Chapter 1

Literature Survey

1.1 Introduction

“The climate, as a major element of the physical environment, influences lifestyles and to a large extent determines agricultural production systems. Agriculture is basic to the survival of man. Profitable farming entails careful planning and management in order to exploit existing climatic advantage and to minimize climatic stress” (De Jager, 1993).

Dry conditions, which reduce the availability of grazing, exert possibly the greatest influence on livestock production. In South Africa the annual rainfall declines from a high of 800mm at the east coast to as little as < 50mm in the dry western regions. This low rainfall leads to aridity that affects grazing capacity. Aridity increases when moving from east to west. Production decreases correspondingly with a consequent increase in farm size. It is due to these arid conditions in the west that we need to establish plants to supplement and reinforce the natural veld during periodic and seasonal droughts.

The main constraint for range livestock is the shortage of feed from native rangelands because of poor grazing management, overstocking and drought, resulting in soil degradation. *Atriplex nummularia* is a drought fodder crop indigenous to Australia, and grows on various soil types. This crop can be used for soil rehabilitation and at the same time provide feed for browsing and grazing animals. It is well known for its adaptation to saline soils and drought stress and provides feed to animals under these conditions (Draz, 1983).

The palatability and nutritional composition of individual plants have an influence on intake from a pure *A. nummularia* pasture. By selecting plants of higher palatability and nutritional value, the production of animals on these pastures can theoretically be increased.

1.2 Atriplex nummularia

A. nummularia is indigenous to Australia and has been planted in South Africa for more than 100 years. *A. nummularia* is a perennial woody fodder shrub from the family Chenopodiaceae. These plants are halophytes which means that they are highly salt tolerant. The leaves are single, blue-grey and covered with a layer of bladder like hairs called trigomes. These have an important physiological function by controlling the ion balance in the leaves. An osmotic adaptation exists in the leaves if the salt concentration in the tissue gets too high. Oxalic acid is formed and is transported to the trigomes where it is converted back to salt. The osmotic potential in the leaves stays relatively normal. The trigomes burst and salt crystals and cell wall contents stays on the leaf surface while new trigomes form. This leads to the accumulation of salt on the leaf surface which probably makes the leaves less palatable (Jones and Hodginson, 1969). Due to the high salt concentration in the plant's roots and leaves, it maintains a high osmotic value in its cellular fluid, which is a physiological adaptation to moisture stress and thus drought resistance (Hoon, 1991). *A. nummularia* further contains a C4-carbon metabolism, which means that photosynthesis is highly effective at high temperatures and light intensities (De Kock, 1980). This species also has a low moisture usage. It needs approximately 304kg water per kilogram DM produced (Hoon, 1991). De Kock (1980) found that this species needed only 250kg of water per kilogram of dry matter produced. These fodder shrubs are also adapted to a wide range of soil types and climatic conditions. It produces under relatively unfavourable conditions a relatively high yield of green forage material (De Kock, 1967). All the above considerations make *A. nummularia* an ideal fodder crop under the relatively unfavourable conditions in the dry and extreme conditions of the arid areas of South Africa.

Due to the high salt content of saltbush, it is important to have enough drinking water available to animals at all times. Brackish water may have a negative influence in the intake of saltbush. Hoon (1991) fed *A. nummularia* to Dorper sheep. The control group received rainwater while the treatment group received brackish water. As soon as the treatment group changed to brackish water, intakes were decreased by 40%. He also observed an improvement in intake as the animals became adapted to the brackish water. Hopkins and Nicholson (1999) reported that there was no effect of feeding *Atriplex* to lambs on tenderness or juiciness and overall panelists ranked meat samples similarly for acceptability.

Saltbush species have been reported to vary in nutritive value and to contain a range of compounds that may have anti-nutritional properties at high concentrations. These include oxalates, nitrates, sodium, potassium and chloride (Masters *et al.,* 2001).

Nutritional value:

Forage values of *A. nummularia* are generally considered to be high (Le Houérou, 1980), although quality is influenced by age and phenological stage at the time of harvest and by previous cutting and grazing management. This could be illustrated by the decrease in protein and ash contents and an increase in fibre content of *A. lentiformis* of the initial clippings and subsequent regrowth (Goodin, 1979).

