



Alpacka – en utfodringsstudie i fält

A field study on feeding of Alpacas in Sweden

av

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Abstract

Alpacas are held in South America mainly for wool production, but also for meat and leather production. South American Camelids, including alpacas, vicuñas, llamas and guanacos, are well adapted to the harsh environment during the dry season in South America. The efficiency of their digestive system is particularly noticeable on high in fibre/low in protein diets.

The anatomy of the alpaca stomach is different from that of true ruminants as alpacas have three compartments instead of four. Alpacas also have unique mucosa producing epithelium of saccules in parts of their stomach. These saccules produce bicarbonate, which buffers pH to near neutral. The last compartment has the same function as both the omasum and the abomasum of true ruminants. The forestomach of alpacas have a higher concentration of volatile fatty acids than the forestomach of true ruminants. Contractions of the alpaca stomach are more continuous than in true ruminants. This contributes to a thoroughly mixed and homogenous content.

Alpacas have a lower dry matter intake per kg body weight, and a slower passage rate of digesta, compared to true ruminants. The digestibility of high fibre forage is higher for alpacas than for true ruminants.

Few studies have been published on alpaca energy and nutrient requirements. Energy requirements have not been established for alpacas and recommendations for daily energy intake are based on studies on llamas. Recommended protein intake in alpacas is based on one nitrogen balance study performed on alpacas, while mineral and vitamin requirements are extrapolated from data on beef cattle, sheep and goats.

Alpacas have been exported from South America to other countries of the world since the beginning of the 1980's. The number of alpaca owners and breeders in Sweden has increased over the last twelve years, and today the alpaca population in Sweden is around 230-350 animals. A common opinion among alpaca owners is that forage with high energy and protein content and commercial concentrates and grain should be avoided. Because of the increasing alpaca population in Sweden, and other countries outside South America, it is important to increase the knowledge about alpaca nutrition.

A 55 day feeding trial was performed at an alpaca farm in the south of Sweden. Twenty-five females were included in the study, twelve of these had offspring and were lactating during the study. Daily feed intake, digestibility and body weight was recorded.

The average dry matter intake was 1.4 % of body weight for non-lactating females, and 1.8 % of body weight for lactating females. Energy intake was 0.14 and 0.18 MJ/kg body weight respectively. All the animals except the crias gained weight during the study. Only the lactating females showed a slight gain in body condition score. Lactating females had generally higher digestibility of dry matter, neutral detergent fibre, crude protein, organic matter and minerals than non-lactating females. There was no difference in wool micron numbers before and after the feeding trial for the females, but the crias had slightly higher values after the study.

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Introduction

The alpaca is the foremost wool fibre producing animal in the Antiplano region of the Andes in South America (Fowler, 1998a). In South America they are also held for meat production. Leather and cria (the alpaca foal) pelts are used for making ropes, rugs and wall hangings (Fowler, 1998a). Alpaca breeding is the main source of income for the inhabitants of the Andean plateau (López *et al.*, 1998).

The alpaca is a grazer and prefers to feed on meadowlands and marshlands. The wet season in South America occurs from December to March, when 75 % of the yearly rain falls, and the vegetation has a high nutrient content this time of year. During the dry season between May and October the vegetation has a lower nutrient and higher fibre content. Camelids native to South America are well adapted to this fibre rich forage (Fowler, 1998b), however many alpacas often suffer from undernutrition during this time of year (López *et al.*, 1998). This has negative effects on production rate for growth and wool, as well as fertility (Fowler, 1998b), the mortality of crias increases and the reproductive ability decreases (López *et al.*, 1998). This should improve if their optimal nutrient requirements were fulfilled (Fowler, 1998b).

The numbers of South American Camelids (SAC), such as llamas and alpacas, are increasing both in North America and in Europe. In these new environments, which are different from that in South America, they are dealing with different management and forage types. San Martín and Bryant (1989) argue that the nutritional superiority of the alpaca compared to true ruminants like sheep, goats and cattle, is not always considered in management systems in North America and Europe.

Today's knowledge about the nutritional requirements of SAC is based on a few detailed nutritional studies and nutritional needs are often extrapolated from data accumulated in studies on sheep, goat and cattle (Fowler, 1998b). The differences in digestion and nutrition between llamas and alpacas, when corrected for body weight, have not been studied. Supplementary feeding to support energy requirements for gestation, lactation or growth has not been studied on alpacas specifically (Van Saun, 2006).

A common opinion among alpaca owners is that alpacas are very well suited for low quality forage and owners often hesitate to feed them high quality forage rich in energy and protein.

The alpaca has a very efficient digestive system, which is especially noticeable on low quality feed, high in fibre and low in protein (San Martín and Bryant, 1989; Warmington *et al.*, 1989; Dulphy *et al.*, 1994; Lopez *et al.*, 1998; Van Saun, 2006) and on high altitudes (San Martín and Bryant, 1989). However, few nutrition studies have been performed on alpacas and data from studies performed on llamas often assumed to be applicable on alpacas. It is known that camelids have even greater nitrogen utilization through urea recycling than true ruminants in order to survive in their harsh native environment with low-quality forages during certain times of the year. Another adaptation in camelids is the slower passage rate of ingesta through the first and second stomach compartments, compared to the passage rate of ingesta in the rumen of true ruminants (Van Saun, 2006). Alpacas have a high ability to adapt to different environments, especially regarding temperature and altitude (Raggi *et al.*, 1996). Nutrition has influence on the wool fibre production but not to the same extent as in sheep and

the effect is more pronounced on fibre length than on fibre diameter (Russel and Redden, 1997).

The aim of this study was to evaluate consumption capacity, digestibility and recording of body weight in female alpacas and crias. All forages in the study were produced in Sweden. The quality of wool fibre (micron numbers) was also examined. The aim was also to find relevant feeding strategies for alpacas in Sweden.

Background

The alpaca origin

The common ancestor of both camelids and true ruminants are thought to be simple stomached animals. The foregut fermentation system of camelids evolved in parallel with that of true ruminants (Fowler, 1998c). Camelids (suborder *Tylopoda*) (figure 1) are ruminant animals as they have an expanded forestomach for microbial fermentation of feedstuff, and that they chew cuds (Van Saun, 2006). The differences in anatomy of the stomach between camelids, which have three foregut compartments, and domestic true ruminants with four foregut compartments, has lead to controversies in proper taxonomic status (Vallenás *et al.*, 1971). Camelids are considered pseudo-ruminants, as opposed to the true ruminants in the *Ruminantia* suborder (Van Saun, 2006). Problems with defining and homologizing the compartments of the stomach in camelids with true ruminants have also arisen (Vallenás *et al.*, 1971). Camelid species are often divided into SAC and Old World Camelids (OWC). The OWC group consists of the Bactrian Camel and the Dromedary (Fowler, 1998a).

Class – MAMMALIA
Order – ARTIODACTYLA
Suborder – TYLOPODA – Camelids
<u>Old World Camelids</u>
<i>Camelus dromedarius</i> – Dromedary camel
<i>Camelus bactrianus</i> – Bactrian camel
<u>New World Camelids</u>
<i>Vicugna pacos</i> – Alpaca
<i>Vicugna vicugna</i> – Vicuña
<i>Vicugna vicugna mensalis</i> (Peruvian)
<i>Vicugna vicugna vicugna</i> (Argentine)
<i>Lama glama</i> – Llama
<i>Lama guanicoe</i> – Guanaco
Suborder – RUMINANTIA
Cattle
Sheep
Goats
Water buffalo
Giraffe
Deer
Antelope
Bison

Figure 1. Classification of camelids and true ruminants (after Fowler, 1998a and Hoffman, 2006)

SAC refer to the two non-domesticated guanaco (*Lama guanicoe*) and vicuña (*Vicugna vicugna*), and the domesticated llama (*Lama glama*) and alpaca (*Vicugna pacos*) (Hoffman, 2006). SAC are also known as lamoids or New World Camelids (Fowler, 1998a). Analysis of the SAC genotype have concluded that crosses between llamas and alpacas have occurred in the past. The guanaco is generally thought the ancestor of the llama. The vicuña and the guanaco derive from a common ancestor two to three million years ago (Stanley *et al.*, 1994). The alpaca has been known as *Lama pacos* for the last two centuries (Hoffman, 2006). Mitochondrial and microsatellite DNA has been used to determine the relationship between SAC and the ancestors of the domesticated llama and alpaca. High genetic similarity was found between the guanaco and the llama, as well as between the vicuña and the alpaca. The vicuña was found to be the wild progenitor of the alpaca, which should be classified as *Vicugna pacos* (Kaldwell *et al.*, 2001). Two wool-types of alpacas are recognized. The suri has straight twisted fibres matted together, and the huacaya has dense crimped fibres (Wheeler, 1995).

SAC in South America

The main location for alpacas in South America are on the high plateau around 4400 metres above sea level (Parraguez *et al.*, 2003), where there are around 2.5 million alpacas today (Hoffman, 2006). Alpacas and llamas are distributed mostly in borders of Peru, Bolivia, Chile and Argentina, but also up to Ecuador and Colombia. Vicuñas and Guanacos are mainly distributed in Argentina and Chile, but also Peru and Bolivia (figure 2) (Hoffman, 2006). The SAC are important to South American livestock economy. Fine wool is produced from the alpaca and from the non-domesticated vicuña. The llama is traditionally used as a pack-animal. The guanaco does not contribute to South American livestock economy as it is not domesticated nor used by humans (Cummings *et al.*, 1972).

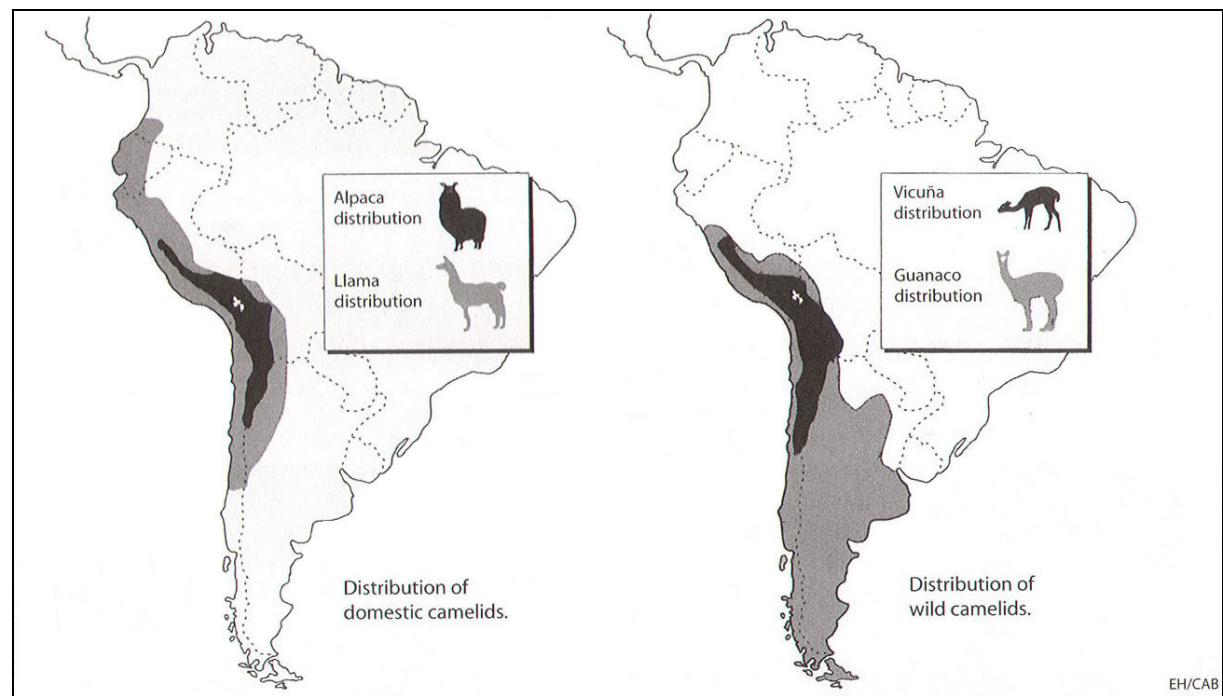


Figure 2. Distribution of SAC in South America (Hoffman, 2006)

The rainy season in the Andes contributes to pastures of high nutrient content. During the dry season, from May to October, when the animals often are in stages of weaning, late gestation or late lactation, poor nutrition contributes to high cria mortality. Living at high altitudes, alpacas have to spend more energy searching for feed to support their nutritional requirement than they would in less challenging conditions (Raggi *et al.*, 1994). Alpacas prefer to graze soft-grass plant types such as rama pasto (*Calamagrostis* sp.) and champa pasto (*Muhlenbergia legularis*). These plants grow in wet areas on the plateaus, known as bofadales. Llamas prefer to graze drier, coarse plant like chilliwa (*Bromus* sp.) and ichu (*Festuca dolichophyla*). These preferences contribute to the natural separation of alpaca and llama herds (Hoffman, 2006).

