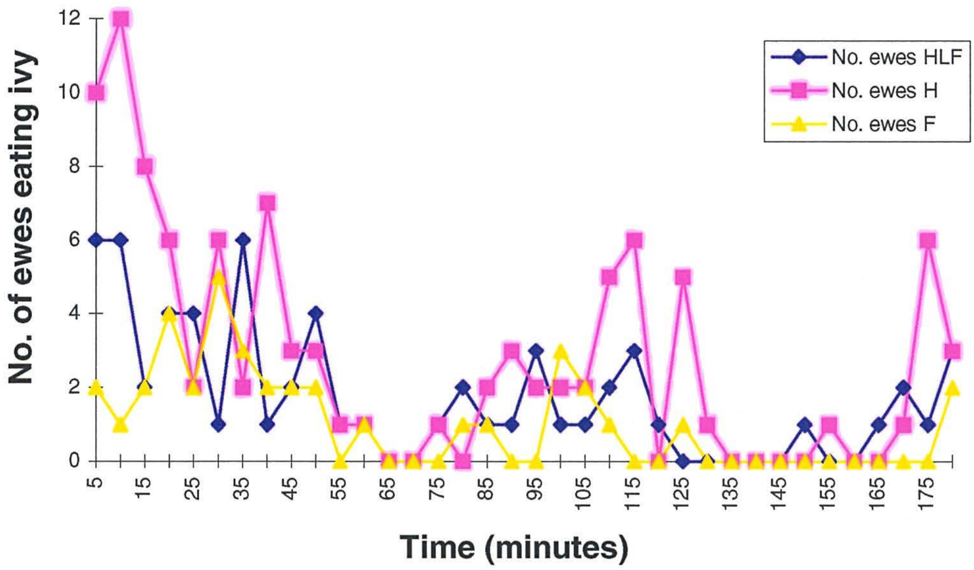
Estimated ME requirement per ewe and ME provided by ivy are given in Table 11.4. The estimated DM intake of ivy plant parts were 34g, 3g, 1g and 3g for leaves, twigs, branches and flower respectively. The ME contribution from these components were 0.33 MJ, 0.031 MJ, 0.006 MJ and 0.032 MJ for leaves, twigs, branches and flower respectively. The ME contribution from the total DM intake of ivy plant was very low 0.399 MJ (0.05 MJ/ewe) compared with the ME requirement per ewe (4.9 MJ/day).

Table 11.4. ivy DM intake, metabolisable energy (ME), DM%, MADF%, IVDMD% and crude protein % of ivy.

	Ivy plant					Total Ivy intake (kg)		Total DM % of ivy plant
	Leaf	Twig	Branch	Flower	**Total**	Day1	0.869	
Distribution % of total DM by component	22.1	2.6	72.1	3.2		Day2	1.178	**36.7%**
% of ivy intake from Chapter 11	83.8%	7.4%	2.5%	6.3%		Day3	1.28	
Estimated DM intake (g)/3 hours	34	3	1	3	41 g	**Mean**	**1.109**	
Metabolisable energy intake *MJ*	0.33	0.031	0.006	0.032	0.399			
Energy requirement per ewe/day	4.9 MJ/day							
ME (MJ/KG DM) range*	9.1-10.2	9.9-11.4	4.6-6.3	9.6-12.1				
mean	9.8	10.3	5.5	10.8				

SEM*=Standar error mean. **range***= The range was according to the equation used (IVDMD & MADF equations for fresh grass, hay and straw). **Chemical analysis** was described in Chapter 10.

Figure 11.1 Number of ewes (sum of 3 replicates) eating ivy from different locations (H=hurdle, HLF=high-level feeder and F=floor)



11.4 DISCUSSION

The objective of this experiment was to investigate the effect of different locations of forage on the eating behaviour of ewes when a high-quality forage was available. The results indicated that ewes ate ivy from the different locations in the order hurdle > HLF > floor. The location preferred by ewes in this experiment (hurdle) was different to that preferred by ewes in Experiment 5 (Chapter 7) where they preferred eating from a HLF. Animals in the present experiment might have preferred eating ivy from a hurdle due to prior foraging-experience. The ewes had experienced foraging ivy from a walls around fields at the University Farm before the experiment was conducted. The ewes therefore displayed a preference for feed location related to prior-foraging experience. Edwards *et al.* (1996 and 1997) found that sheep have the ability to learn the location of preferred food. Provenza (1994) and Scott *et al.* (1995) found that preference of foraging location by sheep depends on the prior-foraging experience. Nolte *et al.* (1990) and Nolte and Provenza (1992) found that lambs consume more of foods they had been exposed to early in life. Burritt and

Provenza (1990 and 1991); Lane *et al.*, (1990); Distel and Provenza (1991); Green *et al.*, (1984) and Squibb *et al.*, (1990) stated that ruminants can remember, for at least 1-3 years, food that produces either aversive or positive postingestive consequences. Gillingham and Bunnel (1989) found similar behaviour in deer; deer demonstrated a memory of successful paths to preferred food. Other factors that effect choice or selection of foraging location were described in Chapter 7.