The nutritional value of *A. nummularia* is relatively high. It satisfies the maintenance requirements of sheep and can even sustain some growth (Le Houerou, 1991). Several grazing studies conducted in Morocco have shown that the introduction of *A. nummularia* as a means of range improvement has increased live-weight gain of sheep and goats compared with those grazed on unimproved range (Chriyaa *et al.,* 1997). They also used *A. nummularia* as a protein supplement for sheep during gestation on a wheat straw diet and got a higher lambing percentage and birth weight. In their work, alfalfa hay and saltbush foliage had the highest values for CP and IVDMD. The NDF value of saltbush foliage and blue wattle foliage was the lowest for all the feeds evaluated. Supplementing straw with saltbush showed the highest increase in DMI. The authors mentioned that the reason for this increase in DMI was that saltbush corrected the protein deficiency of the straw. Animals, which received saltbush foliage as a supplement, were the only ones that gained weight over the whole period of the trial. Table 1 presents the composition of the feeds used by Chriyaa *et al.* (1997). Of particular importance to this study is the composition of *A. nummularia.*

Table 1.1 Chemical composition and *in vitro* digestibility of forages used to supplement wheat straw in sheep feeding (Chriyaa *et al.*, 1997)

Item	**Supplement**				
	Wheat straw	Alfalfa hay	*A.nummularia*	Blue wattle	Medic pods
CP (g/kg)	52	136	137	109	108
NDF (g/kg)	703	466	348	342	557
Mg (g/kg)	1.3	2.6	2.1	5.3	2.9
Al (g/kg)	0.7	0.9	2.7	1.6	5.9
Si (g/kg)	30.0	5.2	5.2	4.4	17.0
P (g/kg)	1.0	2.0	0.5	0.7	2.2
S (g/kg)	1.9	2.7	4.3	7.1	1.8
Cl (g/kg)	8.7	7.5	56.6	7.4	3.6
K (g/kg)	7.4	19.5	11.1	4.6	6.0
Ca (g/kg)	5.5	14.8	6.9	30.1	18.8
Mn (mg/kg)	43.8	37.1	65.2	63.2	75.2
Fe (mg/kg)	783.7	540.9	602.1	432.9	-
Cu (mg/kg)	4.8	8.0	4.8	5.1	6.3
Zn (mg/kg)	12.6	22.4	27.8	19.8	106.9
IVDMD (g/kgDM)	447	586	622	488	507

Sheep feeding on fresh *A. nummularia* can have intakes of up to 1.5 kg/day (Steynberg and De Kock, 1987). Wilson (1977) fed dried leaves of four shrubs and four trees to merino wethers in metabolism crates. One of these shrubs was *A. nummularia*. A crude protein concentration of 20.6% and a neutral detergent fibre concentration of 46%, both on a DM basis, were reported. Digestibility's of 70.4% for NDF and 82.0% for N were found. The author determined the OMI as 432 g/day. Apparent digestibility of 68.8% was converted to a true digestibility of 86.3% with the equation y = 14.5 + 1.042 x (Van Soest *et al.*, 1966).

Weston *et al.* (1970) measured the values of various parameters relating to digestion, eg. nutrient digestibilities, flow of digesta and their constituents through the rumen and abomasums and the concentrations of end products of digestion, of sheep fed *A. nummularia*. The chemical composition and digestibility of the saltbush were within the ranges reported in other literature for saltbush grown in semi-arid environments. The values of most parameters measured were within, or close to, the ranges observed with pasture grasses and legumes. However, with saltbush, the stomach played a less important role in the digestion of organic matter and fibre. It further appeared that the ruminal absorption of volatile fatty acids was impaired. The protein of the saltbush was extensively degraded to ammonia in the rumen and accordingly the protein value of the diet was much lower than indicated by its digestible crude protein content.

The saltbush as offered to the sheep, by Weston *et al.* (1970), contained 8% of water. The levels of crude protein, sodium and potassium on a DM basis were 19.8%, 4.0% and 3.4% respectively. The sheep showed a daily OMI of 510g. The authors found 60.8% of the organic matter to be digested. 72% of the dietary N intake left the rumen as NAN. The loss of dietary N during passage through the rumen was ascribed to microbial deamination of dietary nitrogenous substances. This was reflected in the presence of significant quantities of ammonia in the rumen. Ammonia levels in the rumen fluid were in the order of 27 ±3 mg N per 100ml. The overall digestibility of dietary N was in the order of 75.8%. The level of volatile fatty acids in the rumen fluid was 8,5mmol/100ml. The pH of the rumen fluid was found to be in the range of 6.9 to 7.1.

Ben Salem *et al.* (2004) used *A. nummularia* Lindeque foliage (atriplex) and *Opuntia ficus indica* f. *inermis* pads (cactus) as alternative N and energy supplements respectively. The author fed 24 Barbarine lambs, which were allotted into four homogeneous groups and housed in individual crates, barley straw *ad libitum* supplemented with either barley grains and soybean meal; or barley grain and atriplex; or cactus and soybean meal; or cactus and atriplex. By replacing soybean meal with *Atriplex*, no effect on DMI of straw was observed. The authors did find that sheep fed cactus had a lower straw DMI than those fed barley. Diets of barley and soybean (BS), barley and atriplex (BA) and cactus and soybean (CS) had the same OM and fibre (NDF and ADF) digestibilities, which were significantly lower than those for cactus and atriplex (CA). Daily gain of lambs averaged 119g, 180g, 81g, 59g respectively for diets CS, BS, CA and BA. The authors attributed the low growth levels with *Atriplex* diets to the high level of soluble N in *A. nummularia.* Table 1.2 shows the composition of the experimental feeds. The composition of *A. nummularia* is of particular relevance.

