Adaptation of Semi-domesticated Reindeer to Emergency Feeding

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Abstract

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Emergency feeding of reindeer occasionally becomes necessary due to deep snow or ice crust preventing the reindeer from reaching the vegetation on the ground. The artificial feed stuffs available are not optimal for reindeer in poor condition and adaptation problems may occur.

The aim of this thesis was to compare emergency feeding strategies based on lichens and feed stuffs commonly available in practice. Seventy-two reindeer calves were kept outdoors and continuously followed by observing their behaviour and collecting physiological data. The reindeer were first fed insufficient amounts of a lichen-based diet, followed by one starvation day to mimic a feed emergency situation. Four feeding strategies were then applied and the adaptation of these calves was compared with a control group, which received the lichen diet *ad libitum*. The control group remained healthy and showed consistent behaviour throughout the experiment and a group fed the lichen diet, after the starvation day, quickly recovered. This may be related to a substrate specific group of lichen utilizing bacteria that was found in their rumens.

The adaptation to diets based on commercial reindeer feed and silage resulted in initial problems with diarrhoea and malnutrition. Another symptom was “wet belly syndrome”, which started during the restriction period and continued during feeding. The fluid making the reindeer fur wet was found to be of internal origin, but the disease was not linked to any specific diet. As feeding proceeded, the animals adapted to the commercial feed and their behaviour became similar to the control group. The adaptation was confirmed by increased concentrations of protein, urea and insulin in the blood plasma, higher counts of protozoa and concentrations of volatile fatty acids in the rumen and gains in muscle and fat depots. This thesis shows that collection of a wide range of physiological data, together with behaviour studies in animals kept under equal conditions was a suitable method to evaluate the adaptation of reindeer to emergency feeding. It became clear that the general condition of the animals, before the feeding started, as well as the diet composition, affected the ability of the reindeer to adapt to feeding.

Keywords: Rangifer tarandus, feed intake, metabolism, metabolisable energy, protein, glucose, pH, protozoa, rumen bacteria.

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To feed or not to feed...

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Appendix

Papers I-V

This thesis is based on the following papers, which will be referred to by their Roman numerals:

I. Nilsson, A., Danell, Ö., Murphy, M., Olsson, K. & Åhman, B. 2000. Health, body condition and blood metabolites in reindeer after submaintenance feed intake and subsequent feeding. *Rangifer* 20(4): 187-200.

II. Nilsson, A., Murphy, M. & Åhman, B. 2003. Rumen content in reindeer (*Rangifer tarandus tarandus*) after submaintenance feed intake and subsequent feeding. (Manuscript).

III. Åhman, B., Nilsson, A., Eloranta, E. & Olsson, K. 2002. Wet belly in reindeer (*Rangifer tarandus tarandus*) in relation to body condition, body temperature and blood constituents. *Acta Veterinaria Scandinavica* 43, 85-97.

IV. Nilsson A., Norberg, H., Olsson, K.. & Redbo, I. 2003. Behaviour in semi-domesticated reindeer during submaintenance feed intake and subsequent feeding. (Manuscript).

V. Wiklund, E., Nilsson, A., & Åhman, B. 2000. Sensory meat quality, ultimate pH values, blood metabolites and carcass parameters in reindeer (*Rangifer tarandus tarandus* L.) fed various diets. *Rangifer* 20(1): 9-16.

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List of abbreviations

ABSE	Automatic Blood Sampling Equipment
ASAT	Aspartate aminotransferase
BW	Body weight
C	Control group
CW	Carcass weight
CP	Crude protein
DM	Dry matter
L	Lichen group
LU	Lichen utilizing (bacteria)
ME	Metabolisable energy
Pellets	Commercial pelleted reindeer feed
PL	Pellets+Lichen group
PS	Pellets+Silage group
SP	Silage+Pellets group
TC	Total culturable Count (bacteria)
VFA	Volatile fatty acids
WSC	Water Soluble Carbohydrates

Introduction

The genus *Rangifer* (reindeer and caribou) belongs to the family *Cervidae* and is classified as a ruminant within the order *Artiodactyla*. The genus includes only one species, *R. tarandus*, but several subspecies which all live in the Northern Hemisphere (50°-82 °N). Today, all reindeer in Sweden are semi-domesticated and kept in an extensive pastoral reindeer husbandry system. The focal resource in reindeer husbandry is the natural pastures, which are grazed by the animals. Sami reindeer husbandry uses grazing land based on immemorial rights. The pasture is not optimal for other domestic herbivores. The reindeer are adapted to seasonal variations in the quantity and quality of the diet, and they can utilize plants like lichen, that have very low nutrient value for other ruminants.

Although well adapted, free ranging populations of reindeer typically undergo large fluctuations in the number of animals (Solberg *et al.*, 2001)**.** Unfavourable weather conditions and predation, in combination with a high grazing pressure when animal numbers are high, may reduce the population dramatically within a few years (Helle, 1982). It then takes many years for the population to recover. In reindeer husbandry, there is an ambition to avoid large reductions in animal numbers due to difficult weather conditions, for both animal welfare and economic reasons.

Nutrient intake is generally low during the winter for reindeer and they are often in rather poor condition by the end of winter. The limited feed availability becomes critical when the ground vegetation is unavailable due to deep snow or the formation of ice crust. The effect of snow and ice, for the reindeer, will be an even more limited feed intake resulting in inadequate nutrition, ranging from semi-starvation to complete starvation. Even a short period of complete feed deprivation is hazardous for a ruminant and it is necessary to provide alternative feed without delay if pasture is unavailable. Feedstuffs for these situations must therefore be available at short notice.

The traditional emergency feed is the arboreal lichens, growing on trees (e.g. *Bryoria* spp. and *Alectoria* spp.). Nowadays, these lichens are not available in sufficient amounts due to modern forest management (*e.g.* Mattson, 1981). As an alternative, ground lichens (mainly *Cladina* spp.) collected beforehand could be fed to the reindeer. However, these are difficult to obtain in amounts large enough to feed whole herds for longer periods. Instead, artificial feeds have to be used during critical periods. The extent of emergency feeding necessary varies between years and this kind of feeding is relatively common certain years. For example, in 1998 emergency feeding was applied by 40% of the Swedish reindeer herding enterprises (Statistics Sweden, 1999). However, the feed-stuffs that are available in these situations often cause dietary problems (Staaland & Sletten, 1991; Josefesen, 1997) and may even result in deaths among the animals. Thus, there is an obvious need for better feeding strategies for these situations.

Natural winter diet of the reindeer

A common winter diet for reindeer is composed of lichens (mostly *Cladina* spp.), mixed with shrubs (e.g. *Empetrum* spp., *Vaccinium* spp.), grasses (e.g. *Deschampsia flexuosa*) and sedges (*Carex* spp.) (Gaare & Skogland, 1975; Boertje, 1984; Mathiesen *et al*., 2000). The amount of lichen in the diet may vary substantially, but under relatively good winter pasture conditions, lichens are considered to form 50-80% of the diet (Kumpula, 2000). Since lichens have a low content of nitrogen and minerals (Staaland & Sæbø, 1993), the reindeer need a mixed winter diet to obtain a well-balanced intake of nutrients. Reindeer are, however, not dependent on lichens if there is other suitable food available. During the summer, the diet of reindeer is dominated by graminoides, leaves and herbs (Gaare & Skogland, 1975; Boertje, 1984) and there are also populations of reindeer that forage mainly on graminoides throughout the year (Leader-Williams, 1988).

Lichens appear to be suitable as feed for reindeer in most situations. Lichens are energy-rich, highly palatable and easily digested by the reindeer (Nieminen & Heiskari, 1989; Holleman & Luick, 1977; Danell *et al*., 1994; Jacobsen & Skjenneberg, 1975). The lichen is a symbiosis of fungi and algae, with a unique structure and a chemical composition which differs considerably from those of vascular plants. The *in vitro* digestibility of different species of lichens varies between species and genera (Storeheier *et al*., 2002). *Cladina* spp. and *Cetraria* spp., which are commonly eaten by reindeer, contain only 1-2% water soluble carbohydrates (WSC) of dry matter (DM) and less than 3% crude protein (CP) (Svihus & Holand, 2000; Storeheier *et al*., 2002). The fibre fraction contains only small amounts of cellulose and lignin, whereas the hemicellulose fraction in *Cladina* spp. is 70% of DM or more (Storeheier *et al*., 2002). Lichens contain specific carbohydrates such as lichenin and isolichenin (Llano, 1956) with structures similar to cellulose and starch, respectively, but with specific glucosidic bindings (Culberson, 1969). The utilization of lichens requires a special adaptation of the rumen ecology; reindeer digest around 75% of the organic matter in lichen (Nordfeldt, *et al*., 1961; Jacobsen & Skjennberg, 1975, Wallsten, 2003) whereas only a minor fraction is digested in the rumen fluid of sheep or cows (Presthegge, 1954; Garmo, 1986; A. Nilsson & M. Murphy, unpublished results).

