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# Influence of quantity and quality of forages on intake and production of grazing sheep

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## SUMMARY

The performance of grazing sheep is very variable, depending on the type of soil and vegetation, time of grazing, location and altitude. In addition there are differences in breeds and condition of the sheep.

One of the important factors in achieving good and efficient growth is the quantity of available herbage. Therefore it is important not to start grazing in spring until sufficient herbage is available and to keep the stocking rate low enough to maintain a steady grazing pressure throughout the grazing season. However, animal gain and forage availability are not always positively related, a finding which could be due to differences in forage quality. This relationship of quantity and quality is ever-changing and depends on many factors, such as variation between plant species and season, as well as defoliation and general structure of the sward. It is important to understand how these factors affect the herbage intake, which is the single most important factor in meeting the nutrient requirement of the grazing sheep. The amount consumed is the product of bite mass, rate of biting and grazing time. However, this has not been studied under the varying conditions of the north, where there is apparently no significant difference in the amount of herbage intake of ewes with their suckling lambs, for example on the wet lowland pastures, which support a relatively high pasture density and low lamb growth, and the dry highland range, where the forage density is much lower and the lamb growth is greater although forage quality is similar. These results are not fully understood and can not be explained by experimental results from more southern locations.

By combining quantity and quality into one parameter, described as available nutritive mass, a growth response model can be established within each type of pasture or rangeland. It could possibly be used to develop a general grazing index for sheep, using Near Infrared Reflectance Spectroscopy and/or in the near future using remote sensing directly to monitor sheep pastures and rangelands for grazing conditions at any particular time.

Key words: available nutritive mass, forage, grazing, herbage, intake, performance, quality, quantity, sheep.

## YFIRLIT

*Áhrif magns og gæða gróðurs á át og vöxt beitarfjár*

Þrif sauðfjár á beit eru mjög breytileg eftir því á hvernig landi það gengur, að því er varðar jarðveg og gróðurfar, beitartíma, staðsetningu og hæð yfir sjó. Þá hefur tegund og ástand fjárins áhrif.

Forsenda þess að féð þrífist vel er að nægilegur gróður sé fyrir hendi í beitilandinu. Það er því mikilvægt að byrja ekki beit á vorin fyrr en nægilegur gróður er kominn og hafa beitarþungann ekki meiri en svo að beitarálagið sé sem stöðugast út beitartímann. Því er þó þannig farið að vegna breytileika í gæðum beitargróðursins fara aukið framboð hans og betri þrif fjárins ekki alltaf saman. Þetta samband magns og gæða gróðurs breytist stöðugt og hafa þar margir þættir áhrif, s.s. tegundir plantna í beitilandinu og hlutfall þeirra, beitartími, beitarþungi og ástand og gerð beitilandsins almennt. Það er mikilvægt að skilja hvernig þessi atriði hafa áhrif á át fjárins, sem er mikilvægasti þátturinn í því

að fullnægja þörfum þess. Hversu mikið skepnan étur er síðan hægt að skilgreina sem margfeldi þess hve munnbitarnir eru stórir, hversu hratt bitið er og hversu lengi. Þetta hefur ekki verið rannsakað við norðlæg skilyrði sem eru mjög breytileg. Við þessi skilyrði hefur þó komið í ljós að á þurrum lyngmóa á afrétti, þar sem þrif lamba eru mjög góð, og í óframræstri mýri á láglendi, þar sem þrif þeirra eru mun lakari, er átið mjög sambærilegt. Aftur á móti virðast ærnar þrífast betur á láglendismýrinni en hálendismóanum þannig að ástæðan fyrir mismuni á vænleika lambanna getur legið í minni mjólkurlagni ánna í mýrinni. Þessir þættir eru þó engan veginn nægilega þekktir og verða ekki skýrðir með niðurstöðum tilrauna sem gerðar eru við suðlægari skilyrði.

Með því að sameina í einn þátt bæði magn og gæði gróðurs og skilgreina sem aðgengilega næringu er hægt að reikna út líkingu yfir þrif fjárins innan hverrar tegundar beitilands eða skyldra gróðurlenda. Með þessu er mögulegt að þróa beitarstaðal fyrir sauðfé á mismunandi beitilandi, þar sem innrauð mælitækni væri notuð og/eða í framtíðinni fjarkönnun til að kanna ástand og beitarþol landsins á hverjum tíma.

## INTRODUCTION

Sheep farming is only practised in limited areas of the north. In most of the large mainland areas such as in Canada and Russia sheep production only exists in the more southern parts, leaving sheep production in the more northern parts only in western Europe. In these northern countries grazing is an important farming practice in spite of the relatively short grazing season as compared to other parts of the world. It therefore plays a major role in the management and economy of sheep farming under these conditions.

Although the system of sheep production is not the same in the various northern countries, there are similarities between Iceland, Scandinavia and Scotland, where the management is governed by the rather short period of vegetative growth and where extensive grazing on native pastures or rangelands is common. Still, there are significant differences between these countries in factors that can affect the nutrition and performance of the sheep, such as climate, geology, botany and topography (Ólafsson, 1973a).