Table 1.2 Chemical composition of feeds on dry matter basis (Ben Salem *et al.* 2004)

	Barley straw	Barley grain	Soybean meal	*A.nummularia*	O.F.I *f. inermis**
DM (g/kg)	868	859	883	286	177
OM (g/kg)	948	976	931	745	762
CP (g/kg)	34	141	465	178	46
NDF (g/kg)	764	289	370	445	338
Ca (g/kg)	4.4	0.8	3.1	13.6	52.1
P (g/kg)	1.2	2.2	7.1	1.8	1.0
Na (g/kg)	2.6	0.2	3.0	47.0	0.6
K (g/kg)	16.4	7.8	25.9	28.9	26.0
Mg (g/kg)	1.0	1.1	2.4	8.4	10.9
Cu (mg/kg)	6.1	2.4	17.8	13.0	6.5
Fe (mg/kg)	160.7	40.4	299.8	285.1	170.8
Mn (mg/kg)	36.7	11.6	26.9	56.5	248.9
Zn (mg/kg)	18.3	22.3	48.3	47.0	31.0

*O.F.I. f. inermis ; *Opuntia ficus indica* f. *inermis* (spineless cactus)

The stage of growth and maturity considerably affects the nutritive value, palatability and utilization of *Atriplex* species. Such plants are nutritious in the wet season, while they are relatively poor during the dry season (El Shaer *et al.*, 2000, as cited by Aganga *et al.*, 2003). In contrast, Aganga *et al.* (2003) stated that *Atriplex* species contains higher concentrations of nitrogen in winter, compared to summer, when it has high concentrations of sodium. As a supplementary fodder, *Atriplex* species should not make up more than 25-30% of a sheep's diet (Aganga *et al.*, 2003). Casson *et al.* (1996) suggested that the high salt content of saltland forage plants is likely to be the major determinant of palatability and that dilution of salt content through the availability of other feed resources would be necessary to improve intake and performance. Table 1.3 illustrates more nutritional values of *A. nummularia* as cited by Aganga *et al.*

(2003). From Table 1.3 it is clear that stage of growth and maturity influence the nutritional composition of *A. nummularia.*

Table 1.3 Chemical analysis of *Atriplex nummularia* (Watson and O'Leary, 1993 as cited by Aganga *et al.* 2003)

Content	Cut 1	Cut 2	Cut 3	Cut 4	Ave regrowth
Ash (g/kg)	181	247	220	223	230
CP (g/kg)	92	131	91	85	103
ADF (g/kg)	337	243	317	306	289
NDF (g/kg)	497	405	489	472	455
Lignin (g/kg)	104	92	93	84	90
Na (g/kg)	64.2	75.3	71.1	68.8	71.1
Ca (g/kg)	4.9	6.8	4.9	4.8	5.5
K (g/kg)	19.8	23.2	20.4	17.4	20.3
Mg (g/kg)	3.6	4.3	4.6	4.9	4.6
P (g/kg)	2.2	2.6	2.0	1.5	2.0
Na/K	5.5	5.5	5.9	6.7	6.0

This fodder has a low energy value (6.1MJ/kg) (Hobson *et al.*, 1986) but a relative high protein value (21%) (Jacobs and Smit, 1977; Verschoor, 1992). According to Wilson (1977) the fibre digestion of *A. nummularia* is relatively high and the N content and digestibility are above average. This is a fodder with enormous potential in the arid zones, but it needs some kind of energy supplementation. When supplemented with energy, it can sustain production when natural veld cannot (Steynberg and De Kock, 1987).

Table 1.4 Mean values for chemical factors for the most preferred and least preferred plants of river saltbush and old man saltbush (Norman *et al.,* 2004)

Measurement	Old man Saltbush		River Saltbush	
	Most preferred	Least preferred	Most preferred	Least preferred
P-CDOMD %	59.06	60.62	50.04	53.83
P-COMD %	82.09	82.19	66.06	71.91
ADF %	17.11	17.85	26.80	24.71
NDF %	30.54	32.22	42.28	39.45
N %	2.46	2.03	1.62	1.55
N:S	5.60	4.42	4.34	3.89
S %	0.45	0.48	0.38	0.41
Total ash %	28.00	26.30	24.21	24.97
Soluble ash %	23.08	21.63	19.79	19.93
Na %	7.25	6.89	5.93	7.04
K%	3.63	3.83	2.67	2.66
Cl %	11.76	11.64	10.30	12.35
Ca %	0.77	0.73	0.82	0.85
Phosphate %	0.15	0.14	0.13	0.13
Mg %	0.77	0.78	1.00	1.17
Mn mg/kg	146.68	170.17	142.15	288.46
Zn mg/kg	18.84	19.61	18.76	21.67
Fe mg/kg	189.50	178.40	186.11	200.56
B mg/kg	113.77	109.77	70.09	81.97
Oxalate %	3.29	2.97	2.56	2.69
Nitrate mg/kg	249.27	94.74	110.49	80.35
Crude tannin%	0.14	0.09	0.12	0.09