One consequence of the adaptation by reindeer to feeding on lichens is that the insufficient intake of nitrogen must involve a more effective recycling of urea (Hove & Jacobsen, 1975). Reindeer are one of the ruminant species that are able to minimize nitrogen losses by decreasing the glomerular filtration rate in the kidneys (Valtonen, 1979). Urea nitrogen may then be transported via blood to the rumen where it is used by the microbes. This mechanism seems to be unaffected by the plasma urea concentration, but is more likely regulated by the nitrogen intake (Valtonen, 1979). High concentrations of urea in blood plasma can thus arise both as an effect of a high dietary protein intake as well as from muscle degradation when the energy intake is low.

Feed-stuffs and feeding

Environment and handling

In an emergency feeding situation the whole herd has to be fed. This means that groups of up to 500 animals can be maintained in the same pen. The pen size should be adjusted to the current recommendations, with a maximum of 100 animals per ha (Staaland & Sletten, 1991; Åhman, 2002). The social structure of the reindeer herd is a dominance ranked hierarchy, with young animals tending to become subordinate in a feeding situation with the limited space in the pen. Subdominant animals may be prevented from eating by more dominant ones, if there is not enough feed or not enough space at the feeding area. The reindeer herding practice usually involves little handling of individual animals, and the close contact with humans may therefore be stressful for the animals.

Varying access to feed has been reported to influence the behaviour of reindeer (Kosmo *et al*., 1978). A group of reindeer fed restricted amounts of feed rested more and had a higher rate of aggressive behaviour than another group of reindeer that were provided *ad libitum* with feed. The social structure within the herd seemed to be an important reason for some animals to refuse eating, and may contribute to the emaciation and death (Kosmo *et al*., 1978).

Feeds

Hay and grass silage are frequently used as supplementary feed for reindeer on pasture or for feeding during the moving and gathering of the reindeer herd (Staaland & Sletten, 1991; Statistics Sweden, 1999). The silage preserved in Northern Sweden, with the main purpose of being fed to cows or sheep, generally contains 9-11 MJ metabolisable energy (ME), 11-16% CP and 5-7% WSC (Spörndly, 1999). However, the quality varies substantially, due to factors like plant species and the phenological state of the grass, climatic conditions during growth and preservation method (*e.g.* Pauly, 1999). The varying quality of silage is reflected in the inconsistent results obtained from various feeding trials. Reindeer fed a third cut silage consumed half as much DM per kg body mass compared to sheep (Syrjälä-Qvist, 1982), although the *in vivo* apparent DM digestibility was the same for reindeer and sheep (69 and 71%, respectively). In other experiments (Aagnes & Mathiesen, 1995; Aagnes, *et al*, 1996; Moen *et al*., 1998), the DM intake of grass silage by reindeer calves has varied from 0.5 to 1.1 kg per day, while the *in vivo* apparent DM digestibility ranged from 62 to 87%.

The commercial reindeer feeds that are commonly available in practice in Sweden are fairly similar in nutrient composition and ingredients and also similar to the feeds manufactured in Norway and Finland (Staaland & Sletten, 1991; Åhman, 2002). These feeds are often described as supplementary concentrates, although intended for whole feeding. The main ingredients are grains (oat, wheat, barley and their bran products), dried sugar-beet pulp and soybean meal, with additional vitamins and minerals. The nutrient content, based on DM, is 9-14% CP, 8-15% crude fibre and around 11-13 MJ ME per kg (Staaland & Sletten, 1991). Nowadays, these feeds are always pelleted and the general term *pellets* has been used for commercial feeds in this thesis.

Water

Water availability is essential for reindeer and may significantly influence the outcome of the feeding. Snow is often used as the only water source. Water may also be provided by a running stream passing through the corral or by warmed water in cribs or buckets. The water requirement of the reindeer is dependent on DM and nutrient intake, ambient temperature and the digestibility of the rations (Valtonen, 1979). Adult female reindeer eating pellets have been reported to drink 3.2-3.5 l of water per day, while reindeer fed lichens drank only 0.1 l per day (Soppela *et al*., 1988). Artificial feeds, such as grass silage and pellets, generally have a higher protein and mineral content than the natural winter diet (Staaland & Sletten, 1991). Due to the limited capacity of reindeer to concentrate urine (Valtonen & Eriksson, 1977) excess of these nutrients may cause the reindeer to require more water to excrete the excess of nitrogen or mineral load. Reindeer fed a high protein diet have been reported to drink twice as much as those on a low protein diet (Valtonen, 1979). However, increased water intake in the form of snow or ice may result in an increased cost in the form of thermal energy for the reindeer (Soppela *et al*., 1992).

Utilization of diet

The classification of reindeer according to the ruminant type was thoroughly discussed by Mathiesen (1999). After considering his own investigations and works by *e.g*. Hofmann & Stewart (1972), Hofmann (1989) and Gordon and Illius (1994), Mathiesen concluded that semi-domesticated (Norwegian) reindeer, *Rangifer tarandus tarandus*, are mixed feeders, and should be classified as an intermediate feeding type, with a large flexibility in the gastro-intestinal system. Reindeer utilize fibrous grasses poorly (*e.g.* Aagnes *et al*., 1996) and select a variety of more digestible plant species when grazing on natural pasture (Coté, 1998). The retention time of forage in the rumen could be an important factor in feed utilisation. The turnover time in the reindeer rumen has been reported to be related to food intake and to change on seasonal basis (White *et al*., 1984). Aagnes & Mathiesen (1994) reported rumen fluid turnover time to range between 23 and 69 hours in reindeer eating lichens, while reindeer on summer pasture had a turnover time at 10 hours according to White & Trudell (1980).

The rumen contains a complex system of microorganisms living in symbiosis with the host (*e.g*. Hungate, 1966) and the rumen ecology and status are affected by changes in forage quality and quantity. Seasonal differences in the number of viable bacteria have been found in several investigations (Hobson *et al*., 1975; Orpin *et al*., 1985; Syrjälä *et al*., 1973; Cheng *et al*., 1993), while others found no such differences (Olsen *et al*., 1997). Strains of *Prevotella*, *Fibrobacter*, *Streptococcus* and *Clostridium* dominated in the rumen fluid of free-living reindeer in winter (Aagnes *et al*., 1995). The number and composition of protozoa are affected by diet and nutrient intake (Westerling, 1970; Syrjälä-Qvist *et al*., 1973). The role of protozoa in the reindeer rumen is, however, still unclear (Mathiesen, 1999), but protozoa could be expected to be better as an amino acid source to the host than bacteria (Olsen, 2000).

In ruminants, the major part of the carbohydrates are decomposed by the microorganisms in the rumen to volatile fatty acids (VFA), mainly acetic, propionic and butyric acids, together with small amounts of valeric, iso-butyric and iso-valeric acids. These acids are absorbed across the rumen wall and used as an energy sources for the animal. Butyric acid stimulates papillae development (Sakata & Tamate, 1979) and high levels of VFA in the rumen of reindeer results in larger papillae and an increased absorptive surface area (Josefsen *et al*., 1996; Soveri, 1995). Butyrate is primarily converted to β-hydroxybutyrate, and transported via blood to the liver. Propionate is important for the gluconeogenesis, which provides the main source of blood glucose. Rumen pH and VFA are important indicators of rumen activity and depend on diet quality and quantity, which influence the rate of salivary secretion, the rate of VFA production and the VFA absorption across the rumen wall (Church, 1983). The regulation of rumen pH is important for efficient microbial fermentation and the rate of VFA absorption is highly dependent on the rumen pH.

Besides the rumen status, blood metabolites can be used to evaluate the nutritional status of reindeer (Soveri, 1995). Insulin is a key hormone in the regulation of glucose homeostasis, food intake and nutrient storage and partitioning (Rhind *et al*., 2002). Variations in protein intake and utilization are reflected in the blood concentrations of the plasma protein and urea. A considerable amount of ammonia may be absorbed from the rumen into the portal blood, transformed into urea by the liver and then excreted or recycled via the saliva or the rumen wall. Some results on measurements on rumen content and blood metabolites from reindeer on moderate winter pasture are presented in Table 1.