Export of alpacas from South America

The first large-scale exports of alpacas from South America to North America took place in 1983 and 1984. Since then there has been large exports from South America to Canada, Australia, the United Kingdom, Switzerland, New Zealand, Poland, the Netherlands, Germany, France, Italy, Israel and South Africa. The alpaca populations in these countries are continuously growing. In these import countries alpacas are held mainly for shows and for wool production. The first alpaca show in North America took place in 1990. The wool industry provides handling of very small quantities of wool at a time, which enables owners of only a few alpacas to have their wool in different colors processed separately. Australia has been the foremost high quality wool producing country outside South America (Hoffman, 2006).

The first bigger import of alpacas to Sweden was in 1995 (Boström, 2007). Today there are between 230 (Svenska Djurhälsovården, 2007) and 350 alpacas in Sweden (Gerber-Santesson, 2007). The population is still growing, as more people become interested in alpacas. The Swedish alpaca is mainly held as a pet. The wool is taken care of, but there is no wool industry, thus the wool is mainly used by private traders. The alpaca in Sweden is also held for shows and competitions (Gerber-Santesson, 2007).

Camelid anatomy

The camelid has a split upper lip, which is highly tactile and used as a sensory organ to investigate feeds. Foreign bodies in the gastric compartments are rarely found in camelids because of their investigative feeding behaviour. The lower lip of camelids is less mobile than the one of caprine or ovine (Fowler, 1998c). The incisor teeth of the alpaca are firmly attached to the lower jaw. When grazing, the teeth are pressed towards the dental pad in the upper jaw (Fowler, 1998b), and the alpaca is able to graze very short plants. The cleft upper lips are useful when selecting feed, as they are controlled independently of each other (Fowler, 1998b; Hongo *et al.*, 2006).

Alpacas do not use their tongue when grazing. They rarely protrude the tongue from the mouth, as they do not lick themselves, their new-born offspring or salt blocks. Different types of forage require different times of chewing, but in general alpacas ruminate feed for one third of daylight time, as they are not as active in darkness (Fowler, 1998b). Alpacas chew the cud 25-35 times in 15 seconds at a time. The pattern of chewing during rumination is in a horizontal figure eight arc, as opposed to the unilateral elliptic pattern of bovine and deers (Koford, 1957).

Location, number and histology of the salivary glands are similar for camelids, cattle, sheep and goats (Fowler, 1998c). Alpacas have a salivary pH of 8.6, with no significant difference before, during or after feeding (Ortiz *et al.*, 1974). The pH of the ruminal contents are close to neutral, which favour cellulolytic digestion (Hoover, 1986; Van Soest, 1994).

Alpacas have larger thoraces and lung capacity than sheep and cattle. During the eructation cycle, the respiration stops while gas is eructated. Dougerty and Vallenás (1966) suggest that the volume of gas eructated per unit of body weight is the same for alpacas as for cattle, and they discussed the possibility that these two species have similar fermentation processes.

Stomach morphology

The morphology of the SAC stomach is different from that of true ruminants. The SAC stomach contains only three compartments, as seen in figure 3 (Smith *et al.*, 1994). The first two compartments have partially mucosa producing epithelium. The last compartment has a similar function as both the omasum and the abomasum in true ruminants, but the differences between camelids and true ruminants in stomach function are still noticeable, especially considering the mucosal surface in camelids. There are no strict compartmental analogies between pecoran and camelid stomachs, considering the anatomic differences (Vallenás *et al.*, 1971).

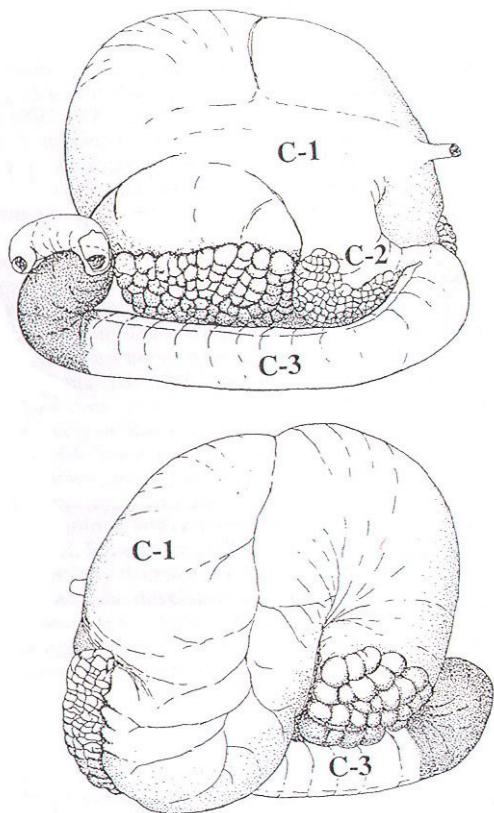


Figure 3. The stomach of SAC (Smith *et al.*, 1994)

The first compartment (C-1) takes up a large part of the left abdomen (Fowler, 1998c). The size of C-1 is approximately 83% of the gastric volume (Vallenás *et al.*, 1971). The entering of the esophagus is on the craniodorsal midline of C-1 (Fowler, 1998c). A horizontal pillar

divides the compartment in a cranial and a caudal part. The ventral surface of C-1 is covered by a mucinous glandular epithelium from the glandular saccules (Fowler, 1998c). Non-papillated, stratified squamous epithelium covers the non-glandular areas in C-1 (Eckerlin and Stevens, 1973). The glandular mucosa of C-1 is folded (Cummings *et al.*, 1972). True ruminants do not have any counterpart to the two sacculated areas of C-1 in the camelid stomach (Vallenás *et al.*, 1971).

The location of the second compartment (C-2) is on the right craniodorsal surface of C-1 (Fowler, 1998c). This compartment makes up 6% of the total gastric volume. C-2 contains a dorsal smaller curvature and a ventral greater curvature. Ingesta is in liquid form in this compartment (Vallenás *et al.*, 1971). C-2, except from the lesser curvature, is covered with papillated glandular mucosa. The lesser curvature has stratified squamous epithelium (Eckerlin and Stevens, 1973).

There is a narrow tubular passage, 1-2 cm in diameter (Heller *et al.*, 1986), between C-2 and the third compartment (C-3) (Vallenás *et al.*, 1971). The diameter of C-3 is five times greater than the diameter of the narrow passage. This last compartment makes up 11% of the total gastric volume (Vallenás *et al.*, 1971). The opening into C-3 is on the cranial mesial part of C-2, and lies caudal and ventral to the liver on the right side of C-1 (Fowler, 1998c). The proximal four fifths of C-3 is similar to C-1 and C-2 but without saccules (Eckerlin and Stevens, 1973). The proximal part has been viewed as the equivalence of the omasum, and the distal part as the equivalence of the abomasum of true ruminants (Vallenás *et al.*, 1971). The last one fifth contains gastric and pyloric glands (Cummings *et al.*, 1972; Eckerlin and Stevens, 1973).

Stomach motility

The contraction of C-1 goes from caudal to cranial, opposite to the cranial to caudal wave in true ruminants (Fowler, 1998b). Each contraction cycle starts with the ventricular groove, followed by a single rapid contraction of C-2. The ventricular groove contracts again, as well as the caudal sac of C-1. Next sequence is the cranial sac of C-1 followed by C-2, and then the caudal sac of C-1 (San Martín and Bryant, 1989). This last sequence is repeated 3-6 times during a cycle followed by a brief rest and then a new cycle. Eructation occurs 3-4 times during a cycle (Van Saun, 2006). The average length of a cycle is 1.8 ± 2 minutes, and counts from one contraction of C-2 to the next contraction of C-2. The stomach contracts 3-4 times per minute in a resting animal, and 4-5 times per minute during and immediately after feeding (Fowler, 1998c).

The activities of the stomach compartments are more continuous than in the true ruminants (San Martín and Bryant, 1989). The increased motility is also thought to play a role in that camelids are fairly resistant to bloat as opposed to true ruminants. Another result of the increased motility is the more thoroughly mixed and homogeneous content of the forestomach (Van Saun, 2006).

Function of the camelid stomach

The bicarbonate secretion in C-1 and C-2 buffers the pH to near neutral (Cummings *et al.*, 1972; Eckerlin and Stevens, 1973; Vallenás, 1991). During contraction of C-1 the mucous glandular epithelium of the saccules in both the cranial and caudal sacs

empties (Fowler, 1998b). Smaller particles and fluid is mostly found in the ventral cranial sac of C-1 (Fowler, 1998c). C-2 is covered with glandular epithelium, except for the lesser curvature. The pattern of the cells in C-2, which is not as deep as in C-1, is like the pattern of the reticulum of true ruminants (Fowler, 1998b). The contractions of C-2 move most of the bulky contents into C-1, leaving mostly fluid and smaller particles in C-2. Larger particles, which have moved into the canal between C-2 and C-3, are rejected back into C-2 when the canal contracts (Heller *et al.*, 1986). Water is absorbed in the cranial four-fifths of C-3, leaving the ingesta quite dry (Fowler, 1998c).

The flow of ingesta to C-3 is regulated by particle size. The passage rate of feed through the gastrointestinal tract varies, but is on average four days in llamas on a diet of 1-1.5 kg hay and 0.5 kg concentrate mixture a day. No measurements on alpaca passage rate have been published. The retention time of fluid in the stomach compartments is significantly shorter than for particles. Small particles (0.2-1.0 cm) are retained in C-1 and C-2 for 19.2 ± 1.5 hours, and large particles (2.5-4.0 cm) are retained for 25.0 ± 4.6 hours. In C-3 the retention time for large particles is shorter than for small particles (Heller *et al.*, 1986).

Digestion and absorption in the small intestine is the same for alpacas as for true ruminants. In addition to the foregut fermentation, alpacas also have a fermentative function in the hindgut, but the activity is not as important as that in the foregut (Van Saun, 2006). SAC has a continuous flow of bile as they lack gallbladder (Fowler, 1998b).

As well as in true ruminants, newborn camelids have a undeveloped first foregut compartment with the last compartment well developed (Fowler, 1998c). When the newborn suckle, the milk is shunted past C-1 to C-2 and on to C-3 (Fowler, 1998b).

Volatile fatty acids

When compared to other ruminants camelids have shown a higher concentration of volatile fatty acids (VFA) in the fermentation chambers of the stomach (San Martín, 1991). The pH near neutral of the SAC stomach neutralizes the VFA, which are then kept as ions and more slowly absorbed (López *et al.*, 1998). The saccules of C-1 and C-2 also contribute in buffering the stomach pH during feeding (Eckerlin and Stevens, 1973).

The VFA concentration in the stomach of alpacas increases during feeding, with its peak concentration 30 minutes after finished feeding (Vallenás and Stevens, 1970). The effective absorption system in the stomach of camelids is probably the reason why the drop in pH is less significant in these species (Hintz *et al.*, 1973). Within 5 to 6 hours after feeding VFA concentration in the fermentation chambers returns to preprandial levels (Vallenás and Stevens, 1970).

In a feeding trial, where the diet was composed by 0.9 kg of concentrate and *ad libitum* alfalfa hay, the pH of the digesta dropped after concentrate intake with its lowest value 2.5 hours after finishing feeding. Within 6 to 7 hours the pH was returned to the same level as before concentrate intake. Low ingesta pH was correlated to high total VFA concentration (Vallenás and Stevens, 1970).

VFA absorption from the proximal four-fifths of C-3 is similar to the absorption from C-1 and C-2 (Fowler, 1998c). Caudal to the stomach, llamas and alpacas have a lower concentration of VFA when compared to sheep, cattle and deer. According to

Vallenás *et al.* (1973) SAC either have a greater absorption of VFA in the stomach or less microbial activity beyond the stomach. Rubsamén and Englehardt (1978) states that SAC have more complete and rapid absorption of VFA than true ruminants, due to the glandular areas in the stomach which also stimulate further production of VFA.