Norman *et al.* (2004) examined the nutritive value and preference by sheep of two saltbush species, *A. amnicola* (river saltbush) and *A. nummularia* (old man saltbush). The sheep demonstrated a strong preference for river saltbush over old man saltbush, as estimated by the consumption of individual bushes.

Significant variation between old man and river saltbushes was found for many of the plant factors tested as illustrated in Table1.4. River saltbush differed from old man saltbush in that it had lower pepsin-cellulase digestion of the organic matter (P-COMD) and pepsin-cellulase digestion of organic matter in dry matter (P-CDOMD), higher ADF and NDF, less N, S, K and B, a lower N:S ratio, lower total and soluble ash, more Mg and less nitrates. Within each species, different factors were found to be related to preference. Within river saltbush, greater preference was associated with, lower Na and Cl and higher tannins. For old man saltbush preference was related to higher N, nitrates and N:S ratio. Differences between species were greater than differences within species for these factors affecting preference and palatability. These results were not consistent with known preference and selection principles derived from a range of other publications (Forbes, 1999; Forbes and Mayes, 2002). Norman *et al.* (2004) therefore, concluded that selection within or between species of saltbush was not primarily associated with digestibility, fibre, CP, S, minerals, nitrate or oxalate.

1.3 Palatability

Palatability is a complex phenomenon determined by animal, plant and environmental variables. Evidence exists that sheep and cattle sometimes possess different degrees of sensitivity to palatability factors when a choice of feeds is offered. Individual animals differ in their preferences for plant species. Some forage species and even genotypes within a species may be unpalatable to grazing ruminants. This is possibly due to factors like alkaloids, which lower the palatability of the forage. Natural and induced environmental factors frequently influence selection by ruminants (Gorden, 1978). The features of a food material that are sensed before it is swallowed, of which an animal is consciously aware, are often collectively called the palatability of that food (Forbes, 1998). Palatability is often confused with acceptability or preference of a food. The palatability of a food is not only a function of the food, because the acceptability of the food depends on what the animal has previously learned of that food (Forbes, 1998). According to Grill and Berridge (1985) palatability is “a response measure which is based on the outcome of the central nervous system's integration of taste and internal-state signals combined with cues arising from previous associations". Brobreck (1957) suggested that stimulation of the appetite centre, through a variety of stimuli, results in a neural motor outflow producing reflexes of attention, approach, examination, and incorporation or rejection of food. Final choice of food is thus determined by the responses elicited from the special senses to stimuli from the food. Gorden (1978) defined *Relative Forage Palatability* as: "A plant characteristic(s) eliciting a proportional choice among two or more forages conditioned by plant, animal and environmental factors which stimulate a selective intake response by the animal. This characteristic(s) may also be described in terms of acceptability, preference, selective grazing, and relish conditioned by sensory impulse." It is often thought that animals will have a higher intake on a more palatable food than a less palatable food. This may be true for short-term intake but not for long-term intake.

1.3.1 Factors that influence forage palatability

Animal factors:

The animal factors that influence palatability may be partitioned into five major categories: (1) the senses, (2) species or breeds, (3) individual variations, (4) previous experience or adaptation, and (5) physiological condition (Gorden, 1978).

The senses affecting the palatability of a food are touch, vision, olfactory, taste, and instinct. Without visual and taste cues animals cannot identify the appropriate diet. Animals become aware of food first by their senses, particularly vision and olfaction. They move towards the food and eat a small amount initially to be able to further characterize it by its taste and texture. Familiar food is eaten in greater quantities as long as the animal has learned that no major discomfort has followed previous meals of that food (Forbes, 1998).

Animals selectively remove the leaves from the stems with the sense of touch (Arnold, 1966). This is done by leaf plucking with the lips and is very common in the concentrate selectors such as goats.

Bazely and Ensor (1989) found that none of their sheep learnt to discriminate between green and yellow of the same brightness but could differentiate between different brightness' (41 to 77% reflectance). This does not mean that sheep do not have color vision, but brightness might be important for grass reflecting the amount of protein in the feed like ryegrass. The sight of food induces changes in the firing rate of some neurons in the lateral hypothalamus of the conscious sheep (Maddison and Baldwin, 1983), and sight may be more important than odor in food recognition in sheep and other ruminants. However, temporary covering of the eyes does not interfere with the preference for certain herbage species by grazing sheep (Arnold, 1966), suggesting that they use smell, taste and tactile stimuli to a great extent to discriminate between different species. Individual neurons in the lateral hypothalamus and *zona incerta* respond to the sight, but not the smell of the food, and then only palatable food, not food that sheep won't eat. Cells that formerly responded to food later respond to salt instead when the animal is made sodium-deficient (Forbes, 1998).