It was observed that ewes ate ivy in sequences starting from the hurdle; then they went to the HLF and when they had finished eating from these two locations they started eating ivy from the floor. This indicates that the preference of ewes to foraging ivy from the hurdle did not prevent them from foraging from the other locations. So it can be concluded (as noted in Chapter 7 and 10) that the drive to eat is stronger than reasons for not choosing other locations.

The results also showed that ME contribution from ivy during the experiment was low at 0.4 MJ/ewe (i.e. 0.13 MJ/ewe/h) compared with the ME requirement per ewe (4.9 MJ/day). This indicates that ME intake did not meet the daily requirement of ewes as previously discussed in Chapter 10.

The conclusion that can be drawn from this experiment is that choice of foraging locations is affected by prior-foraging experience. But prior- foraging experience to a location did not prevent ewes eating from other sources or locations.

CHAPTER 12

General Discussion and Conclusions

Forage is an important feed source in sheep production systems. Forage includes grass and browse plants. The DM composition of forages is very variable and depends on stage of growth, management, location, altitude and season (Agricultural Research Council, 1980; McDonald *et al.*, 1988).

This study was carried out to investigate the use of high-level feeder (HLF) in both in-door and out-door experiments to study the foraging behaviour of sheep. The work was based on a series of experiments. The main objectives and results of each experiment are summarised in Table 12.1.

12.1 Use of the high-level feeder

The experiments demonstrated the use of a high-level feeder to observe foraging behaviour. Based on the behaviour of ewes when eating from the high-level feeder (HLF) and its design, the HLF can be considered as an artificial tree (AT).

Table 12.1 Main objectives and results of each experiment

Experiment Chapter	Objectives	Main results and conclusions
1 Chapter 3	Evaluate the use of HLF	•The high-level feeder technique can be used to simulate foraging from a tree providing a method to investigate foraging behaviour.
2 Chapter 4	Investigate effect of supplement type on the eating behaviour of Welsh Mountain and Cambridge ewes with Ivy on the HLF as a feed source.	•Sheep ate ivy from the HLF with behaviour patterns similar to those observed when sheep browse from a tree. • Ewes tended to spend less time eating ivy from the HLF when hay and concentrate supplement were available. •There were differences in behaviour between Cambridge and Welsh Mountain ewes.
3 Chapter 5	Investigate the extent to which the behaviour of Welsh Mountain ewes (small breed) was affected by the presence of Cambridge ewes (large breed) in a grazing environment.	•There was no breed effect on the time spent grazing or eating from a HLF. •Reduced intake per ewe was noted in a mixed-breed treatment.
4 Chapter 6	Investigate the effects of different forage sources on the behaviour of Welsh Mountain ewes when they are available separately.	•Ewes selected ivy > hay > straw •The high-level feeder can be used as a feeder to examine selection of forages.
5 Chapter 7	Investigate the effect of location of forage when a medium-quality forage is available.	•Ewes display a preference for eating hay from a HLF located at the centre of the pen compared to a side-feeder. •In the absence of hay in the HLF they ate from a side-feeder.
6 Chapter 8	Investigate the selection of forage when three sources of forages were available simultaneously.	•Ewes selected ivy > hay > straw. •Additionally, the HLF is considered as useful tool for studying selection and preference of a forages.
7 Chapter 9	Examine the extent to which sheep overcome an obstacle in order to eat from HLF.	•The HLF and obstacle techniques are useful techniques when the degree of preferences for feeds is to be studied. •Sheep have the ability to take a decision to work harder in order to move faster to preferred feeds.
8 Chapter 10	Examine whether there is an effect of prior-foraging experience on selection of feed from alternative sources.	•Prior-foraging experience increased the time spent eating ivy from the sources that they were accustomed to eating from. •Eating ivy time increased without an increase in ivy intake.
9 Chapter 11	Investigate the effect of locations of feed when a high-quality forage is available.	•Ewes ate ivy from the different locations in the order hurdle > HLF > floor. Ewes preferred to browse ivy from one location (hurdle) due to prior-foraging-experience.