Series of grazing studies on rangelands were first carried out in Iceland in 1964 (Ólafsson, 1973b). The pioneer in these studies was the late Dr. Gunnar Ólafsson, former director of the Agricultural Research Institute in Iceland, to whom this symposium is dedicated. His main emphasis was on plant preference of sheep (Ólafsson, 1973cd) and the chemical composition and *in vitro* digestibility of herbage (Ólafsson, 1973ef). He also did some work on the consumption of herbage by sheep and optimum stocking rate. This work was continued at the Agricultural Research Institute*) and some of it, as well as related work reported by others, will be discussed in this paper.

## SHEEP PERFORMANCE

The pastures and rangelands used for sheep grazing in the north are variable. The most obvious differences are found between the improved pastures and natural rangelands. The pastures can be divided, for example, according to soil type or vegetative composition, and the rangelands can be divided into many categories, such as lowland and highland or dry and wet areas. Different categories are used in different countries and under different conditions. Grazing practices also differ between locations and there is a great variation in the growth rate of ewes and their lambs due to differences in breeds and condition of the sheep.

In Iceland lambs generally grow better in the highlands and mountains during the peak growing season than on the lowlands (Figure 1), whereas their dams appear to thrive better on the lowland mire than on the high-

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lands (Figure 2). In the early grazing season the lambs in the highlands apparently do not gain as well as in the mid-season, and in the late summer and autumn there is a great decrease in the average daily gain of the lambs in the highlands and mountains, whereas there is a more gradual drop during the summer on the lowland (Figure 1) (Gudmundsson and Thorgeirsson, 1989). Therefore delaying the initiation of grazing on the common rangelands in the highlands in early summer has been recommended, as well as putting the lambs on improved pastures in late August (Gudmundsson and Dýrmundsson, 1983).

Under these conditions it is common for the ewes to lose weight during the early summer when they produce a great deal of milk and when the forage has not yet reached maximum growth (Gudmundsson and Bement, 1986). This of course depends greatly on the location, climate and stocking rate. The ewes are on the average heavier at the end of grazing in the autumn on wet and semi-wet rangelands than on the drier soils (Gudmundsson and Thorgeirsson, 1989).

## HERBAGE QUANTITY

It has generally been assumed that growth of suckling lambs in these cool regions is highest in the spring when it is supposedly independent of stocking rate and the dams are producing the highest amount of milk. An explanation of a lower performance early in the season than in mid-season, especially in the highlands as shown in Figure 1, could be a lack of available herbage. One of the most important ways to achieve good and efficient growth of sheep during the grazing season is not to start grazing in the spring until sufficient herbage is available. If this is kept in mind a higher stocking rate can be achieved supporting the same or a greater amount of animal gain, with less strain being put on the pasture or range. The quantity or availability of herbage in relation to the animal is therefore one of the most important factors in fulfilling the nutritional requirement of the grazing sheep for maintenance and production. This is reflected in the effect of the stocking rate on average daily gain and carcass weight, with the greatest effect on dryland, independent of altitude (Figure 2).

The herbage mass changes over the grazing season, depending on the type of vegetation, location and stocking rate. The grazing pressure, defined as the number or mass of animals per available dry matter, is different over a given range of stocking rates and tends to increase progressively with time. However, the stocking rate can be increased without affecting the grazing pressure by increasing the pasture mass available to the animal. This, of course, does not usually happen when the stocking rate is increased, but can be accomplished, for example, by delaying initiation of grazing in the spring or early in the season, by fertilizer applica-

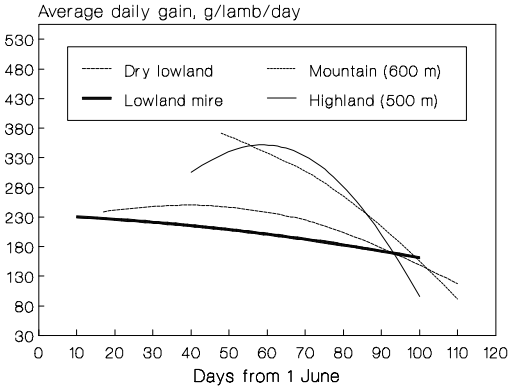


**Figure 1**. Average daily gain of lambs grazing with their dams on different pastures and rangelands in Iceland. Five year data from a large grazing project with stocking rate experiments, with ewes carrying lambs, at different locations, altitudes, soil types and vegetation covers (Source: Gudmundsson and Arnalds, 1976–1980).