Table 1. *Rumen and blood composition in reindeer during winter*

	Free-ranging reindeer
Rumen	
pH[1]	6.5
VFA(mmol l^{-1})[1]	79
Acetate/Propionate/Butyrate ratios[1]	72:18:11
Viable bacteria (ml^{-1})[1]	$25x10^8$
Protozoa (ml^{-1})[2]	$2x10^3$
Blood plasma	
Total protein (g l^{-1})[4]	73
Urea (mmol l^{-1})[4]	6
Glucose (mmol l^{-1})[4]	4

[1]Data from Aagnes *et al*., 1995

[2]Data from Westerling, 1970

[4]Data from Nieminen, 1980

Starvation and malnutrition

Reindeer respond to acute starvation similarly to most domestic ruminants (Church, 1984). The rumen pH increases while DM and concentration of total VFA decrease and the composition of individual acids changes (Sletten & Hove, 1990; Aagnes & Mathiesen, 1994). The bacterial population can be reduced by more than 90%, with considerably changed composition, after 3 to 4 days of starvation (Mathiesen *et al*., 1984; Aagnes *et al*., 1995). The protozoa population of the reindeer rumen is generally reduced following a period of insufficient nutrient intake (Westerling, 1970; Syrjälä *et al*., 1973; Mathiesen *et al*., 1984).

Most blood characteristics of the free ranging reindeer show a seasonal variation (*e.g*. Nieminen, 1980; Nieminen & Timisjärvi, 1983). Blood glucose concentration in reindeer is rather high compared to other ruminants (Nieminen, 1980), but may decline as an effect of decreased energy intake (Larsen *et al*., 1985b; Soveri *et al*., 1992). The concentration of plasma protein and urea in reindeer blood increases with the increased protein intake when energy supply is sufficient (Valtonen, 1979), but may also increase during low protein intake as an effect of increased urea recycling (Hove & Jacobsen, 1975; Säkkinen *et al*., 2001). The concentration of plasma insulin has been shown to decrease in reindeer given restricted feed ratios (Larsen *et al*., 1985b) and insulin may play an important role in the regulation of fat mobilization (Larsen *et al*., 1985a; Stimmelmayr, 2002).

Transition to pellets or silage feeding

The transition to a new diet needs to be cautious, especially after starvation when the body condition of the reindeer is deteriorated, and the ability to utilize the diet is crucial to avoiding further energy losses (*e.g*. Kosmo *et al*., 1978). The less the difference in properties between the old diet and the new feed, the better is the chance of a safe adaptation (Skjenneberg & Slagsvold, 1968; Jacobsen & Skjenneberg, 1975; Sletten & Hove, 1990). An emergency practice recommended for starving reindeer by Soveri (1995) is to start with small amounts of lichens and allow several weeks for the liver and rumen ecology to adapt to larger amounts of lichen and other foods. As lichen may not be available in sufficient quantities, other feed-stuffs usually have to be a major part of the diet in a feeding situation. However, even small amounts of lichen mixed into pellets or silage may increase the palatability of the feed, thereby assuring that the reindeer start eating (Nilsson *et al*, 1996c).

When feeds with different physical and structural properties are mixed and given to groups of animals, it is not possible to control the individual intake of specific feed stuffs. Some individuals may prefer a single feed component and overeating may also occur (Staaland & Sletten, 1991; Nilsson, 1994). A high intake of pellets, which are rich in WSC and starch, during the initial phase of feeding may reduce the rumen pH and favour the growth of lactic acid bacteria, contributing to rumen acidosis and diarrhoea (Nordkvist, 1973; Bøe *et al*., 1982; Sletten & Hove, 1990; Josefsen, 1997). There is a risk of the loss of fluids and electrolytes that can be debilitating for the animal if the diarrhoea becomes severe.

High-quality, leaf-rich timothy silage has been recommended as emergency feed for reindeer (Utsi, 1998; Norberg & Mathiesen, 1998) and has not been reported to cause acidosis even when the WSC content was as high as 30% (Olsen & Mathiesen, 1998). Fibrous silage, on the other hand, seems to have a long retention time in the rumen and can cause a large increase in the reticulo-rumen content (Olsen, *et al*., 1995; Aagnes & Mathiesen, 1996; Utsi, 1988). Failure of reindeer to digest fibrous silage has also been reported (Olsen *et al*., 1995) and reindeer show limitations in their utilization of roughage, particularly due to poor cellulolysis (Olsen, 2000). Starvation (Olsen *et al*., 1998), prolonged feeding of lichens (Olsen & Mathiesen, 1998) or feeding of timothy silage (Olsen *et al*., 1997; Olsen & Mathiesen, 1998) are factors suggested to negatively affect the number of cellulolytic bacteria in reindeer.

Effect of prolonged feeding on health and energy stores

The first two weeks is usually the most critical phase when feeding reindeer (Kosmo *et al*., 1978; Bøe *et al*., 1982; Staaland & Sletten, 1991). Another critical period, when digestive disorders may occur, sometimes arises after three to five weeks of feeding (Kosmo *et al*., 1978; Nilsson *et al*., 1996a, b). Unsuitable feeds, such as low quality roughage diets, can cause a gradual weight loss, leading to emaciation and even death (Syrjälä-Qvist, 1985; Nilsson, 1994; Aagnes & Mathiesen, 1995). Signs of inert behaviour and mobbing have been observed after three weeks of feeding with only silage (Nilsson *et al*., 1996a). Low-ranked reindeer were not allowed by the others to eat during the initial part of feeding, and this was probably the cause of a late outbreak of diarrhoea in the low ranked animals (Kosmo *et al*., 1978).

"Wet belly" (or "wet abdomen"), when the animal becomes wet over the lower parts of the thorax and abdomen, is a disorder known to occur occasionally in reindeer during feeding. It has been described from feeding experiments with feed mixtures based on grains and hay- or straw-meal (Persson, 1967; Jacobsen & Skjenneberg, 1979) and from experiments when reindeer were fed mainly grass silage (Nilsson, 1994). Severely affected animals were reported to eat restlessly and lie curled up to a greater extent than healthy animals (Nilsson, 1994).

The purpose of emergency feeding is to prevent starvation and suffering and also, if possible, to improve the fitness of the reindeer when they are let out on pasture again. Improved energy stores, seen in more muscles and fat depots, are especially important for the pregnant females, as their winter condition will effect calf survival and the growth rate of the calves, as discussed by Rönnegård (2003). Feeding pregnant female reindeer pellets from January to May has proved to significantly increase both their body weight and weight of the calf compared to free-grazing and lichen-fed reindeer (Säkkinen *et al*., 1999). On the other hand, reindeer calves fed 80% pellets and 20% silage for 10 weeks gained only little in body weight (Nilsson *et al*., 1996c). However, fat deposits had increased, carcass grading scores were higher and ultimate pH in meat (*M. longissimus dorsi)* was lower for the fed reindeer than for reindeer that had not been fed, indicating that the energy stores had been improved by feeding.

Design of experiments to study adaptation of reindeer

The adaptation of reindeer to feeding has been measured in several experiments, ranging from intense studies of 2-4 animals kept indoors (Eriksson & Schmekel, 1962; Olsen *et al*., 1995) to the feeding of large herds over longer periods of time (Persson, 1966, 1967). Detailed physiological studies usually require specific procedures or environments and it may, therefore, be difficult to study many different traits within the same experiment. Studying few animals may also increase the risk of a large sampling effect. Studies on a larger group of animals may reduce the individual control of the animals. Holistic syntheses are therefore often based on several experiments made under different conditions, which may make general conclusions ambiguous.

When studying the adaptation to feeding the comparison with a well-defined control group is crucial. One strategy is to make a pre-experimental sampling, using animals from the same group as those used in the experiment (*e.g*. Aagnes, *et al*., 1995). This gives valuable information about the effects of diet and the background of the animals. Another strategy, is to use a control group, which is fed a natural diet (usually lichens), and kept in the same way as the experimental animals (Aagnes *et al*., 1995; Säkkinen *et al*., 2001). This, however, may only partly resemble a natural situation on pasture.