Gastric ulcers

Gastric ulcer in alpacas are often associated with diets high in starch, but in nearly all cases of acidosis other circumstances, like other diseases, contribute to a higher stress level (Van Saun, 2007). Gastric ulcers in the mucous membrane of C-3 is common but bleeding ulcers as been reported in true ruminants, has not been seen in SAC. Gastric ulcers can be found in any of the compartments (Fowler, 1998c), but ulcers in the C-1 and C-2 parts and the proximal 75-80 % part of C-3 are not common (Smith *et al.*, 1994). Gastric ulcer has been seen on animals both on good and poor rations, both infested with parasites and healthy (Fowler, 1998c). The majority of gastric ulcers in llamas have been found on the parietal surface of the lesser curvature of the distal part of C-3, and in the proximal part of duodenum. According to Smith *et al.* (1994) stress is involved in the development of third compartment ulcers in llamas, but type of stress is not defined in their study. The effects of grain intake on gastric ulcers has not been studied in alpacas. Grain usually accounts for a small part of llama and alpaca diets (Smith *et al.*, 1994).

Nutrient requirements

Dry matter intake

Dry matter intake (DMI) varies between 1.25 and 1.5 % of body weight for alpacas on maintenance diet and pregnant females, and 2.0 to 2.75 % of body weight for lactating females (Van Saun, 2006). Average intake for alpacas is 1.8 % of body weight which is a 20 % reduction in intake capacity when compared to sheep (San Martín and Bryant, 1989). Hintz *et al.* (1973) found out that SAC was more efficient than sheep in digesting fibre when fed forage rich in fibre, but there were no difference between the species when fed forage low in fibre. There is no differences in DMI between llamas and alpacas when the intake is adjusted for metabolic body weight (San Martín and Bryant, 1989). DMI varied between 1.8 and 2.0 % of BW in a study by Johnson (1994) where two juvenile male llama groups were used in a 2-year trial.

DMI depends on differences in feed composition, availability and the amount of easily digested forage (López *et al.*, 1998; Trabalza Marinucci, 2001). It is also affected by neutral detergent fiber (NDF) (López *et al.*, 1998) and protein content of the forage (San Martín and Bryant, 1989).

Intensively held alpacas in the central zone of Chile consumed 23.0 g DM/kg body weight of hay in 24 hours. This DMI was equivalent to 13.37 MJ metabolizable energy (ME) and 262.2 g crude protein (CP) during 24 hours. The selection of lucerne hay was 77.3 % leaves and 22.7 % stems. A variation in intake between diurnal and nocturnal periods was observed (Raggi *et al.*, 1994).

One study with three female alpacas grazing in fenced semi-natural pastures found that the DMI were 2.8 g/kg BW^{0.75} during late pregnancy, 3.69 g/kg BW^{0.75} during the first 20 days of lactation, and 3.28 g/kg BW^{0.75} during the following 20 days of lactation. Selection of feed was not as prominent in the latter stage of lactation due to a lower quality of the pasture. Selective behaviour was not noticed during late pregnancy (Trabalza Mariucci *et al.*, 2001). One study by López *et al.* (1998) including eight male alpacas measured the daily DMI of four different commercial hay diets. The DMI was 40.1 g/ kg BW^{0.75} for clover, 63.1 g/ kg BW^{0.75} for ryegrass, 39.9 g/ kg BW^{0.75} for wheat straw and 56.9 g/ kg BW^{0.75} for fescue.

Digestibility

The ability to digest forages high in fibre is higher in SAC, when compared to true ruminants (Hintz *et al.*, 1973). The digestibility of feed, relative to metabolic weight, was lower for alpacas than for goats, horses and rabbits when fed two different grass hays. Goats had the highest digestibility. There were no significant differences between goats and alpacas regarding DM digestibility and apparent nitrogen digestibility. A comparison of the nitrogen digestbility between the different species suggests that alpacas are well suited to low nitrogen availability habitats. The retention time of digesta is longer for SAC than for goats and sheep (Sponheimer *et al.*, 2003) which favours fibre digestion as the exposure time for microroganisms is longer (Lopez *et al.*, 1998). SAC have a lower renal excretion and thus a more efficient nitrogen recycling (Hinderer and Engelhardt, 1975).

According to Sponheimer *et al.* (2003) the mean retention time of digesta is longer for alpacas than for llamas, in relation to body size. Furthermore, they suggests that the digestion efficiency of SAC is higher compared to goats, when fed hay low in nitrogen and high in cell wall concentration. They did not show any difference between alpaca and llama when fed other qualities of hay, with more readily available nitrogen. Their study showed that DM digestibility per kilo metabolic body weight is higher for llamas than for alpacas. This indicates that llamas cope better on low quality diets than alpacas do.

Energy requirements

Maintenance

Energy requirements for alpacas are not known, and values for llamas are used. The energy requirements for llamas are 0.35 MJ/kg BW^{0.75}, and is outlined from two studies with five and twenty male llamas respectively (Carmean *et al.*, 1992; Johnson, 1994). The values from these studies are well above the requirement of 0.25±0.01 MJ/ BW^{0.75} estimated by Engelhardt and Schneider in 1977, who also found no difference between llama and sheep digestive capacity. This proves that llamas are more comparable to sheep (0.395 MJ/kg BW^{0.75}) than to cattle (0.507 MJ/kg BW^{0.75}), regarding energy requirements (Spörndly, 2003). An average energy level at 0.3 MJ/kg BW^{0.75} is suggested by Van Saun (2006) regarding the facts that North American camelids often suffer from obesity, and are given diets different from their original seasonally low-nutrient feed in South America.

Growth

The rate of gain (g/day) and composition of gain (fat and protein percent) is needed to calculate the additional ME required for growth. Data on compositon of gain is not available on alpacas. Average daily gain in alpacas, based on llama data and adjusted for body weight, are 30-180 g/day (Van Saun, 2006). Energy requirements for growth can be estimated using the formula for goats (0.03 MJ ME/g gain) (NRC, 1981) since their growth rate is similar to alpacas (Van Saun, 2006). Fowler (1998b) suggests a requirement of 0.037 MJ DE/g gain (Fowler, 1998b), which is equivalent to 0.03 MJ ME/g gain (Van Saun, 2006).

Gestation

Additional ME requirement for the last 3 month of gestation has been suggested to be 0.39 MJ DE/kg BW^{0.75} (Fowler, 1998b), which equals 0.32 MJ ME/kg BW^{0.75}. This is an increase of 90 % of the maintenance energy requirement (Van Saun, 2006).

Trabalza Marinucci *et al.* (2001) suggested that the energy requirement for alpacas in late pregnancy is close to that of llamas, which Carmean *et al.* (1992) has determined to 0.35 MJ/kg BW^{0.75}. Another suggestion for the requirement is by Van Saun (2006), who used data from sheep and converted it to ME requirements, and adjusted for camelids. The estimated gestation requirement (kcal/d) during the last three month is calculated to -33.50 + (65.34 * total birth weight, kg) for the 8th gestation month, -39.74 + (131.68 * total birth weight, kg)) for the 9th gestation month and -86.12 + (203.51 * total birth weight, kg)) for the 10th gestation month.

Lactation

Milk composition and milk yield are needed when calculating energy requirements for lactation. Alpaca milk production has not been outlined, and Van Saun (2006) suggests a range between 0.75 and 2.5 kg/day. Alpaca milk composition was determined by Parraguez *et al.* in 2003. According to this, additional energy requirement for lactation is 3.3 MJ/kg milk (790.11 kcal) (see also table 4). To determine alpaca energy requirement for lactation a formula according to Johnson (1994) was used:

Gross energy (GE) (kcal) = milk fat (g) * 9.5 kcal + milk protein (g) * 5.7 kcal + lactose (g) * 4 kcal.
ME is GE * 0.9. 1 calorie is equivalent to 4.184 joules (NRC, 2007).

This is lower than the estimated requirements for lactating llamas, for which energy requirement for milk production have been estimated to 5.26 MJ ME/kg by Fowler (1998) and to 3.44 MJ ME/kg by Johnson (1994).

Protein requirements

Amino acid requirements are derived from digestion of microbes and undegradable dietary protein. The solubility and degradability of protein for camelids is not known. The limited information availale is used to estimate protein requirements for different physiologig states (Van Saun, 2006).

Camelids are effective in nitrogen recirculation. When fed a low proteine diet, llamas excrete only a small amount of urea, and they use most of the recycled urea

(Engelhard and Schneider, 1977). On a 50 % oat-hay and 50 % pelleted concentrate diet, fecal nitrogen loss in llama males was 36.8 % (Carmeau *et al.*, 1992).

Maintenance

Protein requirements for maintenance, based on nitrogen loss in feces and urine, have been calculated to 2.38 g digestible protein/kg BW^{0.75} according to a nitrogen balance study by Huasasquiche (1974). This is equivalent to 3.5 g CP/kg BW^{0.75} (Van Saun, 2006) on maintenance level. The corresponding value for goats is 4.3 g CP/kg BW^{0.75} and for angora goats 4.7 g CP/kg BW^{0.75} (NRC, 2007). Another suggestion for protein requirements by Fowler (1998b) are based on goat values, where the protein requirements are set to 31 g CP per Mcal DE. Assuming that ME is 82 % of DE, this applies to 37.8 g CP/Mcal ME (NRC, 2007).

Growth

Protein requirement to support growth depends, as well as energy requirements for growth, on composition and rate of body weight gain. Van Saun (2006) suggests that goat data is also applicable on alpacas. Every gram gained in body weight requires 0.284 g CP (NRC, 1981).

Gestation

Gestation protein requirement are needed for fetal, placental, uterine and mammary development. During the last 3 month of gestation the typical fetal growth curve leads to increased protein requirements for the pregnant female. CP requirement, to add to maintenance requirement, is 0.94 g CP/ kg BW^{0.75} for the 8th gestation month, 1.94 g CP/ kg BW^{0.75} for the 9th gestation month and 3.23 g CP/ kg BW^{0.75} for the 10th gestation month (Van Saun, 2006).

Lactation

Lactation protein requirement is dependent on milk yield and protein content of milk. Van Saun (2006) used the milk protein concentration of 34 g/kg milk for llamas (Morin, *et al.*, 1995), and assumed that the total true protein digestibility was 85 % and a biological value of 66 % (NRC, 1985). This yielded a CP requirement of 60.6 g/kg milk. According to a mean protein value of 67 g/kg alpaca milk (table 4, Parraguez *et al.*, 2003), and a net protein value of 56.1 %, which is based on dietary protein source digestibility and utilization efficiency in sheep data (NRC, 1985), this results in a lactation requirement of 119.4 g CP/kg milk.

Mineral requirements

Mineral requirements for camelids are not defined, nor are there proof that they should be different from any other ruminants regarding specific minerals. Values for camelid requirements are therefore generated from mineral requirements for beef cattle, sheep and goats. Beef cattle and sheep have very similar mineral requirements per kg body weight, which supports the assumption that there is no difference in mineral requirements between

species. The extrapolated camelid values also assume that there is no difference between species in mineral digestion, absorption and utilization. The extrapolated values of macrominerals (table 1) and microminerals (table 2) are suggested as minimum nutrient requirements (Van Saun, 2006).

On DM basis the diet should contain over 0.3% Ca, and the Ca:P ratio (Ca:P) should not be under 1.2:1. Camelids do not appear to be as sensitive for copper (Cu) toxicity as sheep. Copper deficiency has been diagnosed in alpacas and llamas (Fowler, 1998b).

Table 1. Suggested minimal llama and alpaca macromineral requirements for differing physiologic states, based on beef cattle, sheep and goat data (after Van Saun, 2006)

Mineral	Average requirement ^a	Extrapolated requirement			MTL ^c
		Daily intake ^b (g/day)	Diet ^c	Group ^d	
Calcium	30 mg/kg BW	1.8-4.8	0.2-0.24	M	2.0
	145 mg/kg BW		0.53-0.73	G (1-12 month)	
	60 mg/kg BW		0.30-0.48	G (12-36 month)	
	0.40 g/kg Fetus	2.4-6.4	0.45-0.56	P	
	3.0 g/kg Milk	2.3-7.5	0.45-0.62	L	
Phosphorous	26 mg/kg BW	1.6-4.2	0.17-0.21	M	1.0
	75 mg/kg BW		0.27-0.38	G (1-12 month)	
	42 mg/kg BW		0.21-0.28	G (12-36 month)	
	0.15 g/kg Fetus	0.9-2.4	0.28-0.33	P	
	1.7 g/kg Milk	1.3-4.25	0.32-0.45	L	
Magnesium ^f	19.4 mg/kg BW	1.2-3.1	0.13-0.16	M, G	0.4
	27.3 mg/kg BW	1.6-4.4	0.18-0.22	P, L	
Potassium	92.6 mg/kg BW	5.6-14.8	0.6-0.7	M, G, P	3.0
	121 mg/kg BW	7.3-19.4	0.8-0.96	L	
Sodium	10.5 mg/kg BW	0.6-1.7	0.07-0.08	M, G, P	2.0
	17.5 mg/kg BW	1.1-2.8	0.12-0.14	L	
Sulfur	28.5 mg/kg BW	1.7-4.6	0.19-0.23	M, G, P, L	0.4

^a Extrapolated from nutrient requirements for beef cattle (NRC, 1996), sheep (NRC, 1985) and goats (NRC, 1981a).