*1. mynd. Daglegur meðalvöxtur lamba sem beitt er með mæðrum sínum á mismunandi beitiland á Íslandi. Fimm ára niðurstöður úr stórum beitarþolstilraunum með lambær á ýmsum stöðum í mismunandi hæð yfir sjávarmáli og með mismunandi jarðvegsgerð og gróðurlendi.*

tion, and by supplemental feeding. In general, cultivated and fertilized lowland mire has high herbage production and can be stocked heavily and still maintain a relatively low and steady grazing pressure throughout the grazing season (Figure 3). On drained uncultivated mire an increased stocking rate increases grazing pressure much more drastically, but there is no additional increase during the late grazing season. In the dry highlands, however, where the stocking rate is much lower, a little quantitative increase in the stocking rate considerably decreases the available dry matter, thus increasing the grazing pressure, with an exponential increase during the latter half of the summer. In addition to greatly decreasing the available herbage per animal, this could cause damage to the vegetation and the sward in general, thus permanently reducing its productivity.

Increasing herbage mass, for example by decreasing the stocking rate, should increase intake and gains. As herbage allowance increases above what the animal can consume, the efficiency of pasture use declines and consequently the residual herbage mass at the end of the grazing season increases (Bement, 1969). Therefore it seems reasonable that during short-term grazing, individual animal gains could be considered in the context of post-grazing residual herbage mass (Bement, 1969; Sheath *et al.*, 1987). This has also been well established under more northern conditions (Gudmundsson and Arnalds, 1976–1980). The length of the grazing period depends, of course, on location, type and condition of each individual pasture or rangeland. It has to be kept in mind that the estimates of residual pasture mass alone do not account for pre-grazing mass or grazing pressure, making this measurement difficult under farming conditions as a predictor of animal performance, especially as it is measured at the end of each grazing period. However, the post-grazing residual herbage mass can be used as a prediction by weighing the animals and measuring the pasture mass several times during the grazing season.

Most of the grazing experiments that could be applied to northern conditions have focused on forage allowance, i.e. on the pasture mass in relation to animal mass or number, as a predictor of animal performance. This includes the effects of pre-grazing forage mass, stocking rate and length of grazing. Therefore an infinite number of combinations of these factors can determine the allowance, which is constantly changing. The changes are especially noticeable at high

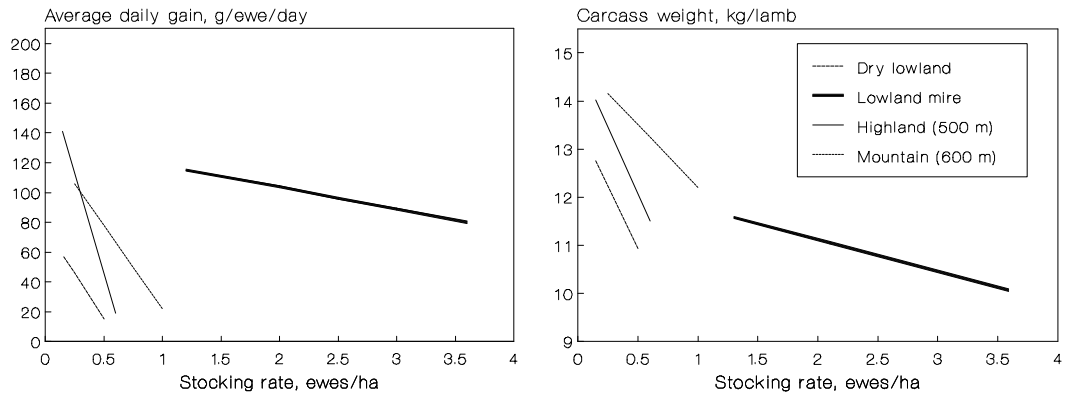


**Figure 2**. Relationship between stocking rate and average daily gain of ewes and carcass weight of twin lambs in Iceland. Data from the same source as in Figure 1.
*2. mynd. Samband beitarþunga og vaxtar áa (t.v.) og fallþunga lamba (t.h.) á Íslandi. Gögn úr sömu tilraunum og í 1. mynd.*

grazing pressure where the allowance is low and where large amounts of forage are consumed relative to available forage. At low grazing pressure, on the other hand, where the allowance is high and where small amounts of forage are consumed relative to available forage, both pasture mass and intake are proportionally much more constant over the grazing period.

The importance of pasture mass or herbage production in relation to the animals grazing the herbage can further be shown by directly relating the stocking rate, defined as number or mass of animals grazing a unit area, to the grazing pressure, as previously defined. As the stocking rate increases, the amount of standing herbage available to the animal decreases, causing the grazing pressure to increase proportionally much faster than the stocking rate (Gudmundsson, 1980). This relationship of stocking rate to grazing pressure distinguishes between the different classes of pastures discussed in this paper (Figure 4). The least proportional increase in grazing pressure per unit increase in stocking rate occurs on the lowland mire, where the herbage mass is greatest, and most on the dry lowland and highland where the herbage mass is much less (Gudmundsson and Thorgeirsson, 1989). This effect of herbage mass on grazing pressure should favour lowland mire grazing over highland grazing, as far as the protection of the vegetation is concerned. However, this is not the case for the nutrition and growth of the lambs (Figure 1), as the gain of the lambs grazing with their dams in the mountains was greater than on the lowland pastures during the peak grazing season. This could indicate that availability may well reflect quality or palatability rather than herbage growth, causing lower lamb performance at higher herbage mass, and depending highly on species composition available.