Olfactory ability varies between different species; carnivores are able to smell their prey over a long distance (Forbes, 1998), while poultry have no sense of smell. Herbivores, having a poor ability to smell, are surrounded by their food and the ability of smell is of little use in seeking food (Forbes, 1998). Arnold (1970) found that the smell of food was an important determinant of food choice by sheep, although Tribe (1949) thought that odor had little part to play in selection of plant species by grazing animals. Tribe (1949) found that young sheep, without olfactory lobes, discriminated less than intact sheep between stale or faeces-contaminated and fresh-cut herbage. When given a known food, sheep do not use odor to control intake (McLaughlin *et al*., 1974) although it's odor may be used to differentiate between foods (Pfister *et al*., 1990). Cattle deficient in sodium have the ability to detect sodium bicarbonate at up to 20m by smell (Bell and Sly, 1983). Bell and Sly (1983) found that anosmic (animal of which the olfactory gland is removed) cattle took longer to identify salt solutions than the control, but they could still taste the salt. This shows that the senses of taste and olfactory are separate. Sheep showed a reduced intake from a container tainted with carnivore faeces and a higher intake (95%) from the uncontaminated container (Pfister *et al*., 1990). The sheep went as far as possible away from the odoriferous containers.

Taste is a more proximate guide to food quality than vision and olfaction. The taste of a food is a powerful tool for the animal to associate the nutritional value of the food (Forbes, 1998). For example; a bitter taste is often associated with toxins in the food. Animals can adapt to a less tasteful food. When sheep were fed quinine-treated hay, they discriminated against it in the preliminary period. Thereafter they ate equal amounts of quinine-treated and untreated hay in a 5-day choice period (Jones and Forbes, 1984). This demonstrated adaptation as they learned that there were no harmful consequences to eating this unpalatable hay. Sheep and goats are sensitive to bitter, sour, salty and sweet solutions (Goatcher and Church, 1970). Preferences for taste can be blocked by including 5-50 ppm of monosodium glutamate in the solution. Sheep prefer the taste of butyrate to several other compounds. Arnold *et al.* (1980) tested 32 chemicals found in plants for food preference by sheep and found that butyric acid increased preference but not total intake. When foods containing 25 ml of 2M acetic acid kg^{-1}, 1g kg^{-1} of quinine or 20g kg^{-1} of sodium chloride were offered *ad libitum* to sheep, intake was less than the intake of untreated food (Baile and Martin, 1972).

Animal species differ in the forage plants selected. Marten (1973) showed a greater ability of sheep than cattle to differentiate between grazed clones of reed canarygrass. Both sheep and cattle selected reed canarygrass on the basis of alkaloids, both discriminating against high alkaloid content in the grass. As mentioned above, Goatcher and Church (1970) found that cattle were more sensitive, than were sheep, to concentrations of solutions that differed in sweetness, saltiness, and sourness. Sheep were more sensitive than cattle to bitterness. Arnold (1970) reported differences in preference curves of four breeds of sheep for citric acid and acetic acid.

Previous experience also affects the preference for a specific plant species by an animal. When animals were previously exposed to a less palatable species, they will initially consume this species in almost equal amounts than an unknown, more palatable species. This was well demonstrated in a study by Marten and Jordan (1974). These authors found that for sheep preconditioned on less palatable reed canary grass, the preference for more palatable orchard grass was reduced to a non-statistically significant difference. In a study done by Marten (1978), lambs initially preferred a strip of alfalfa-grass to the birdsfoot trefoil. After exposing the lambs to only birdsfoot trefoil, however, the lambs consumed the birdsfoot trefoil as regularly as the strip of alfalfa-grass.

Plant Factors:

Plant factors that may influence forage palatability to animals are: (1) species, (2) intraspecific variation, (3) chemical composition, (4) morphology or physical traits, (5) succulence or maturation, (6) availability in non-controlled situations, and (7) form of forage controlled by mechanization (Gorden, 1978).

While some investigators (Tribe, 1949; Heady, 1964) emphasize that specific plant species and plant characteristics do not elicit standardized palatability responses by animals, certain forage plant species, genotypes within species, and plant characteristics do elicit very predictable palatability responses by grazing ruminants.

Numerous associations reported between plant characteristics and plant palatability to ruminant animals have proven to be highly situation-specific, making them worthless as general selection criteria. Among these are concentrations of sugar or soluble carbohydrates, protein or nitrogen, fibre or cell walls, cellulose, ether extract or fat, individual minerals or total ash, carotene, vitamins, organic acids, tannin, and silica (Marten, 1969).