Animals spent 30%-48% of their time eating ivy and sycamore from the HLF in the in-door environment and 25% in the grazing environment (Chapter 3). The results also demonstrated that sheep ate from the HLF both in-doors and in a grazing environment. Whilst other authors have used techniques to simulate browsing (Meuret, 1988; Ortega-Reyes and Provenza, 1993) they have not described a construction that attempts to directly simulate a tree as used in the present study.

It was observed that when only a few leaves remained on branches of the high-level feeder, that ewes searched for these leaves. It was also observed that when old branches (all leaves removed) were replaced by new branches the animals went to the HLF and started eating from them immediately. The results also showed that even if they had prior experience of eating from other locations they still ate from the HLF. The ability of ewes to overcome an obstacle in order to eat ivy from the HLF (Chapter 9) shows that ewes were willing to work to reach feed presented in a HLF.

Intake of ivy from a HLF can be calculated either by taking the difference between the weight of branches before and after feeding (as took place in Chapters 3-9), or as described in Chapter 10 (Section 10.2.2.2.3). Intake of forage from HLF was calculated as the difference between weight in the HLF at the beginning and end of the feeding period either ignoring (Chapter 3-9) or including (Chapter 10) the weight of forage on the floor at the end of the period. The method of Chapter 10 has advantages if significant proportions of feed fall onto the floor.

It should be noted that animals sometimes pulled out the leaves of the branches very hard and this led to branches falling on the ground. This wastage is hard to incorporate into calculations to estimate intake and is a disadvantage of the technique as discussed in Chapter 3. For small-leaved browse species the HLF basket could be modified by using wire mesh with smaller holes. The losses were minimal for the type of browse (Ivy/Sycamore) examined in this study.

There were inconsistencies in the observed eating time from the HLF and intakes. For example, in Chapter 5, time spent eating ivy did not differ significantly between treatments although there was a significant difference in measured intake. Such inconsistencies may reflect weakness in the techinque associated with problems of differentiating between consumption of browse and investigative behaviour and may also be associated with measuring small quantities of browse using the difference between intial and final browse weights. The inconsistencies could also reflect changes in consumption rate, with animals either increasing or reducing intake per minute as time spent eating browse is decreased or extended.

The advantages of the high-level feeder technique are that it provides opportunities to investigate the foraging behaviour of animals and their intake of specific forage species or browse species. Studying these topics in desert or rangeland conditions is difficult and expensive, because in such areas it is difficult to make visual observations due to the large areas involved. Use of video-recording in these areas is expensive especially for developing countries because of the need to buy equipment and to provide transport. The high-level feeder technique by using it in an in-door situation could therefore play an important role in the study of foraging behaviour, forage selectivity, preferences and forage intake. For example, selection of forages species by animals can be examined by using several high-level feeders, each high-level feeder having different forage species as demonstrated in Chapter 8.

12.2 Behaviour of ewes when eating from the HLF

Some ewes stood on their hind legs to reach overhanging ivy leaves on the high-level feeders. Gatenby (1986) noted that sheep can eat vegetation up to about 1 or 2 m high depending on their size and ability to stand on their hind legs. Owens (1991) examined the utilization patterns of Angora goats within the plant canopies of two Acacia shrubs and found that goats used a bipedal stance more than quadrupedal stance to reach canopy strata. Figures 2a and 2b demonstrate this behaviour pattern in sheep in the current experiments. This behaviour was seen only in some Cambridge ewes. Welsh Mountain ewes jumped frequently by their fore legs to reach overhanging branches. This suggests that the differences that took place in behaviour of individual animal towards the HLF depended on the size of animal relative to the size of the HLF.

The narrow muzzle and the cone-shape of their head allowed ewes to squeeze their heads between the branches of the trees to select the ivy leaves. The observed behaviour pattern of ewes during eating ivy from the HLF was moving their head forward and downward (jerking movement of the head) and then they cut the leaves using all parts of their mouths (lips, tongue, and teeth). They ate ivy leaves from the HLF, but when all the leaves of branches were eaten they start to eating twigs, young branches and flower.