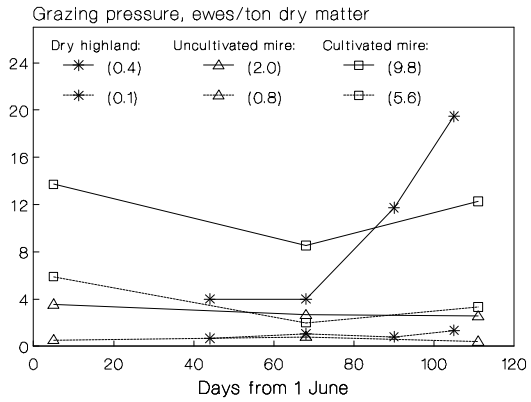


**Figure 3**. Grazing pressure as affected by stocking rate (ewes/ha, shown in brackets) and time of grazing on different pastures and rangelands in Iceland. One year data from the same source as in Figure 1.

*3. mynd. Áhrif beitarþunga (ær/ha, í svigum) og beitartíma á beitarálag á mismunandi beitilandi á Íslandi. Eins árs rannsókn úr sömu tilvitnun og í 1. mynd.*

## HERBAGE QUALITY

One of the most important factors affecting nutrition and therefore the performance of the sheep is the quality of the herbage. This is usually described in terms of digestibility and chemical composition, as has been reported earlier at this meeting by Armstrong and Miles (1993) and therefore will not be discussed here in any detail.

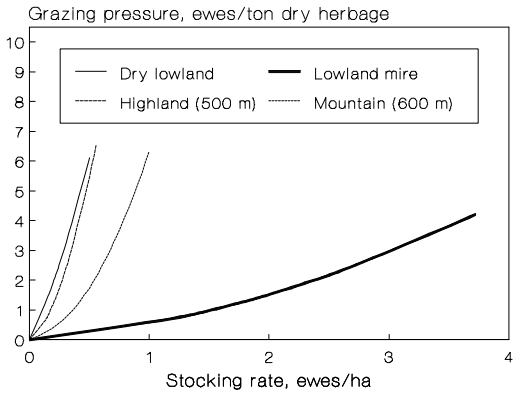


**Figure 4**. Relationship between stocking rate and grazing pressure in Iceland, using data from the same source as in Figure 1.

*4. mynd. Samband beitarþunga og beitarálags á Íslandi. Gögn úr sömu tilvitnun og í 1. mynd.*

One of the reasons that there is not always a positive relationship between animal gain and forage availability is that forage availability measurements do not include the effect of forage quality on animal gain. Therefore the relationship between available dry matter and animal performance can not be taken as evidence that performance can be evaluated from measurements of the amount of herbage alone. This relationship is mostly due to variability between plant species and season, with the general structure and defoliation of the sward having the most significant effect on availability of nutrients.

As grass matures the proportion of the less digestible stem increases and also declines in digestibility, whereas the more digestible leaf becomes a smaller and less digestible fraction of the whole plant. The digestibility of the stems also declines faster than that of the leaves. These changes are reflected in the increasing proportion of cell wall carbohydrates, along with a decrease in digestibility of most components of the herbage. Furthermore, the quality of the herbage ingested by the animal decreases if the grazing pressure causes low availability of herbage, reducing the animals' opportunity for selective grazing. The nutritive value of the vegetation grazed by livestock therefore changes with time and amount, and consequently the balance of nutrients is constantly changing.

The seasonal changes in pasture composition can not be easily separated from the changes due to maturity. When looking at *in vitro* digestibility and protein content in general (Figure 5), the digestibility of grasses, in this case *Festuca rubra*, is very high in the spring, but is greatly reduced during the grazing season. In evergreens, such as *Calluna vulgaris*, the digestibility and protein content are much lower, but do not change much during the grazing season (Ólafsson, 1973a). Earlier at this meeting diet selection of grazing animals has been discussed (Thórhallsdóttir, 1993). However, it is important to point out here that diet selection can stabilize to some extent the quality of what the animal consumes, especially concerning digestibility, as shown in Figure 5, although maintenance of a high quality diet may be accomplished at the expense of absolute intake. This ability of the mature animal to select diets higher in nutritive value than the average nutritive value of the pasture is well accepted in the literature.