Environmental Factors:

Natural and induced environmental factors frequently influence plant selection by ruminant animals. Among these are (1) plant diseases, (2) soil fertility, (3) animal dung, (4) Feed additives, (5) climatic variation, and (6) seasonal or diurnal variations (Gorden, 1978).

In a study conducted by Gorden (1978) in Minnesota, the presence or absence of a plant disease on palatability of two forage species was apparent in a stall-feeding study. He fed freshly cut smooth brome grass infected with Helminthosporium leaf spot and reed canary grass to separate groups of dairy heifers. The reedcanary grass is less palatable than the brome grass. Although brome grass is more palatable, the intakes of the heifers on the infected brome grass were lower than on the reed canary grass. This implies that the infection with a disease can have a negative effect upon the palatability of that plant.
Animals will discriminate against plants contaminated with faeces or urine, as proven by Tribe (1949). This could be due to a decrease in palatability.

1.4 Intake

Feed intake is a behavioral activity representing the amount of food eaten by an animal in a given period of time. Voluntary intake is generally correlated with the amount of nutrients that can be extracted from a feed, for example the feed's digestibility (Illius, 1998). The digestibility of forages is largely determined by features of the plant. Due to interactions between feeds, or between the animal and a feed, the potential digestibility and potential intake may not be achieved. Feed intake is an important aspect of animal production systems because of its close relation to animal performance and profit margins (Gill *et al.*, 1986). The more food the animal can consume, the better the chance of increasing its daily production. An increase in production that results from an increase in food intake is associated with a better efficiency of the production process, since maintenance costs decrease as the productivity increases (McDonald *et al.* 1995). Changes in feed intake have also been associated with the phenomenon of compensatory growth. Animals undergoing compensation, following a period of growth restriction, were observed to greatly increase their feed intake (Baker *et al.*, 1985; Gibb and Baker, 1991). Substantial research has been done to understand the factors that are involved in the regulation of feed intake, yet it is so complex that many of the involved mechanisms remain unclear.

To understand intake control, we need to ask ourselves why do animals eat and why do they stop eating. It is generally accepted that animals eat to supply tissues with the necessary nutrients for maintenance, growth, work and production. Animals stop eating to limit metabolic or physical discomfort and thus the animal has to decide at what point the disadvantage of deficiency or excess of some nutrients outweigh the advantages of trying to meet the animal's energy requirements, which are thought to be the animals main intake 'drives' (Emmans, 1997).

It has long been assumed that, for forage diets, it is the bulkiness of the forages that primarily limits intake. This is a combination of the volume and the time that the undigested food stays in the rumen. Intake is limited by gut fill up to a breakpoint in digestibility, beyond which the relationship between intake and digestibility become negative and controlled by the animal's energy balance (Conrad *et al.,* 1964).

Feed intake is not strictly governed by a single factor, rather it is influenced by an interplay of external and internal factors. External factors are the sum of environmental and dietary cues, conversely internal factors are derived from within the animal. The physiological state of the animal is believed to have an important effect on intake. In ruminants, voluntary feed intake is largely determined by the physiological demands due to maintenance requirements and potential production (Hicks *et al.*, 1986).

There is consensus in the literature that the central nervous system (CNS) is the principal regulatory site of feed intake in animals. Regulatory mechanisms convey either hunger or satiety signals to the CNS, which increase or limit feed intake respectively. The hypothalamus is the portion of the brain that is responsible for feed intake regulation. The lateral hypothalamus responds to hunger signals and the ventromedial hypothalamus responds to satiety signals (Martin *et al.*, 1989).

The following factors affecting feed intake will be discussed: (1) forage factors, (2) animal factors and (3) interactions between feed components.

1.4.1 Forage factors that affect intake

Physical factors

Physical factors are factors that directly influence the initial gut volume occupied by the feed ingested and the rate at which this volume decreases due to digestion and onward passage. The content of fibrous cell walls contributes a large portion of this volume. The cell wall contents are less soluble and take up more space than the cell contents. From 35 to 80% of the organic material of forages is found in the cell wall. The structural carbohydrates in the cell wall; hemicelluloses, cellulose and pectin, are broken down by micro-organisms in the rumen, which enable ruminants to use this energy source, which is not available to non-ruminants. The ease with which the micro-organisms can break these molecules down depends on the distribution of the molecules within the plant (Jung and Allen, 1995). The physical characteristics of the cell wall or fibre particles such as tissue origin, shape, buoyancy and specific gravity, affect the rate at which the particles are broken down and the ease of passage (Wilson and Kennedy, 1996).