It was observed that Cambridge ewes started eating from the HLF before Welsh Mountain ewes. Cambridge ewes prevented Welsh mountain ewes from eating by not allowing enough space for them to eat from the high-level feeder and sometimes by pushing them with their heads. This is probably due to the fact that Cambridge ewes have larger body size and weight than Welsh Mountain ewes. EL Aouini and Sarson (1976) working with sheep on a purely browse diet in the maquis of northern Tunisia, found that intake of browse was closely related to the live weight of the animals and found that sheep can consume up to 3.8% of body weight in dry matter daily. The higher body weight could explain why Cambridge ewes eat for longer. In the indoor experiment (Chapter 4) Welsh Mountain ewes ate for less time than Cambridge ewes. However, the results of Chapter 5 suggested that there was no effect of Cambridge ewes on the eating ivy behaviour of Welsh Mountain in a grazing situation. Although Cambridge ewes were aggressive and prevented eating ivy by Welsh Mountain ewes (Section 10.2), the Welsh Mountain were able to maintain the ivy intake from the HLF in the presence of Cambridge ewes by eating ivy from the HLF when Cambridge were performing other activities (e.g. grazing or ruminating).

12.3 Selection of forages

The literature shows that animals of different species have the ability to select their diet from a free choice of two or more types of foods available to them in order to make up a balanced diet, for example, in birds (Forbes and Shariatmadari, 1994; Uzu *et al.*, 1993; Forbes, 1995), pig (Kyriazakis *et al.*, 1990; Bradford and Gous, 1991) and sheep (Glimp, 1971; Cropper *et al.*, 1985, 1986; Hou *et al.*, 1991a; Gorgulu *et al.*, 1996; Hills *et al.*, 1998). The factors that affect feed selection and behaviour were described in detail in Section 2.1, 2.2 and 2.3. Both external and animal factors control diet selection.

External factors include, palatability, chemical composition and flavour. Animal factors include species, requirements for nutrients and starvation. For example, Dumont *et al.* (1995) found that efficiency of feed selection by animals decreased when they were starved. The basic method of feed selection was reviewed by Lynch *et al.* (1992). When an animal starts eating the coginitive systems (sight, smell, touch and taste) produce stimuli to recognise and assess the palatability of the available feeds which result in diet selection.

Chapter 6 showed that when forage species were available seperately ewes spent 19% of the time eating ivy, 9% eating hay and very little time (0.1%) eating straw (Table 6.1). When forage species were available simultaneously (Chapter 8), ewes selected ivy > hay > straw, spending 15%, 0.8% and 0% of the available time eating these species respectively. Reasons why sheep prefer ivy to the other forages were considered in Chapters 6 and 8. These included, flavour, brightness, shape, prior-experience, (5) post-ingestive-consequences, smell and sight and nutrient content. Of the factors listed above, prior-foraging experience, smell, taste and shape factors are more likely to explain the preference for ivy exhibited by ewes in this study. It was observed in Experiment 6 that ewes investigated the available forages by apparently smelling them.

12.3.1 Factors affecting selection of foraging locations

There are several factors affecting selection of foraging locations as described in Chapters 7 and 11. These incude (1) quality of feeds available at different locations (El Aich *et al.*, 1989; and Scott *et al.*, 1995; Samuel *et al.*, 1980; Bailey, 1988; Distel *et al.*, 1995; Cosgrove *et al.*, 1996; Guevara *et al.*, 1996; and Bailey and Sims, 1998); (2) presence of feeder and drinker (Haskell and Hutson, 1994); (3) location of supplementary feed (Roath and Krueger 1982; Senft *et al.*, 1985; Lawrences and Wood-Gush, 1988 and Stuth, 1991); (4) prior-foraging experience (Nolte *et al.*, 1990; Nolte and Provenza, 1992; Provenza *et al.*, 1992; Provenza, 1994; Scott *et al.*, 995; Edwards *et al.*, 1996 and 1997; Burritt and Provenza, 1997); and (5) memory, for example ruminants can remember, for at least 1-3 years, food that produce either aversive or positive postingestive consequences (Burritt and Provenza 1990 and 1991; Lane *et* *al.*, 1990; Distel and Provenza 1990; Green *et al.*, 1984; and Squibb *et al.*, 1990).

The results of Chapter 10 showed that prior-foraging experience or training increased the time spent eating a forage from the source or location that sheep were accustomed to eating from. Chapter 7, 10 and 11 concluded that ewes were capable of choosing between sources or locations even when the same type of forage was available in different locations. It was also found that the preference of ewes to foraging from a specific location did not prevent them from foraging from the other locations. Accordingly, it can be concluded that drive to eat by ewes is stronger than the reasons discussed in Chapter 7, 10 and 11 for not choosing other locations.