Under more uniform conditions, such as grazing perennial ryegrass (*Lolium perenne*) pasture, the relationship between pasture and diet digestibility by lambs has been studied during summer grazing (Penning and Gibb, 1979; Jamieson and Hodgson, 1979). When the lambs are suckling, the digestibility of their selected diets is very high and steady, with no evidence of decline as pasture digestibility declines due to forage maturation (Penning and Gibb, 1979). When studying weaned castrated male lambs, on the other hand, a significant positive linear relationship was observed between diet digestibility and pasture digestibility, although in all cases the digestibility of the diet was much higher than for the pasture as a whole (Jamieson

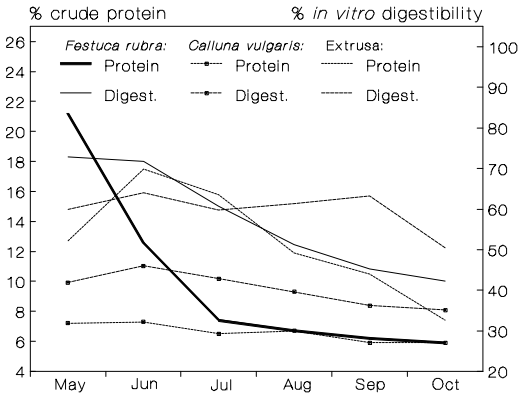


**Figure 5**. Changes in protein content (% in DM) and *in vitro* digestibility (% in DM) of two types of plants and extrusa during the grazing season (Source: Ólafsson, 1973a).

*5. mynd. Breytingar yfir beitartímann á magni próteins (% í þurrefni) og meltanleika í tilraunaglösum (% í þurrefni) í túnvingli, beitilyngi og hálfsopssýnum.*

and Hodgson, 1979). These results are, of course, highly related to the rumen development of the lambs. It is therefore apparent that the effect of the available herbage and its quality on animal performance is not necessarily direct, as it is rather the amount and quality of what the animal consumes that are the real determinants of animal performance. Therefore it is important to understand how these factors affect herbage intake.

Figure 6 shows the chemical composition in the herbage selected by esophageally fistulated ewes grazing dry highland and lowland mire. The highland herbage has a higher proportion of highly digestible compounds which are mainly soluble carbohydrates, with much less difference in the protein content. The lowland pastures, on the other hand, have a higher amount of less utilized compounds such as cellulose and hemicellulose. What is most interesting, however, is the high amount of lignin, and associated low amount of hemicellulose, in the extrusa from the highland compared to the lowland. This, of course, could explain some of the differences in animal per-formance that exist between grazing areas, but there is very little difference in *in vitro* digestibility between these rangelands and the difference that does exist is in favour of the lowland. This difference in the fiber and lignin fractions with similarity in digestibility is most likely due to the different plant composition of the sheep extrusa selected on the lowland and the highland, because of different digestibility of these fractions of different plant species (van Soest, 1982).

There is usually a greater proportion of dead material on the lowland than on the highland and also on the wet rather than dry ranges, of course depending on previous stocking rates. Dead material has low nutritive value compared to green herbage. Therefore, the amount and position of dead herbage in the sward can influence the quality of what the sheep consume. Although sheep show a preference for green leaves and tend to reject pseudostem and dead material, they eat more dead vegetation as the selection opportunity decreases, for example as grazing pressure increases or when a high proportion of dead material exists in the grazing zone. This increased consumption of dead herbage will decrease both the intake and animal performance (Sheath *et al.*, 1987). The amount of pasture left after grazing therefore affects the digestibility of the pasture

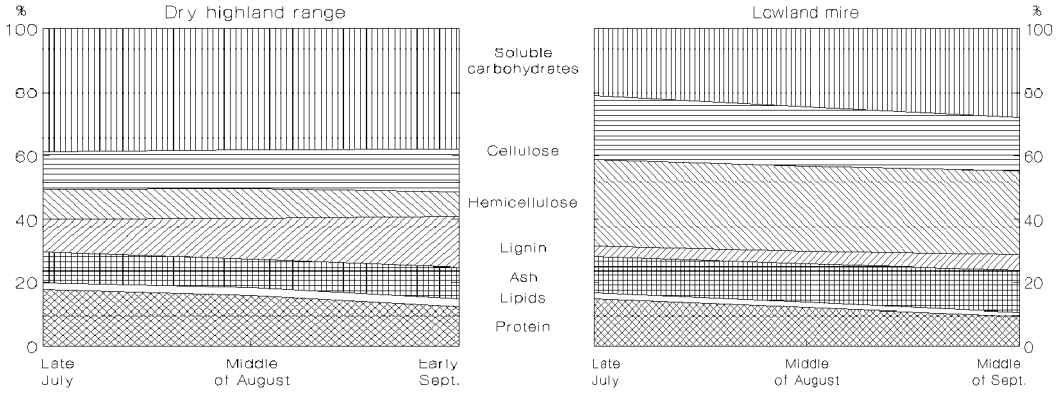


**Figure 6**. Chemical composition in extrusa samples from lowland mire and dry highland in one year study in Iceland. The cell wall is partitioned into cellulose, hemicellulose and lignin according to Goering and van Soest (1970).