Except for obvious sickness, the wellbeing of animals and the effects of stress are difficult to define and quantify, although many have tried (*e.g*. Seyle, 1973; Broom, 1996). Measurable and often supposed to be objective indicators, like blood plasma concentrations of cortisol and aspartate aminotransferase (ASAT) and even urea and glucose, have been proposed and used as indicators of stress in reindeer (Hyvärinen *et al*., 1976; Rehbinder & Edqvist, 1981). Abomasal lesions in slaughtered reindeer have been revealed as a sign of prolonged stress (Rehbinder *et al*., 1982; Rehbinder, 1990). The use of blood values is complicated by the effect of the sampling procedure itself and *e.g*. increased cortisol concentrations may be due to the physical restraint connected to sampling (Sire *et al*., 1995). The behaviour of the animals is an alternative indicator that can be used without handling or disturbing the animals (Kosmo *et al*., 1978) and may therefore be a valuable trait in combination with other measurements and registrations.

Aims of the thesis

The aim of this thesis was to compare different feeding strategies based on commonly available feed-stuffs used in emergency situations. The reindeer were kept under conditions close to those found under practical conditions in order to continuously follow their adaptation by observing their behaviour and collect physiological data. During the course of the first experiment, the syndrome wet belly was observed. The aim of the second experiment was to clarify causes behind this disease.

Specific questions to investigate were:

- How will insufficient availability of a lichen-based diet affect the general condition of the animals?
- How will the adaptation to various feeding strategies differ from a return to free access to lichens?
- As reindeer are adapted to eating lichens, can rumen bacteria specialized for lichen utilization be detected?
- Is it possible to minimize disorders during transition to feeding of certain emergency diets?
- Can behaviour be used as an early indicator of dietary disturbances?
- How will prolonged feeding after the emergency phase affect the body condition of the recovering animals?

Methods and experimental design

The intention of the experiments conducted was to mimic a practical feeding situation as much as was possible (Fig. 1). To detect how the adaptation affected the whole animal, a wide range of sampling procedures were performed. In studies, prior to the main experiment, techniques to be used in this study were tested and developed.

The design and practical handling at group feeding and for sampling at slaughter was based on experiences from previous feeding experiments with reindeer intended for slaughter (Nilsson *et al*., 1996a, b, c). An automatic blood sampling equipment (ABSE) was compared with conventional blood sampling via vein puncture (Wiklund *et. al*. 1994; Nilsson *et al*., 1996d). ABSE proved well suited to gathering undisturbed samples without restraint, but the installing of the equipment was rather complicated and had disadvantages in cold temperatures (Nilsson *et al*., 1996d). Therefore, conventional blood sampling performed in a strictly standardised manner was chosen for these experiments.

Rumen sampling by a sond tube on live animals was tested and compared with samples from the same slaughtered animals (A. Nilsson & M. Murphy, unpublished results). The sonding technique was rather complicated and the samples were not representative of the entire rumen content. Sampling at slaughter was therefore chosen, as it also allowed more animals to be sampled. Rumen samples need to be stored under anaerobic conditions and processed immediately. Since a large number of various samples were collected at slaughter some waiting time was unavoidable before processing the samples. However, the same standardised performance of processing at all slaughter occasions allowed comparisons within the study.

Pilot studies of the behaviour of reindeer were performed to develop an ethogram of suitable behaviour categories.

Animals and experimental design

The animal experiments were conducted at the research station of the Department of Biology, University of Oulu, Finland (latitude 65°N, 25°E). The main experiment included 72 semi-domesticated eight-month-old female reindeer (*Rangifer tarandus tarandus*) calves, originating from the southern part of the Finnish reindeer herding area. This experiment was carried out during the winter of 1996/97 and is the base for all papers **(I-V)**. A follow-up study was carried out in the winter of 1997/98 and included 20 animals (**III**). The animals had not been enclosed or artificially fed prior to the experiment and had not been included in any other experiments.

Reindeer from three different deliveries were equally but randomly allotted from each delivery into five experimental groups and kept in pens of about 500 m^2 each. The main experiment included three periods: the pre-experimental period, the restriction period, and the feeding period (Fig. 1).

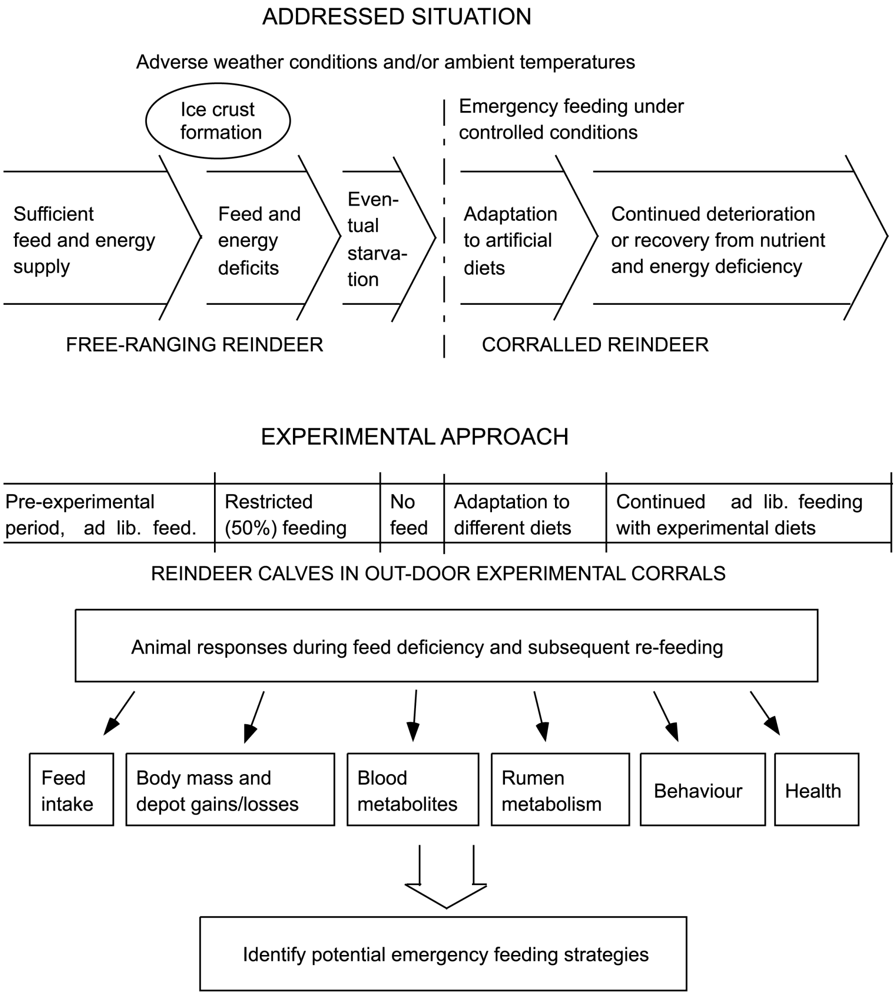

Figure 1. Illustration of the main components of the experimental scheme. The upper part of the figure describes the situation before and during an emergency feeding situation, while the lower part describes how the experimental approach was designed to mimic the practical situation and how the adaptation was measured.

During the pre-experimental period, all reindeer were offered a lichen based diet *ad libitum*, consisting of 80% lichens, *Cladina* spp. and 20% of a mix of bilberry shrubs, *Vaccinium myrtillus,* and *Salix* spp. leaves (on DM basis). The lichens were stored dry and then soaked prior to feeding and thus contained 70-80% water. The animals had free access to warmed water. During the pre-experimental period, the animals were adapted to the experimental environment and feeding methods. The animals were also accustomed to the experimental handling *e.g.* weighing, blood sampling and behavioural studies. After the pre-experimental period, the live weight (LW) development differed between animals from different deliveries and was therefore taken into account in the statistical model.

A control group (group C) was offered the lichen-based diet *ad libitum* throughout the experiment. During the restriction period the other four groups were given 50% of the *ad libitum* ration for eight days, followed by one day of total feed deprivation.

The feeding period was then focused on three possible options that occur in practice. The first option is that the emergency situation is solved by changed weather or that the animals are moved to new pasture. The second situation is when the reindeer herder has access to collected forage (lichen) and gives it as a supplement with pellets. The third option is that natural feed is not available at all, and feeding with readily available silage and pellets is started. Group L, that was re-fed the lichen diet *ad libitum*, illustrated the first option. The second situation was represented by group PL, that was fed a diet of 80% (DM basis) commercial pelleted reindeer feed (pellets) combined with 20% lichen. Two groups were fed combined diets based on pellets and silage to mimic the third option. One of them, group PS, was fed a diet of 80% (DM basis) commercial reindeer feed (pellets) combined with 20% silage. The final group, SP, was fed silage *ad libitum* for five days and thereafter adapted gradually to a diet of 80% pellets and 20% silage.