When results of Chapters 6, 7, 10 and 11 are considered it is clear that preference for location is affected by factors associated with the location (height, safety), the forage available at each location and prior experience. The preferences exhibited in Chapters 6, 7 and 11 were ivy HLF > hay side-feeder; hay HLF > hay side-feeder; and ivy hurdle > ivy HLF > ivy floor, respectively. These results imply that the factors affecting choice of location can be ranked feed quality > prior-experience = location factors. Thus, whilst factors affecting location or prior-experience may exert an influence when feeds available at each location are similar, these factors become less important when feed quality differs at each location.

12.4 Contribution of ivy to the maintenance requirement of ewes

The type of ivy used in the experiments was common Ivy (*Hedera Helix*). This type of ivy is found over the greater part of Europe and Northern and Central Asia and it was recommended as a food for sheep and deer in Roman times (Grieve, 1994).

Both Chapter 10 and 11 showed that ME contribution from the ivy plant to ewe maintenance requirement was very low for the periods given. The ME requirement per ewe per day was estimated to be 4.5 MJ/ewe/day. The ME provided by ivy per ewe during the experiments was 0.3-0.4 MJ (0.1-0.13 MJ/ewe/h). This result indicates that the ME intake did not meet the daily requirement of ewes. In order to meet the daily maintenance requirements ewes would have to eat ivy for longer and considerably increase their intake. In these experiments ivy provided only a small fraction of the daily requirement, with the remainder being provided from grazing and concentrates.

12.5 General Conclusions

This study showed that the factors affecting feed intake, selection and time spent feeding are complex, depending on several factors including animal factors (breed differences, interaction and difference between individuals), feed factors (feed type and availability of other feeds/grazing) and external factors (obtacles and location of feeds).

The specific conlusions are:

1- The HLF technique provides opportunities to investigate the foraging behaviour of animals and their intake of specific forage species. Intake of forage can also be calculated.

2- Sheep showed interest in eating from the high-level feeders both in a grazing environment and indoor experiments. The behaviour patterns of ewes whilst eating from the HLF suggest that ewes ate from the HLF in a manner similar to real trees. The HLF can therefore be used as an artificial tree to study browsing behaviour and forage selection.

3- Sheep ate from the HLF in a grazing environment spending 18-22% of their time eating from the HLF and 29-31% grazing. This confirms the classification of sheep as intermediate feeders.

4- The results indicated that feeding behaviour of Welsh Mountain sheep was affected by being in mixed-groups with Cambridge ewes. In an indoor experiment Welsh Mountain ewes ate from the HLF for less time than Cambridge ewes. However, in a grazing environment total eating time from the HLF for Welsh Mountain was unaffected by the presence of Cambridge with the Welsh Mountain ewes eating from the HLF whilst Cambridge ewes were engaged in other activities.

5- Sheep selected forages in the order ivy > hay > straw with very little time spent eating straw.

6- When similar feeds were available at different locations, ewes preferred eating ivy from a hurdle at the side of the pen and hay from a HLF at the centre of the pen. Prior-foraging experience or training increased the time spent eating ivy from the sources that sheep were accustomed to eating from. However, animals trained to eat from specific locations or sources still ate from the other sources. This indicates that the drive to eat by ewes is stronger than other reasons for not choosing a specific location as discussed in Chapter 7, 10 and 11.

7- Ewes overcame obstacles to reach the HLF, but took longer to reach ivy than concentrate and took longer to reach HLF if the obstacle was more difficult to overcome. Use of obstacles provides an alternative approach to preference testing with "free" access, allowing an assessment of how much work an animal is willing to do to obtain a feed or other reward.

8- The results also showed that there are individual variations within breed on time spent eating ivy from different locations.

9- Ewes chose leaves more than the other components of ivy plant presumably due to their greater digestibility and CP content.

10-The results of this study showed that ME from ivy did not meet the maintenance requirement for ewe and that ewes would have to eat ivy for longer and considerably increase their intake in order to meet maintenance requirement.

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Appendix

Appendix 1. Ingredients of concentrate

Ingredients	Percentage
Scottish barley distillers	20%
British sugar beet	15%
Argentinian cotton	15%
Franch maize (rolled)	10%
American orange citrus	10%
Cheshire grass nuts	10%
Argentinian sunflower	7.50%
Toasted American soya hulls	7.50%
British peas (micronesed)	2.50%
Sheep minerals plus vitamins	2.50%

Appendix 2. Composition of ivy

Chemical Composition	**%**
Crude Protein % of DM	24.8
Crude Fat % of DM	16.5
Crude Fiber % of DM	37.2
Ash % of DM	21.3

Appendix 3. Trees and shrub genera identified as having a prime role in fuel production and a secondary forage role.