*6. mynd. Efnainnihald í hálsopssýnum úr láglendismýri og af þurru hálendi í eins árs tilraun á Íslandi. Frumuveggnum er skipt niður í sellulósa, hemisellulósa og lignín samkvæmt aðferð Goerings og van Soest (1970).*

available for subsequent grazing. As previously discussed, some but not all of the seasonal decline in digestibility, and especially in protein composition, can be avoided by selectivity of the sheep. However, cattle and horses are less selective than sheep and can therefore possibly increase the effective quantity of green and growing herbage and the quality of herbage available to the grazing sheep, during interactive or mixed species grazing (Gudmundsson and Helgadóttir, 1980; Gudmundsson, 1985).

It is generally accepted that legume content such as clover in the sward improves both pasture quality and sheep performance and that this improvement increases as the pasture allowance decreases (Gudmundsson, 1986). Therefore clover is more common in improved pastures maintained at low pasture masses, limiting the dominance of grass growth. However, clover growth is limited under northern condition giving relatively low pasture mass compared to grasses (Hermannsson, 1986). Legumes more suited for range conditions and giving a high biomass include, for example, perennial lupines, especially *Lupinus nootkatensis*, but unfortunately they are not suitable for grazing due to the high alkaloid content (Gudmundsson, 1986). Annual sweet lupines (*Lupinus angustifolius*), on the other hand, have produced extremely good growth of weaned lambs during autumn grazing (Gudmundsson and Runólfsson, 1986, 1988).

## HERBAGE INTAKE

The description of nutritive value of herbage gives little information of how much the sheep will eat, although there is generally a positive relationship between digestibility and intake. This is particularly disadvantageous as intake is the single most important factor in meeting the nutrient requirement of the grazing animal and an increase in forage availability, as indicated earlier, is in no way synonymous with an increase in the amount of forage consumed.

In general, the amount of herbage consumed by the grazing animal can be described as the product of rate of intake and grazing time. On improved or uniform pastures intake rate can further be described as the product of bite mass and rate of biting, which is to a great extent governed by the sward (Hodgson, 1985). These sward effects can be described as a function of the distribution (L'Huillier *et al.*, 1984) and the height and density of green material (Allden and Whittaker, 1970). The effects of the two last parameters on ingestive behaviour have been shown in short term studies on artificial swards (Black and Kenney, 1984) and in a grazing

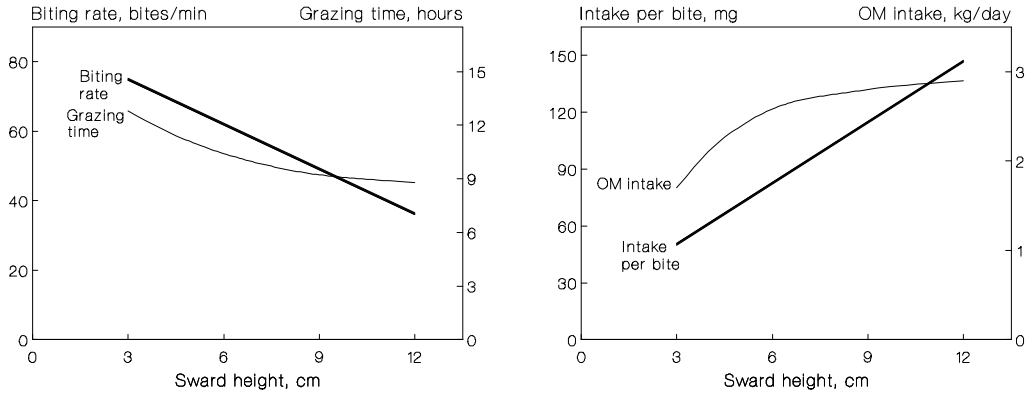


**Figure 7**. Influence of sward surface height on the components of ingestive behaviour (Source: Penning, 1986).

*7. mynd. Áhrif hæðar grassvarðarins á þætti sem hafa áhrif á át.*

experiment (Penning, 1986) on perennial ryegrass pasture (Figure 7). As the sward height and/or density increases, intake per bite increases, but at the same time the biting rate and grazing time decreases. This causes a large increase in intake for each increase in sward height at low availability, but under uniform conditions, such as on perennial ryegrass pastures, when the sward height reaches 6 cm the intake becomes constant in spite of the increase in herbage mass available. It could therefore be assumed that at the same pasture allowance, herbage lower than a height of 6 cm would cause lower live weight gain than taller herbage. Black and Kenney (1984) suggested that forage mass, a combination of height and density, was a better prediction of intake than either component alone, which is in conflict with the results of Allden and Whittaker (1970). This relationship, however, has not been studied under more extensive and/or northern conditions. As much of the sheep rangelands used in the north are very diverse, measuring sward height is not practical, although it has to be assumed, in spite of lack of information for the northern ranges, that intake per bite increases and both biting rate and grazing time decline with increased availability of herbage (Gudmundsson, 1987). Therefore, as availability is reduced, intake per bite declines and grazing time and biting rate increase, but not enough to maintain intake, and as this continues it finally causes the animal to stop grazing (Hodgson, 1985). In spite of this it has been stated before that intake is not determined by allowance alone and it can be assumed that under northern range conditions the bite size is relatively small. Further, in the face of a limitation in herbage consumption, the sheep most probably maintain daily herbage intake by moving between different plant communities, with increased distance travelled as the feed resources diminish, giving the animal distribution on the rangeland a great importance (Gudmundsson, 1987).