^b Estimated daily requirement based on a range of adult body weights from 60 to 160 kg. Calcium and phosphorus pregnancy and lactation intake requirements based on a range of 6-16 kg fetal weight and 0.75-2.5 kg milk production, respectively. Values are in addition to maintenance for total requirement.

^c Dietary concentration (g/100 g) on dry matter (DM) basis for total requirement. Nutrient density calculations based on an assumed range of DM intake between 1.25 and 1.5 % of body weight (maintenance and pregnancy) and 2.0 and 2.75 % of body weight (lactation).

^d Physiologic states of maintenance (M), growth (G), lactation (L) and pregnancy (P) for which the requirement is defined.

^e Maximum tolerable level (g/100 g), defined as largest dietary concentration of a given mineral that could be fed for short periods (3 month) without problems. Based on data from NRC (1980).

^f May need to be increased (0.25-0.35 %) if forages containing high amounts of potassium (>1.5 %) are being fed.

Table 2. Suggested minimal llama and alpaca micromineral requirements for differing physiologic states, based on data derived from beef cattle, sheep and goats (after Van Saun, 2006)

Nutrient	Average requirement ^a	Extrapolated requirement			MTL ^e
		Daily intake ^b (mg/day)	Diet ^c	Group ^d	
Cobalt	1.76 µg/kg BW	0.11-0.28	0.12-0.14	M, G, P, L	10
Copper	0.15 mg/kg BW	9-24	9-12	M, G, P, L	30
Iodine	9.5 µg/kg BW	0.57-1.5	0.6-0.76	M, G	50
	16 µg/kg BW	0.96-2.6	1.1-1.3	P, L	
Iron	0.7 mg/kg BW	42-1120	47-56	M	500
	0.9 mg/kg BW	54-144	60-72	G, P, L	
Manganese	0.36 mg/kg BW	21.6-57.6	24-29	M, G	1000
	0.8 mg/kg BW	48-128	53-64	P, L	
Selenium	5.3 µg/kg BW	0.3-0.85	0.35-0.42	M, G	5
	6.0 µg/kg BW	0.36-0.96	0.4-0.48	P, L	
Zinc	0.53 mg/kg BW	31.8-84.8	35-45	M, G	500
	0.67 mg/kg BW	40.2-107	45-54	P, L	

^a Extrapolated from nutrient requirements for beef cattle (NRC, 1996), sheep (NRC, 1985) and goats (NRC, 1981a).

^b Estimated daily requirement based on a range of adult body weights from 60 to 160 kg.

^c Dietary concentration (mg/kg) on dry matter (DM) basis. Nutrient density calculations based on an assumed range of DM intake between 1.25 and 1.5 % of body weight.

^d Physiologic states of maintenance (M), growth (G), lactation (L) and pregnancy (P) for which the requirement is defined.

^e Maximum tolerable level (mg/kg), defined as largest dietary concentration of a given mineral that could be fed for short periods (3 month) without problems. Based on data from NRC, 1980.

Vitamin requirements

The vitamin requirements for camelids are, as for mineral requirements, not outlined (Van Saun, 2006). All complexes of vitamin B are synthesised by rumen microorganisms, as in other ruminants (Fowler, 1998b; Van Saun, 2006). Certain stress conditions or fermentation disorders can require vitamin B supplements. For camelids, the fat-soluble vitamins such as A, D and E are the most important (Van Saun, 2006). Extrapolations have been made to suggest requirements of fat-soluble vitamins for camelids (table 3).

Table 3. Suggested minimal llama and alpaca Vitamins A, D and E requirements for differing physiologic states, based on data derived from beef cattle and sheep (after Van Saun, 2006)

Nutrient	Average requirement ^a (IU/kg BW)	Extrapolated requirements		
		Intake ^b (IU/day)	Diet content ^c (IU/kg)	Group ^d
Vitamin A	45	2700-7200	3000-3600	M, G
	70	4200-11200	4700-5600	P
	88	5280-14080	3500-5900	L
Vitamin D	6 ^e	360-960	400-480	M, G, P, L
	30 ^f	1800-4800	2000-2400	M, G, P, L
Vitamin E	0.28	16.8-44.8	18.7-22.4	M
	1.1	66-176	73.3-88	G, P, L

^a Extrapolated from nutrient requirements for beef cattle (NRC, 1996) and sheep (NRC, 1985).
^b Estimated daily requirement based on a range of adult body weights from 60 to 160 kg.
^c Dietary concentration on dry matter (DM) basis. Nutrient density calculations based on an assumed range of DM intake between 1.25 and 1.5 % of body weight.
^d Physiologic states of maintenance (M), growth (G), lactation (L) and pregnancy (P) for which the requirement is defined.
^e These values may maintain minimal serum Vitamin D concentrations and may not prevent Vitamin D rickets.
^f Adjusted Vitamin D requirements, based on preliminary data suggesting a higher Vitamin D requirement of 25-30 IU/kg BW. Extrapolated requirements reflect this higher requirement for camelids.

Water requirements

Water intake depends on body weight, activity level, production level, dietary composition and environmental conditions. In general daily water intake is two to three times DMI, but there is a variation between animals on maintenance levels and lactating females. In hot or humid conditions, water intake can increase with 10-15 % daily (Van Saun, 2006). Intensively held alpacas in the central zone of Chile, fed lucerne hay *ad libitum*, consumed 2.15 litres of water per kg DM (Raggi *et al.* 1994).

Alpaca milk production

For the alpaca cria to consume 10 % of its body weight at 20 kg, the alpaca female should produce 2 kilos of milk (Fowler, 1998b). Daily alpaca milk production may range between 0.75 and 2.5 kg (Van Saun, 2006). The cria should double its birth weight during the first month. After that the dam will not produce all the caloric need for the cria. The llama cria consumes 2.5 litres of milk at the age of 49 days. Camelid crias begin tasting solid food at 7-10 days of age, but stomach proportion and effective rumination is not established until 2 month of age. In llamas, peak lactation is reached in the second to third week of lactation, and the lactation curve remains stable during 4 to 6 months (Johnson, 1994). Studies on alpaca lactation period have not been made. Morin *et al.* (1995) studied milk yield on 83 llamas. Regarding milk composition they discovered that llama milk was higher in sugar and lower in fat and energy when compared to milk from true ruminants. Llama milk also contained more calcium but less sodium, potassium and chlorine.

There are no registrations on alpaca milk yield but Parraguez *et al.* (2003) studied milk composition in two groups of alpaca females, from parturition and every 30 days until 5 month of lactation. One group of 24 animals was held in the Andean high plateau, 4400 metres above sea level. The other group of 18 animals was held in the Patagonian region, 12 metres

above sea level. Natural pastures were fed *ab libitum* to both groups. Milk content of protein, fat, lactose, DM and ash was measured and compared between groups and month (table 4).

Table 4. Alpaca milk composition (percent WW \pm SD) in the Andean high plateau (AHP) and in the Patagonia (P) (after Parraquez *et al.*, 2003)

M	Dry matter		Protein		Fat		Lactose		Ash	
	AHP	P	AHP	P	AHP	P	AHP	P	AHP	P
1	17.4 \pm 1.2 ^{a*}	15.3 \pm 0.4 ^{ab}	7.0 \pm 0.8 ^{ac}	6.2 \pm 0.6 ^{ab}	3.7 \pm 0.5 ^{ac*}	1.4 \pm 0.3 ^a	5.3 \pm 0.1 ^a	5.6 \pm 0.2 ^a	1.3 \pm 0.1 ^{ac}	1.8 \pm 0.4 ^a
2	17.4 \pm 1.2 ^{a*}	14.6 \pm 0.3 ^a	6.5 \pm 0.4 ^{bc*}	5.7 \pm 0.2 ^b	5.1 \pm 0.1 ^{b*}	2.1 \pm 0.6 ^{ab}	4.0 \pm 0.3 ^b	5.5 \pm 0.3 ^{a*}	1.1 \pm 0.3 ^a	1.3 \pm 0.0 ^b
3	16.6 \pm 1.5 ^b	15.8 \pm 0.6 ^{bc}	7.2 \pm 1.1 ^{ab}	6.5 \pm 0.6 ^{ac}	3.6 \pm 0.4 ^{ac}	2.5 \pm 0.6 ^{bc}	4.2 \pm 0.2 ^b	5.2 \pm 0.1 ^{b*}	1.6 \pm 0.1 ^{bc}	1.6 \pm 0.0 ^{ab}
4	15.9 \pm 1.4 ^b	16.2 \pm 0.3 ^{bc}	6.8 \pm 0.8 ^{bc}	6.8 \pm 0.2 ^b	2.9 \pm 0.6 ^c	3.0 \pm 0.5 ^{dc}	4.5 \pm 0.0 ^b	5.1 \pm 0.0 ^{b*}	1.7 \pm 0.2 ^{bc*}	1.2 \pm 0.0 ^b
5	16.7 \pm 0.9 ^b	16.9 \pm 1.2 ^{bc}	7.1 \pm 0.9 ^{ac}	7.2 \pm 0.0 ^b	3.5 \pm 0.6 ^{ac}	4.0 \pm 0.4 ^d	4.1 \pm 0.1 ^b	4.4 \pm 0.1 ^{c*}	2.0 \pm 0.4 ^{b*}	1.3 \pm 0.1 ^b
Mean	16.8 \pm 0.7	15.8 \pm 0.6	6.9 \pm 0.3	6.5 \pm 0.3	3.8 \pm 0.6 [*]	2.6 \pm 0.5	4.4 \pm 0.5	5.2 \pm 0.5 [*]	1.7 \pm 0.3	1.4 \pm 0.1

Superscripts indicate significant difference ($p\leq 0.05$) among months in each column.

Asterisk indicates significant difference ($p\leq 0.05$) for each milk component between groups in the same month or in the mean value.

M = Month.

Colostrum

Most species require 8-10 % of their birth weight in colostrum during their first 18-24 hours, which also is recommended for llama neonates (Johnson, 1994). Specific information about alpaca colostrum is not published, but studies have shown that nutrient content of llama colostrum is lower in fat than colostrum from horse, rabbit, sheep or cattle. Regarding substitute colostrum to crias, milk from cow or goat has been recommended, although the milk composition has shown to be not as important for substitute feeding. Although low in fat, llama milk is rich in lactose which provides a good energy source (Johnson, 1994).

Wool utilization

Selecting for a small number of guard hair during the long preiod of domestication has lead to alpaca wool with decreased amounts of guard hair, which is presented on the wild guanaco and vicuña and many llamas (Hoffman, 2006). Selective breeding of alpacas has led to a uniform coat with decreased amounts of guard hairs (Couchman, 1992). The wool fibre is measured both in subjective criterias (handling, luster) and objective criterias (diameter, amount of fiber $>30\mu$, CV and SD variance, weight, growth rate, density, contamination, elasticity and strength). The diameter of the wool fibre is measured in microns, and states the fineness of the fiber (Hoffman 2006).

Materials and methods

Animals

The study was carried out at an alpaca farm in the south of Sweden from October to early December in 2006. The animals used in this study were two groups of females, with and without crias respectively. The group with crias consisted of twelve females and their offspring, who were two to five month old when the study started. The other group involved thirteen females without offsprings. All the animals were of Huacaya breed and the mares were between 10 months and 5 years old when the study started.

Feeding and management

The animals were housed groupwise in a free ranging system with access to an indoor area and exercise paddocks with grass, where they usually also were housed. Hay was used as bedding material in the stable until trial day 40, and thereafter straw was used as bedding material. They were fed once a day and they all had free access to fresh water. Water was served from a bucket to the non-lactating females, and from an automatic water bowl fitted with a float valve to the lactating females and crias.

Both groups were fed roughage *ad libitum* once a day. Roughage composition is shown in table 5 and 6. Roughage was supplemented with rations of a mineral feed (1 gram per kg BW) (table 7), fed in buckets to all females and two of the crias individually once a day.