Region	Family	Genus	Plant parts eaten b livestock
Humid tropics	Sterculiaceae	*Gauzuma*	Young foliage, fruits
	Ulmaceae	*Trema*	Leaves, branches
Tropical highlands	Ulmaceae	*Trema*	Leaves, branches
Arid and semi-arid tropics	Combretaceae	*Anogeissus*	Foliage
	Euphorpiaceae	*Emblica*	Foliage, fruits
	Chenopodiaceae	*Haloxylon*	Foliage
	Rhamnaceae	*Zizyphus*	Foliage, fruits

Source: NAS (1980), Blair (1990)

Appendix 4. The Genera names for some trees and shrubs fodders documented as being useful animal fodders.

Acacia accola	*Dodonaea viscosa*	*Moringa oleifera*
Aeschynomene abyssinica	*Dovyalis* sp.	*Napoleona vogeli*
Atylosia scarabaeoides	*Enrharta calcycina*	*Newbouldia leavis*
Azadirachta indica	*Entada abyssinica*	*Olea africana*
Banksia integrifolia	*Eriosema psoraloides*	*Osteospermum pachypteris*
Baphia nitida	*Eremophila leucophylla*	*Parkia clappertoniana*
Bauhinia purpurea	*Eriocephalus ericoides*	*Parkinsonia aculeata*
Brachychiton populneum	*Erythrina abussinica*	*Peltophorum pterocarpum*
Brachistegia spiciformis	*Eucalyptus brevifolia*	*Pentzia lanata*
Buckinghamia celsissmia	*Exomis microphylla*	*Piliostigma thonningii*
Cajanus cajan	*Felicia filifolia*	*Pithecolobium dulce*
Calliandra calothyrsus	*Ficus thonningii*	*Pittosporum phylliraeoides*
Callitris endicheri	*Flemingia macrophylla*	*Pollichia campestris*
Cassia artemisioides	*Geijera parviflora*	*Prosopis alba*
Casuarina cristata	*Gleditsia triacanthos*	*Pterocarpus erinaceus*
Celtis kraussiana	*Gliricida sepium*	*Ptilotus obovatus*
Ceratonia siliqua	*Griffonia simplicifolia*	*Rhigozum obovatum*
Chamaecytisus palmensis	*Guazuma ulmifolia*	*Ricinodendron headelotti*
Codariocalyx gyroides	*Hermannia trifurcata*	*Robinia pseudoacacia*
Colophospermum mopane	*Hirpicium integrifolium*	*Samanea saman*
Combretum imberbe	*Indigofera arrecta*	*Santalum spicatum*
Cordia africana	*Kigelia africana*	*Sesbania aculeata*
Crotalaria anagyroides	*Leucaena chennoni*	*Simmondsia chinensis*
Cyamopsis tetragonoloba	*Lonchocarpus capassa*	*Spondias mombin*
Dalbergia sissoo	*Lophira procera*	*Tamarindus indica*
Daniella oliveri	*Maireana brevifolia*	*Terminalia arostrata*
Desmanthus barbatum	*Medicago arborea*	*Tetragonia hirsuta*
Desmodium capitatum	*Millettia thonningii*	*Ventilago viminalos*
Dicrostachys cinerea	*Monochlamys albicans*	*Vernonia amygdalina*
		Zizyphus nummularia

Source: Skerman (1977), ILCA (1985), Brewbaker (1986), Turnbull et al. (1986), Blair (1990).

Appendix 5. Composition of Ivy, hay and straw according to dry matter basis.

Compositions	Ivy	Straw*	Hay*
Crude Protein g\kg	248	34	110
Crude Fat g\kg	165	15	18
Crude Fiber g\kg	372	417	298
Ash g\kg	213	71	82

* The sources of straw and hay chemical compositions were from McDonald et al. (1988).

Appendix 6. Digestibility

Faeces liquor of *In vitro* dry matter digestibility (IVDMD) method was used to estimate ivy plant dry matter digestibility (DMD).

A representitive dry matter sample was taken from each replicate of experiment 8 and 9 for each part of ivy plant (leaves, twiges, branches and flower) and kept in separated bag and from those bags triplicates samples were taken to do faecal liquor IVDMD.