It is not only the question of how the animals respond, but also how the swards or pastures respond to grazing that matters in the plant-animal interaction. Grazing reduces the leaf area, depending on stocking rate, which reduces total photosynthesis and therefore the biomass production. The maximum photosynthesis is therefore found on pastures with high leaf production, though this is only possible at very low or close to zero stocking rates. At higher stocking rates leaves are removed, reducing the photosynthetic rate but the requirement for respiration decreases at the same time. The effect of reduced photosynthesis is further offset by less root growth and higher herbage utilization. Under continuous grazing, herbage production and harvesting per unit area, can therefore be greater at relatively high stocking rates, for example maintaining a sward surface height of 4 to 6 cm, than at low stocking rates (Parsons *et al.*, 1983; Parsons and Johnson, 1986; Maxwell and Treacher, 1987). However, the vegetation can become weaker due to a less vigorous root system.

Measurements of intake on lowland pastures in Iceland has shown high total herbage intake rate in spite of relatively poor growth of the lambs and high fibre vegetation (Figure 8). It has to be pointed out that the intake in these experiments is probably overestimated due to the methodology used, using grab faecal samples and chromic oxide and lignin as external and internal markers respectively. However, this does not change the relationship between the intake on these two types of pastures shown in Figure 8, and it is surprising that the intake on the cultivated mire is lower than on the uncultivated mire. This is true both for the ewes and lambs, and it has to be kept in mind that the quality of the pasture is greater on the cultivated than the uncultivated land. Under these conditions where the performance of lambs is relatively poor, the ewes on the cultivated land gained weight during the whole grazing season. The gain was highest

in the early summer and decreased during the grazing season. The ewes on the uncultivated land lost weight in the early summer and gained some weight during the late summer. There was not any apparent relationship between the intake and performance of the ewes. It is well established that the milk production is highest in early summer, but it should be similar or higher on the cultivated than the uncultivated pastures. Because of these results we can not claim that the poor growth of lambs on the lowlands is due to low intake. Rather, it appears caused by some quality or non-nutritional factors such as fungi associated with the lowland mire (Eiríksson *et al.*, 1989) or parasites such as *coccidia* (Gudmundsson *et al.*, 1983).

In other experiments where the sheep were grazed on undrained lowland mire, the actual intake was considerably lower and intake per unit live weight was similar as on the dry highland. In Figure 9 the intake of the ewes and their lambs are both shown per head and related to metabolic body size ($W^{0.75}$). In general the curves have a shape similar to the growth curve in Figure 1, and it is apparent that the maximum intake of the ewes in the highland (Figure 9) coincides with the maximum gain of their lambs in the middle of the summer (Figure 1). This further supports the conclusion made earlier that the sheep are brought to the dry highland range too early, as the available herbage is limiting the consumption for the ewes and consequently not supporting maximum growth of their lambs. The herbage intake of the lambs per head increases surprisingly little over the summer (Figure 9), as during this time the lambs are gaining weight and at the same time they are reducing their intake of milk and the rumen is developing its ability to ferment roughage. In all cases it is assumed that the lambs utilize close to 100% of the milk consumed (Penning and Gibb, 1979).

It is generally accepted (Hadjipieris *et al.*, 1965; Langlands, 1968) that young lambs consume more total dry matter per unit live weight than mature sheep, while they consume much less per head, with the milk intake negatively correlated with herbage intake and positively correlated with growth rate (Penning and Gibb, 1979). The forage intake per unit live weight is much lower for the lambs than the ewes and reaches its peak in early August (Figure 9) or at approximately 8–9 weeks of age, which is in good