Resistance to reduction in particle size is positively related to fibre content; however, relationships between fibre measured using neutral detergent solution and DMI are not always consistent (Reid *et al.*, 1988). Reid *et al.* (1988) also indicated that the fill effect of NDF may vary with different forages. Minson (1990) observed that for groups of forages with similar DM digestibility, fibre content is greater in legumes compared with grasses, temperate compared to tropical grasses and leaf compared to stem. Wilson and Kennedy (1996) suggested that the greater digestibility of legumes compared with grasses may reflect leaf length. Grass particles are inherently long and buoyant, with a low functional specific gravity, and easily entangled, while chewed vascular particles are short and chunky with high functional specific gravity and thus escapes the rumen quicker. This demonstrates that the potential intake not only depends on the fibre content, but also on the structure and the way in which the plant material is broken down during digestion.

The dry matter content of feeds may also influence the space occupied within the gut. Pre-wilting of grass prior to ensiling has consistently been shown to give silages with up to 44% higher intakes compared with unwilted material from the same sward (Teller *et al.*, 1993). An explanation for this higher intake could be that the effectiveness of chewing during eating and the rate of particle breakdown was enhanced with the drier material. Wilting also causes breakdown of the cell walls, leading to easier digestion.

In grazing animals the structure of the sward can restrict intake not only in terms of the space taken up in the gut, but also by limiting the amount of herbage which the animal can actually harvest within a 24h period. Characteristics of the grazed sward, such as plant density and height, can influence intake through their effect on ease of prehension and thus bite size (Hodgson *et al.*, 1991). Stobbs (1973) concluded that the sward bulk density and leaf to stem ratio were the main factors affecting bite size and intake of cattle.

Forage Mass

Ruminants have no difficulty in satisfying their appetite when enough desired forage is available and given the fact that grazing is unrestricted. Under such circumstances they will take in large quantities of forage with each bite (Allden and Whittaker, 1970). Bite size on young uniform swards varies with the physical dimensions of the individual bite and the quantity of forage within the volume encompassed by the teeth (Hodgson, 1996). When too little forage is available, less than 2000kg DM/ha, there will be a reduction in bite size. The animal will try to keep intake constant at a specific level and will spent more time grazing (Allden and Whittaker, 1970).

1.4.2 Animal factors that affect intake

Animal size

As mentioned earlier, the energy requirement of an animal contributes to the amount of intake of an animal. Across species, size is the factor most closely correlated with intake. Larger animals consume greater quantities of food. The relationship is, however, not isometric but scales allometrically with body mass, and intake is commonly expressed on the basis of metabolic body weight, or live weight $(LW)^{0.75}$ (Illius, 1998).

Physiological status of the animal

Physiological status affects energy requirements and hence intake. In lactating animals, where nutrient demand is high, the rapid removal of metabolites from the blood may reduce the degree of stimulation of chemo receptors from the same amount of absorbed nutrients, or rate of passage may be faster reducing the bulk effect (Forbes, 1995). Intakes are normally higher in lactating compared with dry or pregnant cows (Campling, 1966). Invartsen *et al.* (1992) observed a reduction in intake due to pregnancy. He concluded that this reduction in intake was due to hormonal regulation and a physical decrease in space in the rumen due to the increase in size of the foetus.

Grazing animals

Intake of grazing animals is dependant both on intake rate and time spent grazing (Allden and Whittaker, 1970). Bite mass and bite rate are not independent. Newman *et al.* (1994) point out that for a given forage requiring a given time of mastication, an increase in bite mass will cause an increase in time of mastication, decreasing bite rate and resulting in intake rates that are similar. Animals will increase intake rate when time allowed grazing is restricted, once they learn that they are only allowed a restricted grazing period (Romney *et al.*, 1996).

Where sward structure limits bite mass and therefore intake rate, grazing time can be altered to compensate for decreased bite size. There appears to be an upper limit to the amount of time a ruminant will spend grazing (Forbes, 1995). Forbes (1995) suggests that ruminants are unwilling to eat for more than 12h per day. Thus, if bite size falls below a certain limit, animals will not be able to achieve maximum intake capacity. This occurs as a result of an upper limit to oral processing time, which encompasses prehension, mastication and rumination (Illius, 1998).

1.4.3 Interaction between dietary components

Supplementation can be considered as a means of increasing nutrient supply to animals that are unable to consume sufficient nutrients as forage. Supplementation tends to have an overall positive effect on dry matter intake, but may have positive or negative effects on intake of the basal forage (Forbes, 1995).

Supplements that are high in readily fermentable carbohydrate may have a greater effect on inhibition of fibre intake than more slowly fermentable supplements, through depression of digestion of the roughage fraction. Rapid fermentation results in an inhibition of cellulolysis due to a low pH (Terry *et al.*, 1969).