Faeces collection: Freshly voided faeces were collected from Welsh Mountain sheep at the University of Wales, Bangor as droppings from the pasture and carried out to the laboratory for faeces liquor preparation.

Preparation of faeces liquor: The standard method of faeces liquor preparation was as described by El Shaer et al. (1987). Sixty gram of fresh voided sheep faeces were macerated by pestle and mortar and then thoroughly mixed with 200-300 ml of freshly prepared bicarbonate buffer pH 6.8 (Table of Appendix 6) which had been previously saturated by bubbling with CO_2 for approximately 20 minutes. The mixture was then filtered through a double layer of muslin into a dispenser, this step was reapeted 3 times in order to extract as much activity as possible. Then the liquor obtained from the filtration was made up to one litre with buffer and then saturated with CO_2 for further 20 minutes. This normally resulted in a liquor at pH 6.8. The temperature of the faecal liquor was maintained at 39°C throughout.

Table of Appendix 6. Composition of bicarbonate buffer.

Materials	**g/litre**
Sodium hydrogen carbonate **($NaHCO_3$)**	9.80
Sodium hydrogen phosphate **($NaHPO_4$)**	3.70
Sodium chloride **(NaCl)**	0.47
Potassium chloride **(KCl)**	0.57
Magnesium chloride **(MgCl)**	0.06
Urea **($NH_2.CO.NH_2$)**	0.90
Calcium chloride anhydrous **($CaCl_2.2H_2O$)**	0.04

McDougall (1948)

Preparation of acid pepsin: It was prepared from one litre of distilled water, 8.5 ml was removed and replaced by 8.5 ml hydrochloric acid. The solution was then mixed thoroughly and 0.5 g of pepsin powder added. The enzyme was suspended by thorough mixing using a magnetic flea. Acid pepsin was freshly prepared immediately before use.

Estimation of digestibility: From each dry well-mixed ground ivy plant parts representitive sample, 180 mg of ivy leaves was weighed into each of three prewieghed McCartney bottles, which had been oven dried, (105°C for 24 hours) to attain a constant weight, that step was done for twigs, branches and flower of ivy plant. An equal number of associated bottles were used as reagent blanks. Also an equal number of associated bottles were used for stander samples of already known their IVDMD. Eighteen milliliters of freshly prepared feacal liquor were added to each bottle, including the reagent blanks and stander samples. All were then capped with screw-on lids to an air-tight condition and the bottles were shaken by hand to ensure that the sample material was suspended evenly in the liquor. The bottles were then placed in an air incubator (39°C) for 48 hours. The bottles were shaken three times every days during the incubation period.

After 48 hours the bottles of samples were centrifuged at 2000 rpm for 30 minutes. The supernatant liquid was poured off. After this step, 18 ml of freshly prepared acid pepsin solution was added to each bottle which was then incubated for further 48 hours again in an air incubator at 39°C.

After incubation the McCartney bottles were centrifuged at 2000rpm for 30 minutes. The supernatant liquid was decanted leaving the sediment in the bottle. The bottles with their sediment content were dried in an oven at 105°C for 48 hours, and then they were cooled in a dessicator. The cooled bottles with their sediments were then weighed and the weight of the sediment was determined by difference. The proportion of the dry matter in each sample which had been digested was calculated after correction for the mean weight of residue in the associated blank bottles. *In vitro* digestibility was given by the equation:

$$\text{Digestibility \%} = \frac{A-(B-C)}{A} \times 100$$

Where A = Dry weight of sample.

B = Weight of residue after digestion.

C = Dry weight of reagent blank.

Appendix 7. The determination of ash-free modified acid-detergent fibre (ash-free MADF) for ivy plant

Principle: The technique of ash-free MADF was as described by MAFF (1986), and its determined gravimetrically. The plant material is boiled with a sulphuric acid solution of cetyltrimethylammonium bromide (C.T.A.B.) under stander conditions. The ash-free insoluble matter remaining is known as ash-free modified acid-detergent fibre (ash-free M.A.D. fibre). The C.T.A.B. dissolves nearly all the nitrogenous constituents and the acid hydrolyses the starch.

Apparatus: Soxlet extractor, 30 ml vitreosil crucibles (Porosity No. 1) and muffle furnace.

Reagents: Acetone, sulphuric acid-C.T.A.B. solution (dissolve 50 g C.T.A.B. in 5L N sulphuric acid and filter if necessary.

Ash-free MADF estimation:

1- From each dry well-mixed ground (to pass 1 mm sieve) ivy plant parts representitive sample, 1 g of ivy leaves was weighed into each of three prewieghed beaker, also that step was done for twigs, branches and flower of ivy plant.