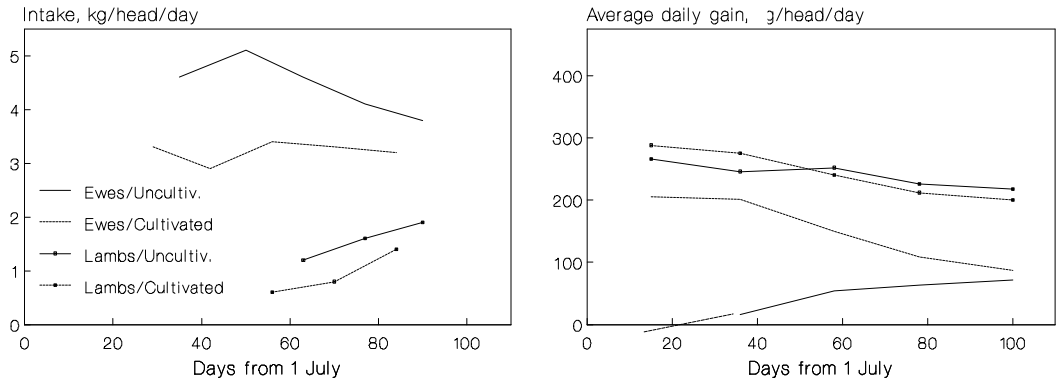


**Figure 8**. Herbage intake and performance of ewes and lambs grazing lowland mire pasture in one year study in Iceland. The intake was measured by the use of chromic oxide and faecal grab samples to determine faecal output and lignin used as internal marker to determine digestibility.
*8. mynd. Át og þrif áa og lamba sem beitt var í eitt sumar á mýrlendi á Íslandi. Við átmælinguna var krómoxíð gefið og notað ásamt saursýnum úr endaþarmi til að meta saurmagn, og lignín í gróðri notað til að meta meltanleika.*

agreement with more southern conditions (Gibb *et al.*, 1981). The intake of the ewes per unit body weight decreases during the grazing season and equals the herbage intake of the lambs in late summer or autumn, depending on the type of pasture or range, when the milk production of the ewes and its consumption by the lambs has reached its minimum.

## THE AVAILABLE NUTRITIVE MASS AND PERFORMANCE

As indicated earlier, quality, especially digestibility, can influence intake and therefore animal performance. However, digestibility of the diet available or selected by the sheep does not differ markedly whether on a highland or lowland pasture, especially when animals graze at high pasture allowances. Although it is important to isolate and study individual quality and quantity factors separately it is also important in practice to have few parameters or even a single parameter to predict grazing conditions and/or sheep performance.

Quantity and quality can be combined into one parameter described as available nutritive mass (ANM) or digestible dry matter allowance. This is the total digestible herbage mass available for each animal or animal unit at any particular time under relatively uniform grazing conditions. It is apparent that on similar pastures or rangelands, depending on altitude and/or location, the ANM influences lamb performance in two ways. For example, the lambs on the dry highland have a much higher maximum gain and carcass production, than those grazing lowland pastures. Secondly, on the dry lowland the animals reach their maximum performance at a much lower ANM than on the highland. The daily live weight gain of both the ewes and lambs was found to increase on the highland as the allowance increased, within the limits of the experiments. On the lowland, however, the growth appears to level off after the ANM has reached 20 g of digestible dry matter.

The ANM could possibly be developed further by adding quality measures such as protein and/or fibre content, making up a general grazing index for sheep, within each type of pasture or rangeland, by the use of advanced modelling. Grazing indexes based on intake and nutritive value have been developed before (Crampton *et al.*, 1960), but in recent years it has become possible, through the use of advanced computer modelling

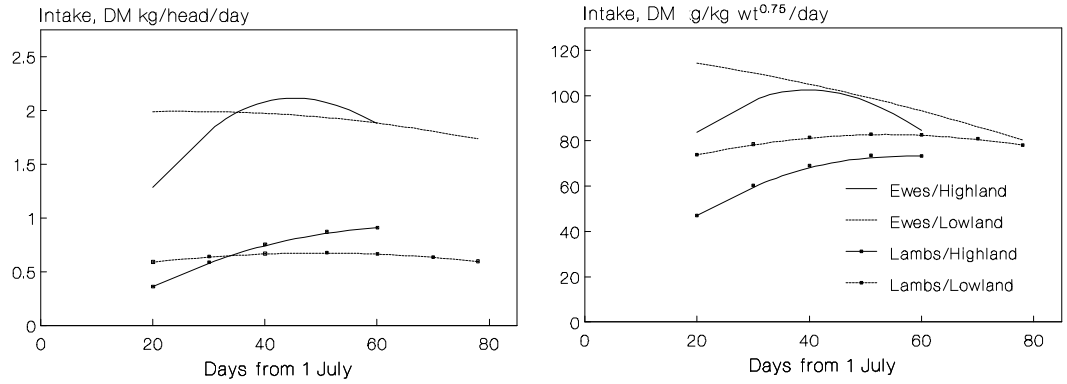


**Figure 9**. Herbage intake of ewes and lambs grazing dry highland range and lowland mire pasture in one year study in Iceland, using a total faecal collection and *in vitro* digestibility to determine the intake.

*9. mynd. Át áa og lamba beitt sumarlangt á þurrann kvistmóa á hálendi og á láglendismýri á Íslandi. Notuð var heildarsöfnun saurs og meltanleiki í tilraunaglösum til að ákvarða átið.*

and Near Infrared Reflectance Spectroscopy (NIRS) or a similar technique, to make them more accurate and at the same time more practical for general use. For example, it is now actually possible to monitor the sheep pastures or rangelands for ANM, using standing herbage mass or height measurements to measure quantity and then determining dry matter and quality immediately with portable NIRS. In the future it should even be possible to do this monitoring directly, for example by the use of remote sensing, either by handhold monitors on the ground or by areal monitoring by airplanes or satellites.

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