Table 5. Forage composition (per kg forage) fed to the two groups

	Non-lact. group	Lact. group
Heat-dried Lucerne	50 %	75 %
Grass hay	40 %	20 %
Molasses	5 %	2.5 %
Vegetable oil	5 %	2.5 %

Table 6. The nutritional value per kg forage

	Non-lact. group	Lact. group
Energy (MJ)	9.0	8.75
Water (%)	12.0	12.0
Crude Protein (%)	10.1	12.55
Digestible Protein (g)	65.0	85.0
Magnesium (g)	2.0	1.8
Crude Fat (%)	3.0	3.0
NDF (%)	28.0	27.5
Calcium (g)	9.0	11.0
Phosphorus (g)	2.0	2.4

Table 7. The nutritional value per kg supplement

Crude Protein (%)	13.931
Water (%)	10.159
Calcium (g)	10.598
Phosphorus (g)	8.000
Sodium (g)	3.95
Magnesium (g)	1.360
Potassium (g)	3.305
Sulphur (g)	0.104
Copper (mg)	208.326
Iron (mg)	497.690
Selenium (mg)	2.040
Zinc (mg)	294.284
Iodine (mg)	15.270
Manganese (mg)	168.239
Cobalt (mg)	3.118
Vit. D3 (mg)	10000.0
Salt (%)	0.8

Experimental design

The experimental diet was introduced gradually during a period of two weeks (figure 1). The animals were fed grass-hay before the study began, and the experimental forage was mixed into the hay with an increase of 7 % each day for 14 days. In the following six weeks the animals were fed according to the experimental feeding strategies. The individually mineral rations started on trial day 22. The collection of faeces was on study day 50 to 54 (figure 4), when one sample of faeces from each animal was collected each day. Samples of faeces from individual crias could not be collected daily.

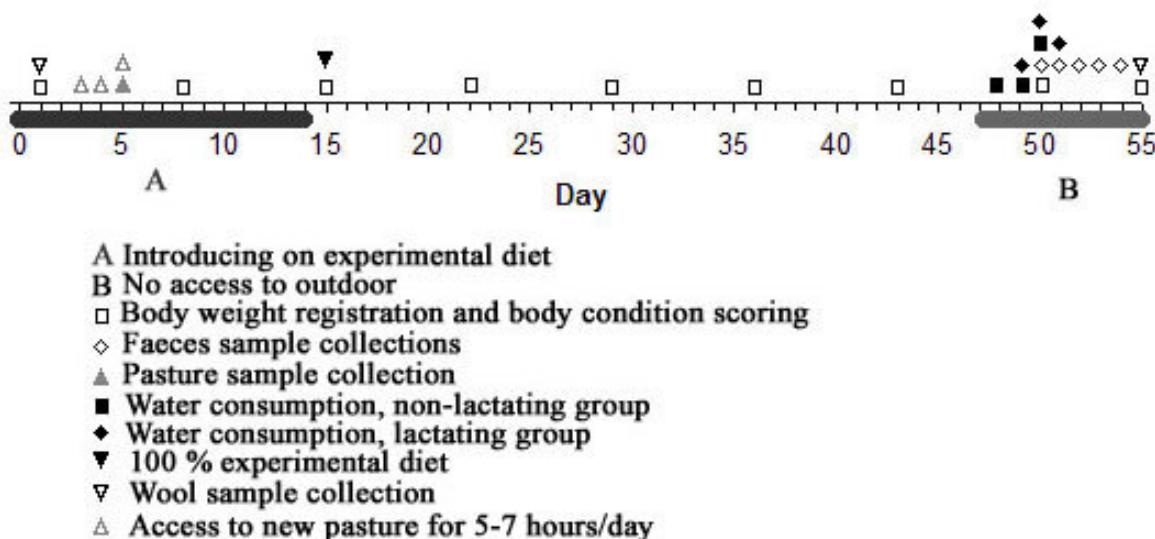


Figure 4. Experimental scheme on 55 day alpaca feeding trial

The experimental diet was based on the energy requirements for maintenance of 0.35 MJ/kg BW^{0.75} (Carmean *et al.*, 1992), and lactational requirements of 3.3 MJ/kg milk (Johnson, 1994; Parraguez *et al.*, 2003). An estimation of 2 kg milk production per day (Fowler, 1998b; Van Saun, 2006) was used. Protein requirements was based on 2.38 g digestible protein/kg BW^{0.75} (Huasasquiche, 1974) which is equivalent to 3.5 g CP/kg BW^{0.75} (Van Saun, 2006) on maintenance level. Protein requirements to meet lactational needs was based on a mean value of 67 g protein per kg milk (table 1) (Parraguez *et al.*, 2003) divided by a net protein value of 56.1% (NRC, 1985) which gives 119.4 g CP/kg milk.

Registrations, samples and analyses

Feed, water and salt

A sample from the feed given was taken once a week. On the next day feed refusals were collected, weighed and stored at -20°C until analysis of chemical composition. Pasture samples were taken once from two different pastures, on study day 5, and stored at -20°C until analysis of chemical composition. All samples were analysed in regards of DM (dried in 103°C in 16 hours), ash (dried in 550°C in 3 hours), organic matter (OM) (*in vitro*) (Lindgren, 1979), CP (Kjeldahl-nitrogen times 6.25) using a 2020 Digestor and a Kjeltec 2460 Analyzer Unit (Foss Analytical A/S Hillerød, Denmark) (Nordic Committee on Food Analysis Nr 6, 3rd ed., 1976), acid insoluble ash (AIA) (Van Keulen and Young, 1977), neutral detergent fibre (NDF) (Chai and Udén, 1998) using a 100 % detergent solution with

both sulphite and amylase. Analyses in regards of the minerals calcium, phosphorus, magnesium, potassium, sodium, sulphur, copper, manganese, iron and zinc was done by Agrilab AB, Uppsala, with Inductively Coupled Plasma Optical Emission Spectrometry (SS-EN 14538:2006).

Water consumption was measured for three days (trial day 48-50 for non-lactating females and trial day 49-51 for lactating females and crias, figure 1) in each group. The surrounding temperature during these days was 7°C.

One block of salt was placed in the stable pens in each of the animal groups. One control salt block was placed on a table out of reach by the animals. The blocks were weighed before and after the study.

Faeces

On study day 50 to 54 individual faeces samples were collected once daily from all females and most of the crias (figure 1). All samples were analysed in regards of DM, ash, CP, acid insoluble ash (AIA), neutral detergent fibre (NDF), calcium, phosphorus, magnesium, potassium, sodium, sulphur, copper, manganese, iron and zinc.

Body weight and body condition scoring

The weight of all animals was registered once a week throughout the study (figure 5). On the day of weighing and body scoring scoring (figure 4), the animals were fed supplements before weighing. The animals were weighted on an portable electronic scale.

After every weighing each animal was body condition scored according to a five degree scale (appendix 1). The animals were assessed on the lumbar area. A thin alpaca has a concave feeling of the lumbar musculature between the dorsal and transverse spinous processes of the lumbar vertebrae. An animal in optimal condition has a musculature at the lumbar area with a 45 degree slope. In an overconditioned animal, the tissue is convex between the spinous processes (appendix 1). Assessment of the pelvis should not be done in alpacas, as it is done when scoring sheep and cattle, since even an overconditioned animal will appear thin. This is because their muscular and adipose tissue distribution is different from sheep and cattle (Carmalt, 2000).

Wool samples

Wool samples were collected on the first and the last day of the study (day 1 and 55, figure 4). Samples were taken from all animals except two females, who were too nervous to handle. The samples were taken from the front of the neck curvature, on either the right or the left



Figure 5. The scale was placed in the stable every week for weighing

side, in level with the jugular vein. All wool samples were analyzed for micron numbers (Laserscan IWTO 12) (Wool Testing Authority Europe Ltd, 2007).

Calculations

Digestibility *in vivo* was calculated according to Olsson (2007). AIA was used as a marker in both forage and faeces. Digestibility (%) was calculated as $[1 - (\text{value in faeces/AIA in faeces}) / (\text{value in forage/AIA in forage})] * 100$, with values (DM, NDF, CP, OM, minerals) and AIA in g/kg DM.

Digestibility of the OM was calculated according to Lindgren (1983), where the digestibility of the OM (%) equals $0.90 * \text{VOS}(\%) - 2.0$ for forages with less than 50 % legumes, and $0.62 * \text{VOS}(\%) + 23.0$ for forages that contain more than 50 % legumes.

Results

General observations

The mean surrounding temperature during the study was +7°C. The lowest temperature was recorded on day 22 in the study, with -4°C and snowfall. The highest temperature was +13°C on study day 26 and 27. The mean surrounding temperature on study day 48 to 51, when daily water intake was measured, was +7°C.

One lactating female and her cria were taken out of the trial on day 32 because of animal owner decision.

Dry matter intake

The average DMI during the 55 day period (figure 6) was 6.0 kg DM/kg BW for the non-lactating group and 8.4 kg DM/kg BW for the lactating group with crias. The DMI increase started earlier and was faster in the lactating group than in the non-lactating group. The average DMI during the five day fecal sampling period was 1.13 kg DM/kg BW for the non-lactating group, which equals to an average of 1.4 % of BW/day and 1.2 kg DM/kg BW for the lactating group, which equals to an average of 1.8 % of BW/day (figure 7). There was a difference in DMI between groups and days ($P < 0.001$).



Figure 6. All the feeding in the pens was in buckets

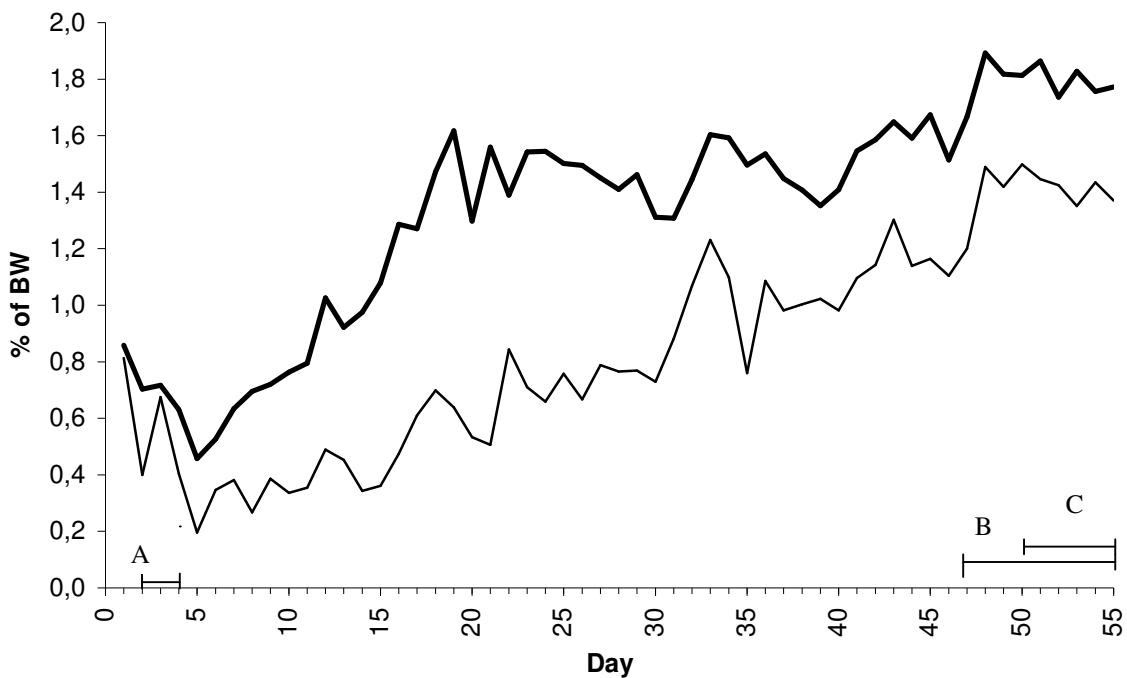


Figure 7. Feed intake (% of BW) for non-lactating female alpacas (thin line) and lactating female alpacas with crias (thick line). A: Access to new pasture for five to seven hours. B: No access to outdoor. C: Fecal sampling

Energy intake

Daily energy intake was on average 0.1 MJ/kg BW for the non-lactating females and 0.16 MJ/kg BW for the sum of the bodyweight of lactating females and their crias (figure 8). Energy intake during the 55 day period varied with the lowest value at 0.037 and the highest value at 0.153 MJ/kg BW for the non-lactating females and 0.107 to 0.187 MJ/kg BW respectively for the lactating females and crias. The increase in energy intake was parallel to the increase in DMI. The average energy intake during the fecal sampling period was 0.14 MJ/kg BW/day for the non-lactating group and 0.18 MJ/kg BW/day for the lactating group. During the study when the animals had outdoor access (day 15-46 in the study), the energy intake varied between 0.037 and 0.133 MJ/kg BW in the non-lactating group, and between 0.107 and 0.166 MJ/kg BW in the lactating group. When the animals had no outdoor access (period B in figure 8) the energy intake varied between 0.122 to 0.153 MJ/kg BW for the non-lactating group and 0.165 to 0.187 MJ/kg BW in the lactating group.