2- 100 ml of sulphuric acid-C.T.A.B. solution was added and then the condenser was fit. Rapidly the solution was bring to the boiling reflux for 2 hours.

3- Filter hot through a filter crucible using gentle suction. Wash the residue with three approximately 50 ml portions of almost boiling water and then with acetone.

4- And then the crucibles and contents were dry in an oven at 95°C overnight, allow to cool in a desiccator and then the weight was taken as ash+MADF.

5- To obtained ash-free MADF the crucibles and their contents were placed in a muffle furnace at 500°C and maintained the temperature until ashing is complete.

6- Allow the crucible and ash to cool in a desiccator and then the weight was taken.

Calculation: Multiply the loss in weight on ignition (g) by 100. The result gives the percentage of ash-free MADF in the ivy plant material.

Appendix 8. Measurement of crude protein (CP) of ivy plant component

The analysis of CP% of ivy plant components was done by Kjeldahl method. This method was calculated the CP from the nitrogen (N) content of the food, which digest the food with sulphuric acid, this process will converts all N that present in the food into ammonia. This ammonia is liberated by adding sodium hydroxide to the digest and then distilled off and collected in standard acid, after that the quantity that collected being determined by titration or by an automated colorimetric method (Kjeltec Auto 1030 analyzer). It is assumed that the N is derived from protein of most feedstuffs containing approximately

16% nitrogen. So by multiplying the N figure by (100/16 or 6.25) an estimate of the CP value is obtained.

Appendix 9

Effects of supplementary feed and competition with Cambridge ewes on the browsing behaviour of Welsh Mountain sheep

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Introduction Trees and shrubs play an important role in increasing feed supplies to *Animal production* in many tropical systems. These feeds sources can be browsed directly by animals or can be cut and carried (Ivory, 1990). Understanding the behaviour of domestic animals is an important tool in improving their management and production (Malechek and Provenza, 1983). An experiment was conducted to examine the effect of between-breed competition on the browsing behaviour of Welsh Mountain sheep, with alternative sources of supplementary feed using Cambridge ewes as the competing breed.

Material and methods A randomised complete block experiment was conducted in a grazing area (37m×25m) using four treatments and three replications. The treatments were 1.Welsh Mountain + concentrate (WOC); 2. Welsh Mountain + hay (WOH); 3. Welsh Mountain + Cambridge + concentrate (WCC); and 4. Welsh Mountain + Cambridge + hay (WCH). All treatments included artificial trees containing Ivy. Ivy and hay were available *ad-lib* but concentrate was restricted to 0.5kg per ewe fed once a day. Four mature ewes of each breed were used. The activities of all ewes were recorded every five minutes for six hours per treatment.

Results The behaviour of both Welsh Mountain and Cambridge ewes was recorded but only results for the Welsh Mountain are presented in Table 1. Behaviour patterns were similar in all treatments except that Welsh Mountain ewes spent more time standing and standing-ruminating when alone than when with the Cambridge if hay was available. This was associated with less time spent eating hay but not less time browsing.

Table 1. The effects of treatments on the behaviour (% time) of Welsh Mountain sheep.

Treatments	Browse	Lying	L-Rum.	S-Rum.	Stand.	Walk	Grazing	Eating*
1. WOC	21.6	10.4	8.2	1.7	7.9	9.5	27.4	13.2
2. WOH	20.6	10.1	9.8	4.5	17	10.1	21.7	6.1
3. WCC	17.5	15.4	7.7	3.4	8.7	7.9	28.2	10.8
4. WCH	19.9	13.4	9.0	2.5	9.7	8.1	28.6	8.5
P-values for treatments	0.732	0.886	0.174	0.143	0.002	0.715	0.411	0.009

Lying-Ruminating (L-Rum.); Standing-Ruminating (S-Rum.);
(**) Eating supplement (Concentrate or Hay).

Conclusions Some behaviours of Welsh Mountain sheep were affected by mixed-grazing with Cambridge ewes and by the provision of alternative sources of feed supplement (hay or concentrates). The presence of Cambridge ewes, representing a considerably larger breed, led to increased time spent by Welsh Mountain ewes standing or standing-ruminating. However, this trend was only observed when hay was available. Mixed-grazing and alternative supplement sources did not markedly affect the browsing behaviour of Welsh Mountain ewes but in the presence of Cambridge ewes they ate less hay and stood for longer, without decreasing grazing time as they did when they could eat hay without competition.

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