On three occasions, animals were randomly selected and slaughtered during the experiment. Eight animals were slaughtered at the end of the pre-experimental period (day 0 of the experiment). Six restrictively fed reindeer and five control animals were slaughtered after the restriction period (day 10). Finally, five reindeer from each group were slaughtered after the feeding period (days 43 an 44). A detailed overview of the design in the main experiment is shown in Fig 1 in paper **I**, where SP should replace the group name SL.

Experimental procedures

Since a wide range of samples were to be taken, the degree of disturbance on the animal and other sampling methods needed to be considered. All samplings were performed in a standardised way and at given times. The animals were fed twice a day and the feed stuffs were mixed in the cribs. Feed composition, daily routines and feeding procedure are described in paper **I**. Once a week (Monday), all animals were taken out of their pens and driven into a sampling room where health checks and LW was measured (**I**). On five allotted sampling animals per group, body temperature was measured and blood samples were collected with the animal restrained in a sampling crush (**I**, **III**). Additional sampling occasions during the restriction period and in connection to slaughter are described in papers **I** and **III**, together with the plasma analysis methods. An additional visit to the sampling room every week (Friday) for all animals was done to check a heart rate measuring device (placed on three animals per group) that was adapted during the experiment and correlated to some behavioural categories (**I**; Eloranta *et al*., 2002). To avoid disturbances from other samplings, the behaviour studies were conducted on sampling free days (usually Tuesday, Wednesday, Thursday) with additional observation sessions during the restriction period as described in paper **IV.**

The handling and sampling routines were similar on all slaughter occasions, as described in **I, II** and **V**. Samples for studies of rumen content were collected on the slaughter occasions and stored cool or frozen before processing and the methods of analysis for VFA and pH are described in paper **II**. The media for total viable count was based on previously collected reindeer rumen fluid, and the media for growth of LU-bacteria also contained milled lichen that was ball-milled as for cellulose (**II**). Measurements of pH in the muscles were conducted according to paper **V**.

Results

Animal behaviour and health (I, III, IV and V)

General performance

All animals appeared healthy during the pre-experimental period and no problems were observed adapting the reindeer to feeding, handling or sampling. All animals in the control group remained healthy throughout the study. For all groups, the dominant activities were lying, eating, ruminating and standing, throughout the experiment. Few recordings of agonistic behaviour or snow intake were made.

The eating behaviour of the reindeer changed as the restrictedly fed animals ate the coarse parts of the lichens and the shrubs that were rejected when the diet was offered *ad libitum*. Restricted feed intake also affected reindeer behaviour, with more animals standing and fewer lying compared to the control group. An indication of the prolonged effect of the insufficient energy intake was observed in that the previously feed restricted animals were lying curled up to a greater extent compared to the control group during the initial phase of the feeding period.

Diarrhoea occurred in groups PL and PS during the initial phase of the feeding period. All animals recovered, but the four worst affected animals had to be treated with antibiotics. During the last three weeks of feeding, the health was stable for the remaining animals in all groups. As the feeding regimen was prolonged, the behaviour tended to be alike between all groups. Group PL had, however, less observations of intake of feed or water and ruminating than groups C and L.

Symptoms of wet belly and excluded animals

Seven feed restricted animals showed the first signs of the disorder wet belly during the restriction period. During the feeding period, four more animals were affected. The characteristics of severely affected animals were that they had wet fur over the lower parts of the thorax and abdomen and were either observed to be restlessly eating, which resulted in increased body weight (due to increased rumen content) or seemed apathetic. The fluid making the fur wet was proven to be of internal origin and the animals had low body temperature. No statistically significant differences were found between healthy and wet belly affected reindeer as regards to blood constituents, although high concentrations of plasma urea were observed among individual wet belly-reindeer. The results from autopsies and the rumen content of the animals with wet belly revealed that the animals were emaciated and showed signs of infections and stress. In the second experiment all animals remained healthy and none of the reindeer showed any signs of wet belly.

During the restriction period, two animals got wounds (one on the mouth and one on the leg) that became infected and needed treatment (antibiotics), and were excluded from the experiment and moved to another pen. The data from those animals were excluded from all analyses except the behaviour studies from before the exclusion period. Six animals were excluded (died or were euthanised) during the feeding period, five from the group SP (malnutrition) and one from group PS (injured eye).

Effects of handling

All reindeer were affected by the restraint and sampling, as indicated by increased concentrations in blood plasma cortisol levels. After last slaughter, the levels of ASAT and cortisol were generally higher in groups PL and PS than in the control group. Only a few signs of minor abomasal lesions were found.

Nutrient intake and utilization (I, II, III and V)

The control group

The average feed intake of the control group was stable at around 1.3 kg DM, giving 13 MJ ME and 64 g CP, per animal and day. The animals drank, on average, 0.3 litres of water per animal. The control group had stable average blood plasma concentrations of 61 g l^{-1} protein, 3 $mmol^{-1}$ urea, 5 $mmol^{-1}$ glucose, and 5 $\mu U\ ml^{-1}$ insulin throughout the experiment. The control group had stable average amount of rumen content, 16% of body weight (BW), pH at 6.21 and total volatile fatty acids (VFA) concentrations of 113 mmol l^{-1} throughout the experiment. The counts of bacteria and protozoa varied over time in group C. The number of total culturable bacteria (TC) decreased and ended up at 28 x 10^8 counts g^{-1} rumen content, while the number of lichen utilizing (LU) bacteria and protozoa decreased to 86 x 10^7 and 103 x 10^3 counts g^{-1} rumen content respectively, over time on the lichen diet.

Effects of feed restriction

The restricted feeding affected some of the blood plasma metabolites with significantly increased concentrations of urea and decreased concentrations of glucose. The rumen content of restrictively fed animals weighed less, had a higher pH, lower DM contents and VFA concentrations, and lower counts of bacteria and protozoa.

Effects of feeding

Group L responded immediately to the return to the *ad libitum* lichen diet, with blood metabolite levels approaching those of group C after one week. Plasma urea concentrations continued to increase in groups PL and PS during the first week of feeding. They declined thereafter and stabilised at a level that was significantly higher than for groups C and L. Plasma protein and insulin concentrations increased gradually in groups PL and PS from the start of the feeding period and were significantly higher than in group C after one to three weeks of feeding. The recovering animals in group SP followed the same pattern as the animals in group PS and PL. After the feeding period, group L showed no alteration in rumen activity compared to group C, whereas groups PL, PS and SP had reduced rumen content, with higher DM and VFA concentrations and higher protozoa counts, compared to group C and L. The composition of bacteria groups was different between the diets. The detected LU bacteria were drastically reduced in number when the diet lacked lichens, in groups PS and SP. These bacteria could thus be classified as a substrate specific group.

The feed intake for groups PS and PL during the last three weeks of the feeding period was 1.8 kg DM per animal and day, giving 18 MJ ME and 231 g CP (group PS) and 174 g CP (group PL). The remaining animals in group SP consumed similar amounts of feed as those in group PS. The average daily drinking-water intake was 1.2 litres per animal for group PL and 2.5 litres for group PS. The remaining animals in group SP drank about 1.5 litres per animal and day. However, the total water intake of groups C and L was significantly higher, as the lichens were soaked in water prior to feeding.

Carcass composition and energy stores (I and V)

The mean carcass weight was 20.2 kg and the mean dressing percentage was 45% for the animals slaughtered at day 0. The BWs at day 1 ranged between 41-44 kg and the mean weight of the groups did not differ significantly. During the restricted feeding the reindeer lost, on average, 1.6 kg BW while reindeer in group C, that were fed *ad libitum*, gained on average 0.2 kg BW. However, all animals lost calculated rumen-free BW after the restriction period. During the feeding period groups C and L lost weight, on average 1 kg carcass weight (CW). Groups PL, PS and the remaining animals in group SP increased BW, CW, and accordingly the dressing percentage, as well as gained fat in the abdominal cavity.

At the last slaughter, group C had significantly lower pH values in *M. triceps brachii* and *M. longissimus* than group PL, while in *M. biceps femoris* there was no difference in pH between the groups. There were no significant differences in ultimate pH values between the three muscles in groups PL and PS.

No abnormalities of the carcasses were observed from any animals at the slaughter occasions. Internal organs were weighed and no significant differences were found between any treatments (A. Nilsson, unpublished results). The average weights per kg CW were; kidneys, 4.9 g, liver, 27.2 g, lungs, 27.9 g and heart 19.8 g.