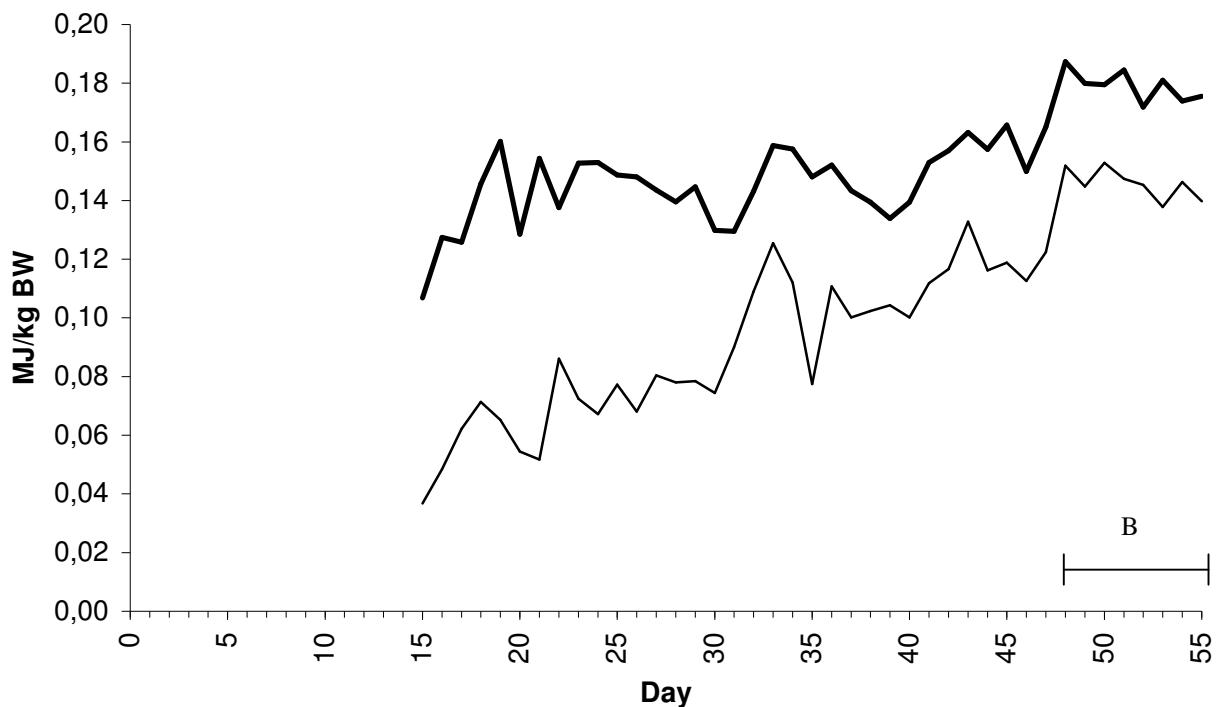


Figure 8. Energy intake (MJ/kg BW) for non-lactating female alpacas (thin line) and lactating female alpacas with crias (thick line). B: No access to outdoor

Body weight and body condition scoring

For the adult animals, there was a difference in body weight between days ($P < 0.0001$) (figure 9). There was no difference between groups ($P = 0.4183$). Mean body weight if the crias is presented in figure 10. Cria weight gain, in percent of BW when the study began, is described in figure 11.

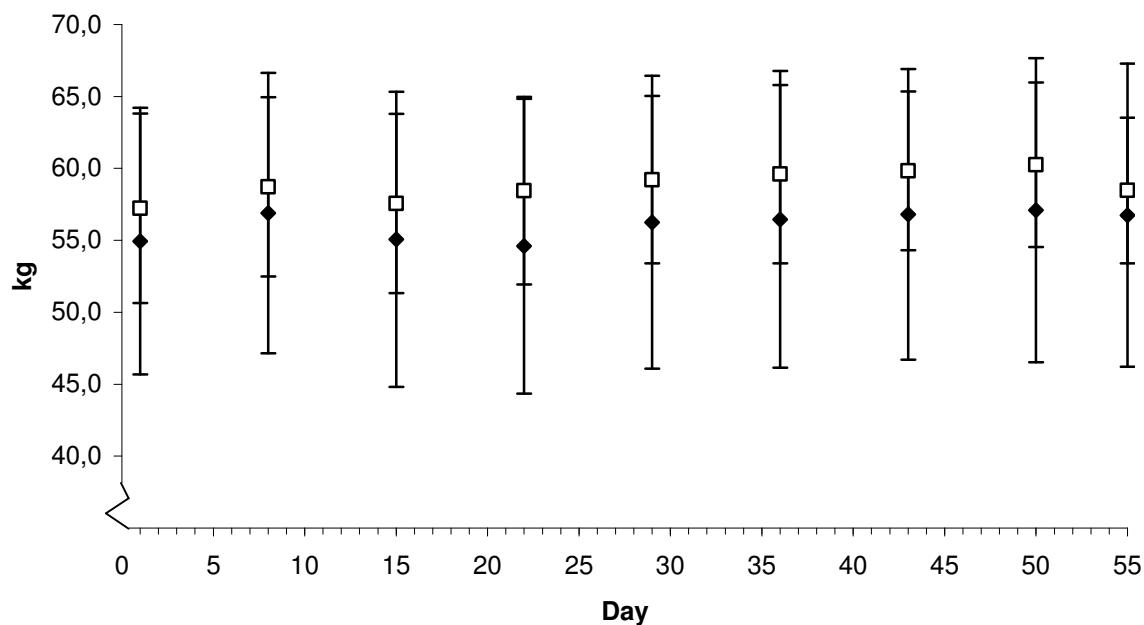


Figure 9. Mean body weight (kg) for non-lactating (black) and lactating alpacas (white)

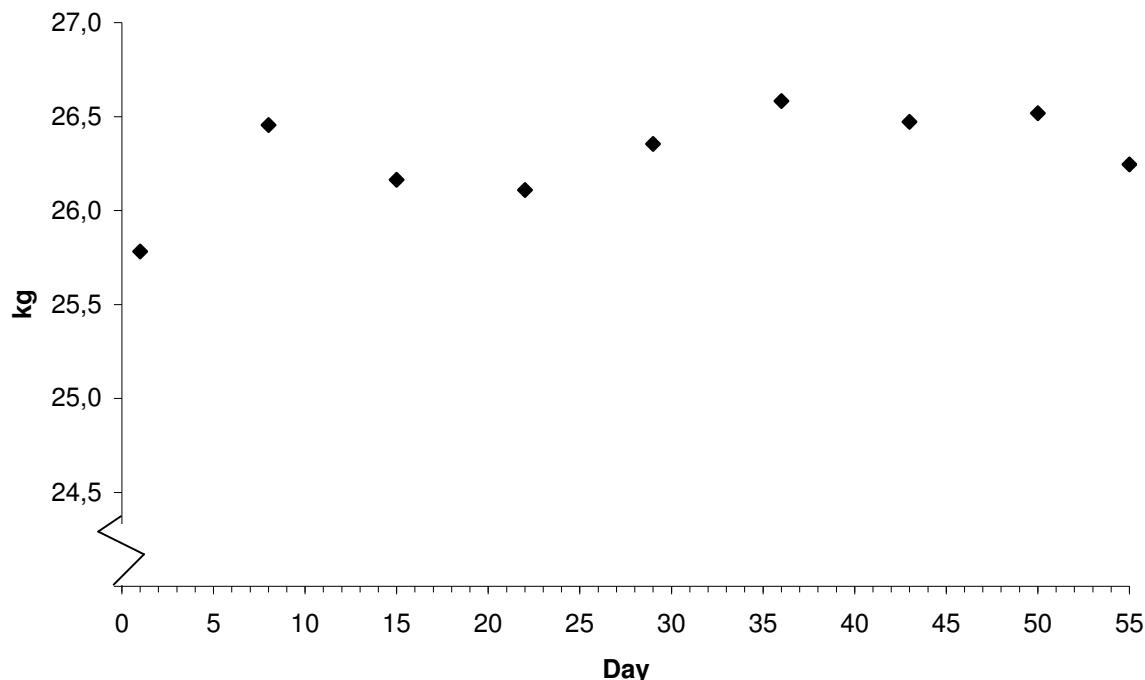


Figure 10. Mean weight (kg) for the cria alpacas

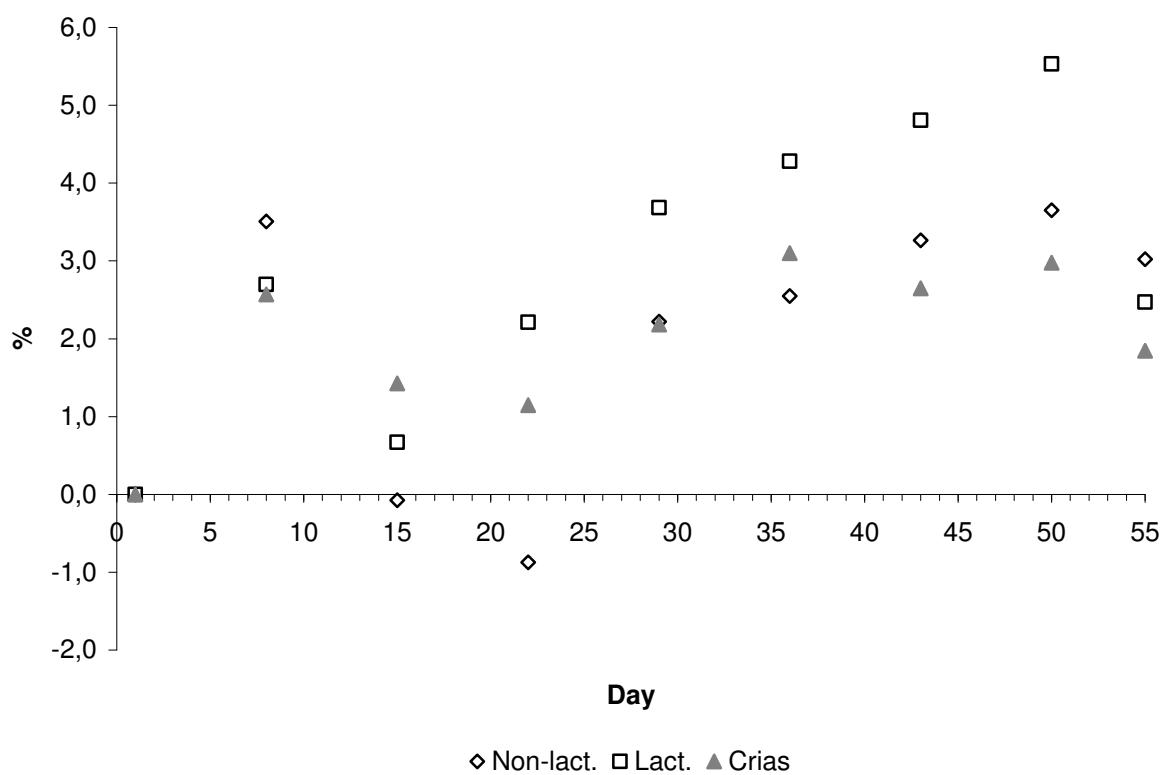


Figure 11. Weight gain (% of BW) in non-lactating, lactating alpacas and crias

Lactating females showed an increase in body condition score ($P = 0.07$) during the study. In the beginning of the study, there was a significant difference in body condition score between non-lactating and lactating females ($P = 0.01$). The non-lactating females had in general

higher scores than the lactating females (figure 12). The body condition score in the non-lactating group did not differ between beginning and end of the study ($P = 0.16$).