Supplementation can be used to increase intake of poor quality feed by supplying a limiting nutrient. The rate of microbial fermentation of forage diets are depressed if ruminal ammonia concentration drops below 50mg nitrogen per liter (Wilson and Kennedy, 1996). Minson (1990) suggested that for feeds with a crude protein content of less than 62 g crude protein per kg of dry matter, fibre digestion is inhibited. He reported on a number of trials in which the intake of forages were increased by 14-77% following provision of supplementary protein. Where ammonia nitrogen concentration limits microbial fermentation, supply of nitrogen to the micro-organisms increase organic matter digestion in the rumen. This increases breakdown and rate of passage of poor quality forage, thereby removing the physical constraint and allowing the animal to consume more feed (Romney *et al.*, 1996).

1.5 Nutrition of goats and sheep

Gentry (1978) (cited by Van Soest, 1982) classified goats as "intermediate browsers" and sheep as "grazers". Lu (1988) has described goats as "mixed-feeding opportunists". Both goats and sheep are considered more capable of selective feeding than cattle because of their cleft upper lips (Hafez, 1975). Goats, however, are notoriously selective and adaptive feeders, as judged by grazing/browsing studies (French, 1970). Goats have a markedly different grazing behavior than other livestock. They harvest material from a wide range of plant species and at the same time exhibit marked preferences as regards the parts of any particular species which they select. Given the opportunity they will graze trees and shrubs to a greater extent than will sheep, and their preferential selection of what is commonly regarded as weed species in modern agricultural systems has led to their use in the manipulation and improvement of both indigenous and sown pasture (Russel *et al.*, 1983; Grant *et al.*, 1984). Levels of herbage intake and performance appear to be more sensitive to herbage mass and sward height than is the case with sheep. As herbage mass declines the DM intakes of goats declines at a faster rate than that observed in sheep, and goats appear to stop grazing at a herbage mass of about 1000 kg DM/ha (Collins and Nicol, 1986).

Well-replicated experiments involving a range of feeds and levels of feeding with pelleted dried grass, medium- and low digestibility grass hay (Ndosa, 1980) and pelleted dried lucerne (Mohamed and Owen, 1982) found no differences between the apparent digestibility's of OM in sheep and goats. Alam *et al*. (1983) showed that the values for sheep may decline over time (after about 10 weeks),relative to those of goats, when given low quality roughages without supplementation. In a study by Domingue *et al*. (1991), unsupplemented prairie straw was better digested by goats than by sheep.

Studies by Domingue *et al*. (1991) have shown that goats have higher rumen ammonia concentrations than sheep when fed on low quality roughage. Alam *et al*. (1983) concluded that this was why goats had a higher DOMI when offered forages with OM digestibilities of less than 60%. Tan *et al.* (1987) noted that the higher intake of DOM and the higher rumen ammonia concentration in goats were not associated with a higher rate of digestion in the rumen when fed unsupplemented barley straw to sheep and goats. The 24- and 48-hour DM rumen degradation of straw was lower for goats than for sheep. Ndosa (1980) found the rate of passage of feed particles to be slower in goats than in sheep while Huston (1978) found the opposite. The results obtained by Ndosa (1980) were against their expectations because they had observed a higher DMI by goats than by sheep. Domingue *et al.* (1991) showed rumen fluid volume in relation to live weight to be higher in goats than in sheep when fed on a low quality straw. This could explain why goats seem able to consume more DOM than sheep, without having higher rates of passage or faster rates of digestion. Goats had, on the average, intakes 17% higher than sheep when fed on forages and hays of various qualities. Other studies showed this difference in intake to be as much as 29% (Ndosa, 1980).

Table 1.5. illustrates a comparison of the nutrient requirements between goats and sheep.

Table 1.5 Nutrient Requirements of goats and sheep (DM basis) (NRC, 1985; NRC, 1981; AFRC, 1998)

Component	Goat	Sheep
CP (%)	10-15	9.5-15
Na (g/kg)	Not available	0.9-1.8
Ca (g/kg)	1.38	2.0
P (g/kg)	1.6-2.8	1.6-3.8
Mg (g/kg)	1.5	1.2-1.8
K (g/kg)	5-8	5-8
Cu (mg/kg)	10-20	7-11
Mn (mg/kg)	20-25	20-40
Zn (mg/kg)	50	20-33

The aim of this study was to identify the nutritional differences between the different palatability groups of *A. nummularia* (Hatfield Select F1). This will help in selecting more palatable plants, which can then be used for seed production. We need to select plants that will produce dry material in the extreme conditions (saline soils, dry and hot conditions) in which the current *A. nummularia* does, but it should have a higher palatability and acceptability and have a nutritional value to maintain animals in a time of food scarcity. This is especially important in the dry arid northwestern and western parts of South Africa where *A. nummularia* plays an important role in animal production systems. This study will also help us understand which nutritional factors in *A. nummularia* affects the palatability of this species.

We also want to identify some differences in the quantity and nutritional quality of the plant material selected between sheep and goats. This will help us to know which type of plants each of these two species prefer and thus what we should select for propagation for each of these animal species.