General discussion

Response to insufficient intake of lichen-based diets

The general condition of the animals and diet composition are key factors for the success of emergency feeding (Soveri, 1995; Josefesen, 1997; Utsi, 1998; **I**, **III**). The specific effects of diet are often confounded by environmental factors and handling procedures (Kosmo *et al*., 1978; Staaland & Sletten, 1991). The difficulty in distinguishing the main effects, such as diet composition, from other effects has contributed to the difficulty in assessing the strategies for emergency feeding. In this thesis, specific efforts were made to minimize variation from effects other than diet and focus on evaluating the response to different diets. A comprehensive experiment with standardised handling and sampling routines gave the same experimental conditions for all animals. Judging from the metabolism and behaviour of the control group (**I**, **II**, **IV**), environment and handling was considered to be fairly constant throughout the experiment.

The pre-experimental period was designed to accustom the animals to the experimental situation, to allow rumen adaptation to the same lichen diet and to equalise the general condition of the animals. However, the body weights at the start of the experiment varied between groups of animals delivered on different occasions (**I**), confirming that the body weight of the reindeer is determined not only by the last period of feed supply but by the grazing conditions during the whole season (Moxnes *et al*., 2001). For the free-ranging foraging animal innumerable choices must be made regarding when to feed, what to feed on and where to feed. These choices are coupled to varying risk assessments from, for example, thermal stress, secondary plant metabolites, predation and starvation (Belovsky, *et al*. 1999). Reallocating such animals from a particular environment to an artificial environment must impose stress on the animal. In the present, as in earlier, experiments animals from different environments were combined (**I**, Nilsson, 1994) which might have increased the variation in the responses. However, in the present experiment animals from the different deliveries were equally distributed to the experimental groups and, at the start of the experiment, all groups had similar mean body weight and concentrations of blood metabolites (**I**). The nutritional status was representative of free-living reindeer on moderate natural winter forage, judging from the concentration of blood metabolites and the properties of the rumen content (Nieminen, 1980; Nieminen & Timisjärvi, 1983; Soveri *et al*., 1992; Olsen *et al*., 1997; **II**).

To test emergency feeding strategies, the reindeer need to be in a nutritional status comparable to the poor body condition typical of an emergency situation. Reindeer have developed special adaptations to survive under harsh conditions with insufficient food supply (*e.g*. Hove & Jacobsen, 1975; Valtonen 1979; Soveri, 1995), but no special adaptations to cope with total feed deprivation have been found (Utsi, 1998). In the present experiment, a winter situation with insufficient feed supply followed by a locked pasture was mimicked during the restriction period (**I**). According to the results, this strategy negatively affected the general condition of the animals (**I**, **II**, **IV**). Weight losses were found together with increased urea and decreased glucose concentrations in blood plasma (**I**, **II**), that were in accordance to reindeer on poor pasture or given insufficient amounts of nutrients (Soveri *et al*., 1992; Valtonen, 1979; Hyvärinen *et al* 1975; Säkkinen *et al*., 1999). The insufficient intake of feed was also reflected in behaviour, as the animals ate components of the feed ration that were otherwise refused (**I**) and spent more time walking around, seemingly seeking for feed, and less time ruminating than the control group (**IV**). The first signs of wet belly, which were observed during the restriction period in the first experiment, and have been connected to malnutrition (Jacobsen & Skjenneberg, 1979; **III**), confirmed that the nutritional status of the feed restricted animals was poor. The effect of the restricted feed intake on the rumen metabolism was less than for totally starved reindeer for 2-4 days (Mathiesen *et al*., 1984; Aagnes & Mathiesen, 1994; Aagnes *et al*., 1995) and indicated that the rumen metabolism was still in function.

Ad libitum access to lichens

Even though their nutritional status had deteriorated, the reindeer recovered rapidly when returned to receiving *ad libitum* amounts of the lichen diet (**I**, **II**). This was in accordance to what has earlier been observed in reindeer offered a pure lichen diet (Sletten & Hove, 1990). Soveri (1995) suggested that the ruminal papillae could absorb VFA originating from lichens even when the reindeer were exposed to severe undernutrition. The maintained ability to utilize lichens sufficiently, even when the animal is in a poor nutritional state, seems to be an advantageous survival strategy. The group of LU bacteria, found in the present experiment (**II**), may have an essential role in the adaptation to lichen. However, these bacteria have not been identified further and nothing is known regarding their growth requirements, apart from the presence of lichen as such. Identification of the LU-bacteria requires DNA sequencing (*e.g*. Tajima *et al*., 1999) and PCR amplification techniques can be employed to investigate the occurrence of these bacteria in different situations (*e.g*. Muyzer *et al*, 1993). Further investigations of the LU-bacteria would improve the knowledge regarding reindeer rumen ecology and the adaptation to lichens. Other investigated animals seem not to utilize lichens as effectively as reindeer, but sheep, cows, and even pigs, have remained healthy on diets containing lichen (Presthegge, 1954).

Deteriorated condition complicated adaptation to feeding

Mixing pellets with lichens and gradually increasing the feed ration is known and recommended as a feeding strategy to enhance the adaptation to a new diet (Åhman & Åhman, 1980; Staaland & Sletten, 1991; Soveri, 1995; Utsi, 1998). Still, in the present experiment this strategy (applied to group PL) resulted in outbreak of diarrhoea (**I**). It was shown that the rumen ecology was in function, but vulnerable to the shift in diet, as diarrhoea occurred also when the pellets were mixed with silage (group PS). The latter strategy had previously worked when applied to reindeer calves in good condition (Nilsson *et al*., 1996c). In order to establish a rumen environment with adequate amounts of bacteria utilizing starch and WSC, time is required for the growth of strains like *Succinomonas* and

Selenomonas (Dehority & Orpin, 1988). In the present experiment, it cannot be stated if, or at what point, the rumen ecology was stabilised, as rumen samples were only taken before and at the end of the feeding period (**II**). The plasma concentrations of urea and glucose in the pellets-fed groups, however, reached those of the controls within two to three weeks (**I**), indicating that the diet could be sufficiently utilized at this time. It took about three weeks before the previously feed restricted animals showed the same behaviour as the control group. Before this, they displayed a less active behaviour and a preference for lying curled up (**IV**). Less active behaviour can be a way to save energy and has been observed in deer and cattle during cold weather (Gilbert & Bateman, 1983; Redbo *et al*., 1996).

It may not seem strange that the strategy with at first feeding only silage (applied on group SP) was the most problematic. The reindeer were in poor condition and feeding silage has been previously shown to be a risk and the effect is dependant on the quality of the silage (*e.g.* Olsen *et al*. 1995; Aagnes *et al*., 1996). However, even relatively coarse silage has been given to reindeer without causing problems during an initial phase of feeding (Nilsson *et al*., 1996a). Digestive disorders and malnutrition often occur amongst reindeer after several weeks of feeding (Syrjälä-Qvist, 1982; Nilsson *et al*., 1996a). The SP strategy, with a gradual increase in the amount of pellets, should therefore have potential as a good strategy, but the severe health problems in group SP demonstrated otherwise (**I**, **III**). On the other hand, reindeer in the second experiment, adapted without problems to only silage (**III**). As the environment and feeding were alike in the two experiments and the silage quality was fairly similar, this shows the difficulties of comparing results from different experiments. Perhaps the initial body condition of the animals differed between the years due to different grazing situations and the reindeer in the first experiment were more vulnerable. The results also demonstrated the difficulty with using silage for reindeer in practice. The silage used in the experiment was ordered from a local producer, with the information that it would be used for reindeer but with no specification regarding nutritional value. This resembles an unplanned emergency feeding situation, where the quality of the available silage usually is unspecified.

Outbreaks of wet belly have previously been reported in connection to malnutrition (Persson, 1967; Jacobsen & Skjenneberg, 1979; Nilsson, 1994; **III**). The reason for the outbreak could not be explained, but it was probably related to the body condition of the animals. Most results in the present experiment indicated that all restricted groups responded alike, but as group SP had the highest frequency of wet belly already during the restriction period, it could have been an indication that these animals were more affected by the restriction (**I**, **III**). Individual variation in initial body condition can influence the outcome of an experiment (Olsen *et al*., 1995; Nilsson *et al*. 1996b, c). No correlation between the time of delivery and the occurrence of wet belly was found. Some concerns about this special condition, including the internal origin of the fluid and low body temperature, were clarified in this study (**III**). The induction of wet belly seems to be unrelated to any specific diet, but connected to insufficient energy intake, according to the outbreak during the restriction period during the first experiment and all animals being healthy in the second experiment (**III**). Since it was not possible to induce wet belly during the second year a preparedness to sample and study animals affected in practice can be a way to continue to investigate this problem**.** Areas to focus on could be to find the fluid secreting skin glands and analyse the composition of the fluid making the fur wet. Since large individual variations in blood constituents like urea and aldosterone were found, it could be interesting to further investigate them in affected animals (**III**).