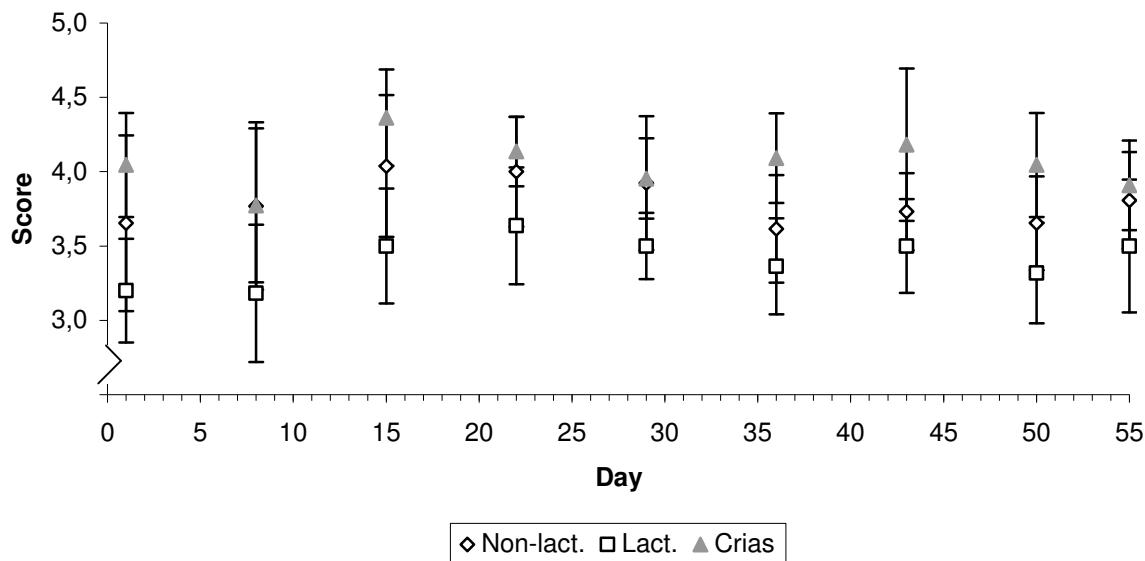


Figure 12. Mean body score for non-lactating females, lactating females and crias

Mineral feed intake

Supplement intake differed between days ($P < 0.0001$) but not between groups ($P = 0.2688$) and there was no interaction between group and day (figure 13).

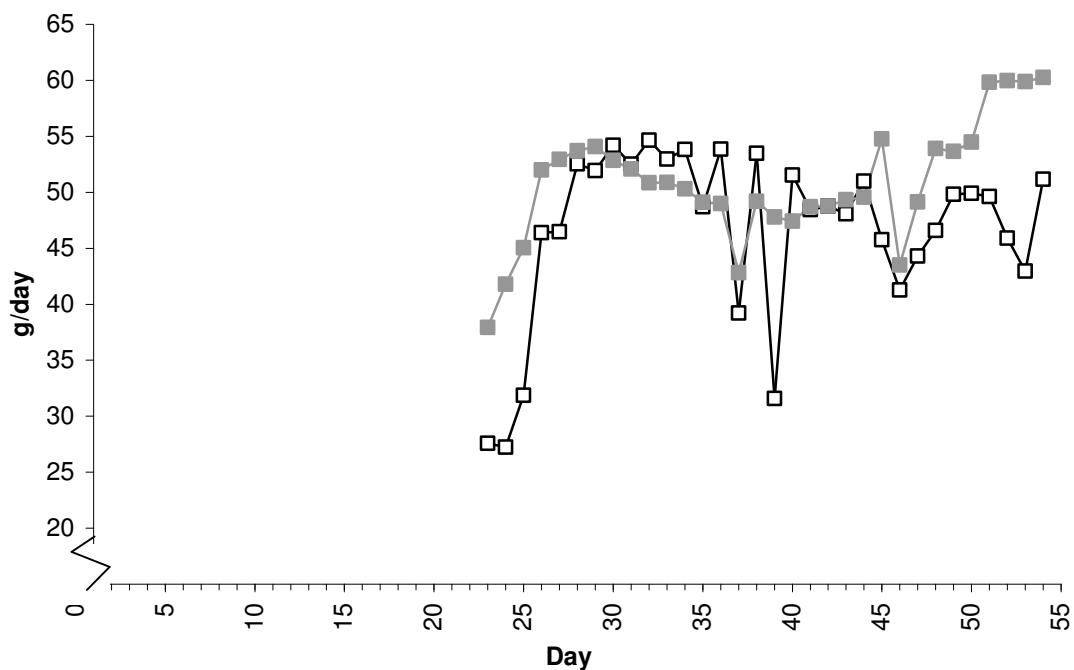


Figure 13. Intake of supplements (g/day) in non-lactating (white) and lactating (grey) alpacas

Water intake and weight of salt blocks

Daily water intake varied between 13 to 38 ml/kg BW for non-lactating females and 34 to 54 ml/kg BW for lactating females and crias (table 8). Water intake per kg DMI varied between 1.2 to 3.6 ml/kg DMI for non-lactating females and 1.9 to 3.1 ml/kg DMI for lactating females and crias.

Table 8. Daily water consumption (ml/kg BW) on non-lactating and lactating alpacas

	Day 1 (ml/kg BW)	Day 2 (ml/kg BW)	Day 3 (ml/kg BW)	Mean ± std dev (ml/kg BW)
Non-lac.	26	38	13	26±12.5
Lac.	54	34	43	44±10

Measurement of salt intake in the non-lactating group failed. The salt blocks were highly influenced by the atmospheric humidity. The salt intake in the lactating group was 0.0014 g/kg BW/day. The control block was reduced with 10.3 g.

Digestibility

The nutrient composition and energy content of forages fed, refusals and pasture varied between the two groups of non-lactating and lactating alpacas (table 9). The contents of NDF in the feed was higher in the refusals. The two pastures contained 10.3-10.7 MJ/kg DM and 254-266 g CP/kg DM, and also contained the lowest values of NDF. Higher NDF values were found in the refusals, 578-587 g/kg DM.

Table 9. Nutrient values of feed (per kg DM)

	Forage (non-lact.)	Forage (lact.)	Refusals (non-lact.)	Refusals (lact.)	Pasture (non-lact.)	Pasture (lact.)
Energy (MJ)	9.5	8.9	8.6	8.4	10.3	10.7
Crude protein (g)	106.8	134.2	69.1	87.0	266	254
NDF (g)	471	446	587	578	432	430
Calcium (g)	7.2	10.8	5.1	6.1	4.3	5.8
Phosphorus (g)	1.8	1.9	1.7	1.6	5.4	4.5
Magnesium (g)	1.1	1.3	0.8	0.9	2.4	2.2
Potassium (g)	20.4	20.5	20.2	19.9	40.9	27.9
Sodium (g)	1.0	1.0	0.8	0.9	0.04	0.7
Sulphur (g)	1.4	1.6	1.0	1.0	3.1	4.1
Copper (mg)	3.4	3.8	2.4	3.8	7.1	8.7
Manganese (mg)	35.5	21.5	24.1	22.2	157.1	188.3
Iron (mg)	172.4	100.2	133.8	103.7	549.7	151.7
Zinc (mg)	23.7	18.5	23.1	21.1	43.7	39.1

The digestibility was lower in the refusals than in the forage (table 10). The lactating females had numerically higher digestibility of roughage than the non-lactating females (table 10 and 11). Digestibility of minerals was generally higher for the lactating females (table 12). The crias had the lowest value of both DM, NDF and OM in regards of fecal composition. The fecal composition of the lactating females was lower in both NDF and OM when compared to non-lactating female fecal composition (table 13). The fecal composition of minerals was for the lactating females lower in the micro-minerals. Cribs had significantly higher values of Ca, P and Fe (table 14).

Table 10. Calculated *in vivo* digestibility of OM (%) calculated from VOS-analysis (Lindgren, 1983)

	Forage	Refusals	Pasture
Non-lact.	60.6	51.5	76.0
Lact.	62.2	58.6	75.9

Table 11. Digestibility of consumed forage (%) in digestibility study in non-lactating and lactating alpacas

	DM	NDF	CP	OM
Non-lact.	69.0	62.0	70.0	69.6
Lact.	74.0	68.0	77.4	74.5

Table 12. Digestibility of minerals (%) in digestibility study in non-lactating and lactating alpacas

	Ca	P	Mg	K	Na	S	Cu	Mn	Fe	Zn
Non-lact.	13.3	9.4	8.8	89.3	63.8	48.8	-183.2	-4.9	-31.9	-83.3
Lact.	24.9	42.2	22.2	91.2	34.3	58.0	-107.5	-17.6	-31.4	-73.7

Table 13. Mean values of fecal composition in non-lactating alpacas, lactating alpacas and crias in regards of DM, NDF, CP and OM

	DM	NDF	CP	OM
Non-lact.	94,98 %	541 g/kg DM	113,5 g/kg DM	930,8 g/kg DM
Lact.	95,16 %	512 g/kg DM	126,5 g/kg DM	924,2 g/kg DM
Crias	94,58 %	448 g/kg DM	137,1 g/kg DM	871,0 g/kg DM

Table 14. Mean values of fecal composition in non-lactating alpacas, lactating alpacas and crias in regards of minerals

	Ca g/kg	P g/kg	Mg g/kg	K g/kg	Na g/kg	S g/kg	Cu mg/kg	Mn mg/kg	Fe mg/kg	Zn mg/kg
Non-lact.	21.8	6.0	3.5	6.7	1.3	2.4	31.4	124.1	789.1	134.6
Lact.	34.3	4.9	4.1	6.6	1.4	2.6	29.1	92.4	488.9	112.6
Crias	38.2	16.2	4.4	5.7	0.9	3.0	23.5	114.1	1643.5	126.8

Wool micron numbers

There was no difference in wool micron numbers before and after the study for non-lactating and lactating alpaca females (figure 14 and 15). The micron numbers after the feeding trial were slightly higher for the crias (figure 16).

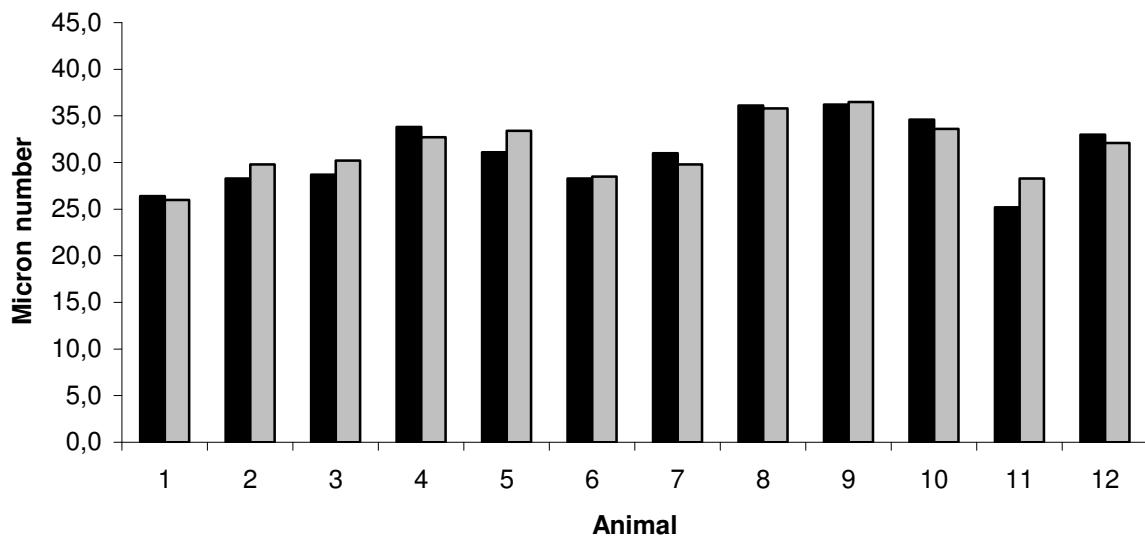


Figure 14. Micron numbers before (black) and after (grey) the feeding trial for non-lactating alpaca females. Samples are from the neck, and taken in the beginning of October (black) and the beginning of December (grey)