Effects of prolonged feeding

Lichens are insufficient for reindeer as the only feed over a longer period, due to the poor protein content (Staaland & Sletten, 1991). Prolonged feeding of the lichen-based diet resulted in declining body weights (**I**, **V**), but not to the same extent as when reindeer have been fed only lichen (Bjarghov *et al*., 1976). This showed that a 20% inclusion of shrubs and leaves was beneficial to the animals, although it did not increase the nitrogen content enough to allow any increase of body weights or fat reserves. Nevertheless, the lichen-based diet kept the animals healthy with stable concentrations of blood plasma metabolites (**I**), to be compared with the elevated concentrations of plasma urea after feeding with only lichens (Bjarghov *et al*., 1976). The levels of the plasma metabolites were within the range of those obtained in free-living reindeer (Soveri *et al*., 1992; Larsen *et al*., 1985a) indicating that the diet mimicked a regular winter diet. However, the rumen ecology seemed to be in a state of a continuing adaptation phase, with increasing amount of LU bacteria and a decline in protozoa over time (**II**). This suggests that the lichen part of the diet before arrival was probably less than the 80% used in the experiment.

Feeding pellets based diets to reindeer for longer periods has a potential to increase body weight and improve body condition (**I, V**). As the feeding was prolonged the animals fed pellets-based diets seemed to improve their nutritional status. Apart from the weight gain, they showed increased concentrations of plasma protein, urea and insulin (**I**) and increased concentrations of VFA and protozoa (**II**). This was in accordance with prior experiments, where reindeer have been fed pellets (Valtonen, 1979; Säkkinen *et al*., 2001; Larsen *et al*., 1985b; Sletten & Hove, 1990), although the increases of weight and fat deposits in the present experiment were relatively small. Perhaps the rumen ecology in our experiment did not become fully adapted to the pellets-based diet. This could be the reason why the concentrations of valeric, isobutyric and isovaleric acid were increased compared to the lichen-fed reindeer (**II**), as was found after the feed restriction. High levels of these acids have earlier been observed in connection with low feed intake (Åhman & Åhman, 1980).

The overall success of an emergency feeding with artificial feed-stuffs may be difficult to assess. The problems that occur in the initial phase of feeding should be evaluated in relation to any improvements found body condition, with gains of muscle and fat, in the remaining animals (**I**, **V**). Significantly improved calving weights have earlier been recorded for adult reindeer hinds as an effect of prolonged feeding with pellets (Säkkinen *et al*., 1999). If transferred back to pasture, the reindeer in groups PL, PS and SP in the present experiment would probably have had a better chance of having a good future production than animals in groups C and L, judged by the improved body condition seen in increased blood metabolites and improved ruminal status (**I**, **II**).

Implications

The risk of losses of animals, to the extent that was realised in the present (**I**) and prior studies (Kosmo *et al*., 1978) is well known to reindeer herders. Many herders hesitate to start an emergency feeding and may, therefore, wait until the situation becomes critical. This may lead to a further deterioration in the condition of the animals and the prognosis of a feeding start may be more complicated. It is important to avoid this negative trend. One way is to develop more suitable feed stuffs. Several promising attempts have been made over the years, for example using seaweed meal mixed into pellets (Sletten & Hove, 1990). Special ingredients, however, make the feeds expensive to produce. More fibrous pellets, intended for emergency situations, have occasionally been available on the market, and were considered to cause less digestive problems than standard pellets. The demand for this kind of feed, however, varied between years and it was not possible to store high fibre pellets for long periods or produce them at short notice in sufficient quantities (personal communication, Å. Strömberg, Lantmännen, Holmsund). The optimal strategy would be to be prepared for emergency feeding situations by keeping a storage of lichens or silage of a specific quality and to initiate the emergency measures at an early stage, prior to the point where serious deterioration of the animals begins to take place. A successful emergency feeding could be seen as not only a way to cope with the acute situation, but may also have positive effects on the long term productivity of the reindeer herd, which could offset the costs of the feeding.

According to the results in this thesis and from several prior investigations, the acute general condition of the animals is crucial for the outcome of an emergency feeding. Consequently, it would be useful to assess the body condition of reindeer to predict the probability of a successful feeding. Earlier studies have pointed out the difficulties in assessing body condition by single measurements like blood sampling (*e.g.* Säkkinen *et al*., 2001). The multiple studies performed here, with weight developments, examination of blood metabolites and rumen content, together with behavioural studies, complemented each other to assess the general condition of reindeer in an experimental situation. In a practical feeding situation, these wide ranges of measurements are impossible to apply for practical and economical reasons. However, regular behavioural studies of the animals could be a useful and simple way to follow adaptation.

As the body condition of the reindeer depends on the previous situation of the animals, the prior grazing conditions and days of starvation are important for the outcome of any feeding strategy. Consequently, the herders continuous follow-up is an important part of the preparedness for a successful solution of any emergency feeding situation. For animals in poor condition, lichens are the best initial emergency feed for reindeer. Strategies with pellets and silage combinations may work, but when the condition of the reindeer is poor, the risk may be greater for severe initial problems.

Conclusions

The results of this thesis show that implementing a wide range of collected physiological data and behavioural studies in one experiment was a suitable method to evaluate the adaptation of the reindeer to various emergency feeding strategies. The general condition of the animals, which is influenced by the background of the animals, affected the ability of the reindeer to adapt to emergency feed stuffs.

Implications based on the results in the thesis are:

- Insufficient intake of a lichen-based diet will deteriorate the condition of the animals, which may lead to health problems, altered behaviour and complicate a change in diet.
- Regaining free access to a lichen-based diet will probably not cause digestive problems, while diarrhoea may occur among reindeer fed emergency rations based upon pellets. Silage alone may immediately cause severe health problems and even the loss of animals.
- Animal behaviour is suggested to be a valuable indicator for the study of the adaptation of reindeer to feeding regimen changes.
- Prolonged feeding with a lichen rich diet results in a gradual loss of body mass in reindeer. Pellets-based diets may result in improved body condition and increased body mass, although slightly unbalanced rumen ecology in this experiment indicated that the animals were not fully adapted to the diet.
- The induction of the disorder wet belly was shown to be independent of any specific diet, as it occurred also on lichen-fed reindeer. The fluid making the fur wet seem to be of internal origin. Affected animals appear to have a lower body temperature than healthy animals.
- Lichen utilizing bacteria, which were found in the rumens of animals fed the diets containing lichen, could be defined as a substrate specific group which may partly explain the specific ability of reindeer to utilize lichen as feed resource.

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Populärvetenskaplig sammanfattning

Nödutfodring av renar

Renen är ett hjortdjur som lever i arktiska och subarktiska områden där den har funnits vild i många årtusenden. I Sverige finns numera inga vilda renar utan alla finns inom renskötseln där de hålls främst för köttproduktion. Renskötseln bygger på att man använder naturliga betesmarker som skogsmark, myrområden och fjällhedar, som i allmänhet inte utnyttjas av andra husdjur. Renen är väl anpassad till stora årstidsvariationer i betestillgång och kan exempelvis utnyttja lav som näringskälla på vintern, vilket de flesta andra djur inte kan. Det är dock inte ovanligt att det uppstår situationer på vintern när betet blir helt otillgängligt för renarna på grund av extremt djupt snötäcke eller hård isskorpa. Om bristen på föda blir alltför långvarig krävs utfodring av renarna för att undvika att djuren svälter eller i värsta fall dör. Ett snabbt foderbyte, särskilt i en svältsituation, medför ofta problem hos idisslare och renen är inget undantag. De utfodringsstrategier som används till ren idag kan ibland till och med förvärra situationen därför är det viktigt att utveckla bättre nödutfodringsstrategier.

Ur hälsosynpunkt är lav ett optimalt nödfoder, eftersom det huvudsakligen är lav renen är anpassad till under den period då nödutfodring behövs. Det är dock svårt att få tag på lav i tillräcklig mängd när hela hjordar behöver utfodras. De fodermedel som vanligen används vid utfodring av renar är hö, ensilage och pelleterat foder för helutfodring av ren. Sedan 1960-talet har olika foderblandningar testats som nödfoder till ren. Resultaten har varierat och ännu finns inga väl fungerande alternativ.

Försöksupplägg

Denna studie genomfördes för att få en ökad kunskap om vad som händer vid en utfodringsstart då renen är i nedsatt kondition. Ett försök, som så långt som möjligt efterliknade den praktiska situationen vid nödutfodring, genomfördes och där hela djuret studerades genom registreringar av foderkonsumtion, beteende, viktförändringar, vomekologi, metabolism och slaktkroppskvalitet.

Försöket genomfördes vid Uleåborgs universitets försöksstation i Finland med försöksstart i slutet av januari 1997. Vädret var normalt för årstiden, temperaturen varierade mellan -28 ºC och +6 ºC och marken var täckt med snö under hela försöket. Totalt ingick 72 ca åtta månader gamla honrenkalvar som tagits direkt från bete och fördelats i fem grupper i varsitt hägn. Samtliga djur tillbringade minst tre veckor vid stationen före försökets start i syfte att vänja djuren vid miljön och den experimentella hanteringen. Alla djur fick under denna förperiod fri tillgång till en diet med 80% lav och 20% blåbärsris och videblad. Inblandningen av andra betesväxter än lav var viktig för att i möjligaste mån efterlikna en naturlig diet. Försök har dessutom visat att enbart lav är otillräckligt som proteinkälla. I försöket ingick en kontrollgrupp som fick fri tillgång till lavdieten. Under försökets första del, restriktionsperioden, fick renarna i de övriga fyra grupperna en begränsad giva av lavdieten i en dryg vecka och inget foder alls sista dagen. Denna tilldelning skapade förutsättningar liknande dem under en gradvis minskning av betestillgången.

Under den följande utfodringsperioden tilldelades grupperna olika utfodringsstrategier. En grupp återutfodrades med full giva av den lavbaserade dieten. Två grupper utfodrades med ett ordinärt pelleterat foder för ren som härefter benämns som pellets. Den ena gruppen fick pellets blandat med 20% lav och den andra gruppen blandat med 20% ensilage, som var ett lokalt producerat rundbalsensilage. För att underlätta tillvänjningen trappades fodergivan upp gradvis till fri tillgång. Den tredje gruppen fick enbart ensilage vid utfodringsstarten och efter fem dagar började pellets gradvis blandas in och andelen var 80% pellets och 20% lav efter två veckor. Ett urval av djur från varje behandlingsled slaktades vid tre tillfällen under försöket; före och efter restriktionsperioden samt efter fem veckors utfodring.

Dålig fodertillgång och svält

Trots att renar är renarnas anpassade till begränsad betestillgång under vintern påverkas de ändå negativt av att näringstillförseln minskar. I försöket förändrades djurens kondition och beteende påtagligt vid restriktiv tilldelning av lavdieten. Blodets glukoshalt sjönk medan ureahalten ökade och djurens muskelvikt minskade ca 1 kg, vilket motsvarar ca 5% minskning av slaktkroppen. Vomekologin var störd med höjt pH-värde, sänkt halt av fria fettsyror samt minskad mängd bakterier. Förändringarna var mindre drastiska än vad som rapporterats från renar som svultit flera dagar efter att de fått obegränsat med lav och den skillnaden var förväntad. Via renarnas beteende sågs också tecken på att djuren var påverkade. De åt de annars ratade grövre delarna av dieten, sökte mer efter föda i snön, idisslade stående och låg i större utsträckning hoprullade än vad djuren i kontrollgruppen gjorde. Enstaka djur drabbades av begynnande symptom på sjukdomstillståndet blöt buk, vilket tidigare beskrivits i samband med att renar utfodrats med grovfoder.

Foderbyte ställde till problem

Utfodringsstarten gick helt utan problem för gruppen som återutfodrades med lavdieten. Renarna återhämtade sig snabbt och blev likvärdiga med kontrollgruppen vad gäller metabolism och viktförändringar. Eftersom denna grupp inte utsattes för ett foderbyte utan återgick till lavdieten som vomfloran redan var anpassad till, kunde födan snabbt brytas ned och djuren tillgodogöra sig energin. Lav har en unik uppbyggnad med speciella kolhydratstrukturer, som är svåra att bryta ner för bakterier som inte är anpassade till lav. I försöket upptäcktes en grupp bakterier i vommen som var beroende av lav som substrat för sin överlevnad och därför fanns i mycket liten mängd hos de renar som inte fick lav. Dessa bakterier kan ha en betydelsefull roll i anpassningen till nya dieter, men det är ännu inte känt vad det är i laven som denna bakteriegrupp behöver.

Utfodringsstarten med de nya foderstaterna gick inte lika problemfritt som återutfodringen med lavdiet. Alla djur började äta av de tilldelade foderstaterna, men i båda grupperna som utfodrades med pellets förekom diarré. Detta beror på att vomfloran, som var i obalans efter restriktionen, inte hade kapacitet att snabbt nog ställa om till den nya dieten som innehöll mer stärkelse och snabblösligt socker än lavdieten. Detta medförde förmodligen att koncentrationen av fria fettsyror ökade allt för snabbt och/eller att pH-värdet sjönk. De djur som var mest illa däran behandlades med antibiotika och samtliga djur i dessa båda grupper återhämtade sig. Metabolismen anpassade sig efterhand till foderstatens högre proteininnehåll och det reflekterades i såväl muskeluppbyggnad som fettansättning. Vid slutslakten, efter fem veckors utfodring, sågs tecken i bland annat fettsyresammansättningen på att vommen ännu inte hade anpassats helt och hållet. Det finns dock få vomstudier på renar fullt anpassade till pellets vilket gör att det är svårt att dra vidare slutsatser hur detta påverkade djuren. Foderstaten speglades även i beteendet, djuren som fick pellets ägnade mindre tid åt att äta och idissla jämfört med renarna som fick lav.

Den grupp som enbart fick ensilage vid utfodringsstarten tvekade inte heller att börja äta och inga djur fick diarré, vilket var i överensstämmelse med tidigare erfarenheter. Dock förvärrades symptomen på blöt buk i denna grupp. Trots att djuren åt nästan oavbrutet av ensilaget visade deras beteende och blodvärden på fortsatt energibrist. Detta kan troligen förklaras med att ensilaget hade för låg halt av tillgänglig energi så djuren svalt trots att de åt hela tiden. Den stränga kylan under första utfodringsveckan försvårade läget ytterligare och efter fem dagar blandades pellets in i ensilaget. Trots detta dog flera djur eller fick avlivas. Läget stabiliserades efter två veckor och fem av tio djur fanns kvar till försökets slut.

Utfodring påverkade slaktkroppen men inte smaken på köttet

De renar som utfodrades med lavdieten förlorade ca 1 kg av muskelmassan under utfodringsperiodens fem veckor. Viktminskningen var dock mindre än för renar i tidigare försök som utfodrats med enbart lav. Det höga energi- men låga proteininnehållet gör lav till ett bra överlevnadsfoder, men för tillväxt krävs ett större komplement av betesväxter. De foderstater som var baserade på pellets hade ett betydligt högre näringsinnehåll och muskelmassan ökade kring 4 kg (ca 20%). Detta innebär att slaktutbytet var högre och att slaktkroppen hade mer fett än från renar som fått lavdieten. Det förekom däremot inga skillnader i smak på köttet mellan de olika utfodringsstrategierna, trots den stora skillnaden i fodersammansättning.

Praktiska rekommendationer

Renarnas kondition, fodrets kvalitet och utfodringens utformning är faktorer som har stor betydelse vid en nödutfodring. Renens kondition och välbefinnande kan till viss del bedömas via djurens beteende och med god säkerhet bestämmas via blodprov och provslakt. Det är betydelsefullt att observera djurens beteende regelbundet för att upptäcka tecken på energibrist. Renar som är i dålig kondition behöver snabb tillförsel av lättillgänglig energi och kallt väder kan göra situationen extra krävande. Djurens kondition är avgörande för valet av foder.

Lav är alltid det bästa nödfodret för renar i dålig kondition, och då plockad lav finns tillgängligt bör detta blandas in i fodret under utfodringens första veckor. Då lav inte alls finns tillgängligt rekommenderas:

- att renar som är i dålig kondition utfodras med pellets, men att renägaren är uppmärksam på risken för diarré vid utfodringsstarten.
- att renar som inte är i alltför dålig kondition via en övergång från ensilageutfodring övergår till pelletsutfodring. Ju sämre kondition djuren är i desto större andel pellets och mindre andel ensilage i foderstaten.
- att vid all utfodring med ensilage analysera fodret och i möjligaste mån välja ett med låg fiberhalt, eftersom kvaliteten på ensilaget är av betydelse för utfodringens utgång.

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