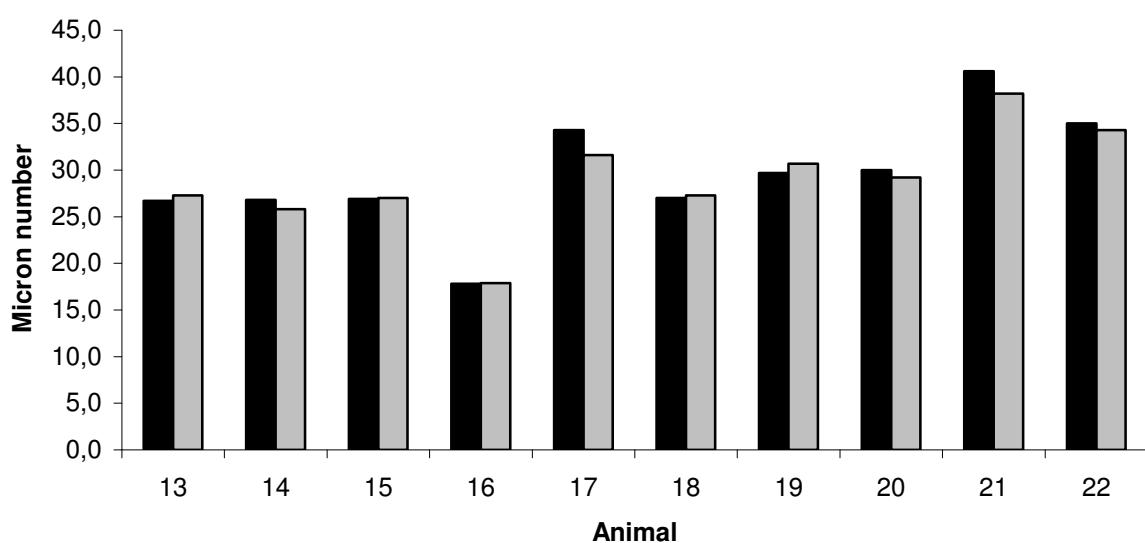


Figure 15. Micron numbers before (black) and after (grey) the feeding trial for lactating alpaca females. Samples are from the neck, and taken in the beginning of October (black) and the beginning of December (grey)

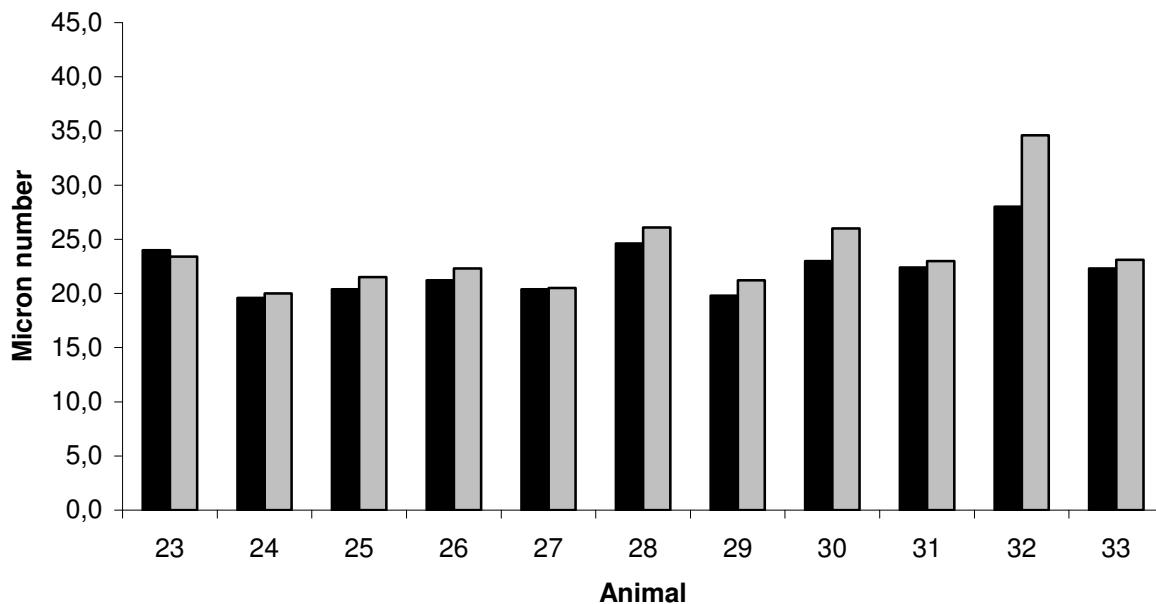


Figure 16. Micron numbers before (black) and after (grey) the feeding trial for alpaca crias. Samples are from the neck, and taken in the beginning of October (black) and the beginning of December (grey)

Discussion

All the animals selected their feed, shown in the high NDF contents in the refusals (table 7). Both groups selected the forage with highest nutritional content first, and did very well on this nutritional intake, but were also feeding on coarser feed particles.

Selection of feed varied within the groups, which gives some insecurity in the digestion coefficients (table 9). The digestion coefficients correspond well with the digestion coefficients of llamas and guanacos found by Hintz *et al.* (1973). Lactating females also had higher digestion coefficients than non-lactating females (table 10). The higher digestibility seen in lactating females may be due to the higher amount of lucerne in their diet. Negative digestion coefficients of minerals were found in both groups for copper, manganese, iron and zinc, which means that the concentration of the substance was higher in the faeces than in the forage. These values may be insecure as the concentration of microminerals in both forage and faeces were very low and there is a risk for measurement errors.

DMI during trial day 47-55, when the animals had no outdoor access, was slightly lower than previously stated in the litterature (San Martín and Bryant, 1989; Van Saun, 2006), but higher than the values found by Raggi *et al.* (1994) and López *et al.* (1998). During the period from when the animals were feeding on only experimental diets (day 15 to 55), the DMI increased with almost 1 %/BW for both groups. DMI was surely affected by the fact that the animals had outdoor access, and that they feed a bit on the bedding, especially as the bedding until day 40 was hay, and thereafter straw. Feed consumption was higher when straw was used as bedding than when hay was used, which suggests that the animals consumed more of the hay-bedding than of the straw-bedding.

The experimental diet was based on the diet fed to the alpacas before the study started, which was hay in *ad libitum* and some lucerne. In comparison the experimental diet was higher in

energy and protein than the diet used before the trial, though it was not at the protein level recommended for lactating female alpacas. The results from this feeding trial show that the alpacas select feed high in protein and energy, leaving the coarse parts. The pastures provided for the animals in the summertime when the females were in peak lactation, was high in protein and energy even in October. As the animals were healthy and most of them had desirable body condition score when the trial started, which was when their lactation curve was going down. This indicates that alpaca females in peak lactation are in need of forage rich in energy and protein, comparable with at least the values in the pastures in table 9, in order to maintain desirable body condition score and milk production when in peak lactation. When milk production is increased, the nutritional needs also increases. The lactating females maintained their body condition very well during the trial period, which took place during lactation month 3-7 as the crias in the group were of different ages. The females even showed an increase in body condition score. This indicates that their nutritional needs were met, and they might also do well on somewhat less in nutritional intake during this stage in lactation.

Energy intake for the non-lactating females was slightly higher than the recommended energy intake for maintenance (Carmean *et al.*, 1992; Johnson, 1994). Energy intake for the lactating females was lower than what is recommended, if they produce 2 kg milk a day (Johnson, 1994; Fowler, 1998; Parraguez *et al.*, 2003). However, the fact that crias did not increase in body weight during the study may indicate that milk production was low in the females, but the low weight gain in crias may also be due to a seasonal growth pattern.

Body condition was relatively steady during the trial period, for all animals. It is likely that the variation in body condition scoring in this study was due to my own inexperience, and my own references were a bit different from week to week. Also, it was difficult to make the animals stand in exactly the same position during scoring each week, which might have affected the results. Both the non-lactating and lactating females gained slightly in weight during the trial period. The crias did not gain body weight during the trial period. During the procedure of weighing, it was a challenge to have the scale in exactly the same position each week, as it was built up every week, and this might have affected the results. According to San Martín (1991), crias have a low body weight gain during their first year. This might be comparable to the seasonal variation in body weight gain seen in lambs; who have lower body weight gain during the dark period of year when daylight is shorter and this is not compensated with artificial light (Meiner, 2007).

Water intake per kg DMI varied between 1.2 to 3.6 ml/kg DMI for non-lactating females and 1.9 to 3.1 ml/kg DMI for lactating females and crias. These values are much below the water intake for intensively held alpacas in Chile, fed lucerne hay *ad libitum*, which consumed 2150 ml/kg DMI (Raggi *et al.* 1994). Water intake by male llamas varied between 1700 to 1900 ml/kg DMI in a study by Engelhardt and Schneider (1977). Mengistu *et al.* (2005) studied water intake of Ethiopian Somali Goats, when watered once a day consumed 2170 ± 0.1 ml/kg DMI.

The results of the salt intake measurements agree with the literature that camelids do not use their tongue to lick on salt blocks (Flower, 1998b).

When offered energy and protein rich roughage *ad libitum*, young animals, pregnant and lactating females may still need a supplement of concentrate to fulfill their nutritional requirements. With a high quality forage (around 10-11 MJ and 160-170 g CP/kg DM) this

supplement does not need to be more than 0,5 kg of a commercial concentrate (around 11 MJ and 140 g CP/kg) for any category of animals. Another alternative is high-fat oats, which have a lower starch content than standard oats. The risk of acidosis and gastric ulcers for alpacas is unclear. According to Van Saun (2007) gastric ulcers have been associated with high grain diets, but in nearly all cases other circumstances contribute to acidosis problems. Van Saun (2007) states that diets that provide more grain than roughage is clearly too high grain diets for alpacas, and that the amount of grain that can be fed varies with the type of starch and how it is processed. There is no research documenting the amount of starch that can be fed safely, but according to Van Saun (2007) the recommendation for horses at 2 g starch/kg BW may also be reasonable for alpacas.

In different studies male SAC on maintenance nutritional level has been fed between 0.003-0.015 kg cereal based concentrate/kg BW (Vallenás and Stevens, 1970; Heller *et al.*, 1985; Carmean *et al.*, 1992) without signs of GI-tract problems such as acidosis or gastric ulcers. The amount of grain needed to induce acidosis in camelids may be smaller than for true ruminants. Acidosis has occurred in camelids fed diets with 0.15-1 kg corn, oat and barley mix a day (Cebra *et al.*, 1996). The risk of acidosis may be higher in excessive grain diets or aggressive eating behaviour, and is induced with products containing mostly processed barley and corn grain (Van Saun, 2006a). Llamas have, in different studies, been fed 50 % of their daily intake of hay and 50 % concentrate with no problems with acidosis (Carmean *et al.*, 1992, Johnson, 1994).

A source of error in the wool micron number analysis could be the very small amount of sample analysed from each animal. The slightly higher values in the crias after the study may be because they grew older, as the micron number is lower with a lower age.

Sammanfattning

Alpackan härstammar från Sydamerika, där den hålls i huvudsak som ullproducent, men också för kött och tillverkning av rep, mattor och prydnader av skinnen. Alpackan hör till familjen kameldjur och är ett partåigt hovdjur. Alpacka, vicuña, lama och guanaco är de inom familjen som härstammar från Sydamerika och kallas därför också för South American Camelids (SAC). Till familjen hör också den baktriska kamelen och dromedaren.

SAC är anpassade för att tillgodogöra sig föda med högt fiberinnehåll, som de livnär sig på under torrperioden i Sydamerika. Men denna hårda tillvaro innebär också att många djur lider av undernäring, vilket påverkar ulltillväxten negativt, reproduktionsfunktionerna blir sämre, inklusive ökad földödlighet.

Antalet alpackor och lamor utanför Sydamerika ökar sedan de började exporteras i början på 1980-talet. I nya miljöer utsätts djuren för andra former av djurhållning och nya fodermedel. Många alpackaägare är tveksamma till att utfodra sina djur med foder som har ett högt innehåll av protein och energi. Man är också rädd för att utfodra med kraftfoder, då magsår anses vara vanligt hos alpackor. Kunskapen om alpacka utfodring baseras idag till stor del på studier av lama eller extrapolerade värden från nötkreatur, får och getter. Det finns inga specifika studier på alpacka när det gäller energi-, mineral- eller vitaminbehov.

Alpackan är en effektiv foderomvandlare, speciellt på foder med högt fiberinnehåll och lågt proteininnehåll. I jämförelse med nötkreatur, får och getter är alpackan också bättre på att

återvinna kväve genom recirkulation av urea. Alpackan har en förmåga att lätt anpassa sig till nya miljöer, speciellt med avseende på altitud och temperatur.

Kameldjur har till skillnad från de traditionella idisslarna, nötkreatur, får och get, endast tre avdelningar i magen. I de första två avdelningarna finns slemproducerande körtlar. Den sista avdelningen har samma funktioner som både bladmagen och löpmagen hos traditionella idisslare. Körtlarna i de första två avdelningarna producerar bikarbonat, som bidrar till att pH i förmagarna hålls närmre neutralt. Förutom sin buffrande verkan gör pH också att fibrer bryts ned effektivare, samt att de flyktiga fettsyrorna absorberas längsammare.

I den här studien utfördes ett utfodringsförsök på en gård i södra Sverige under oktober till början av december 2006. Försöket pågick under 55 dagar och omfattade studier av foderintagskapacitet, smältbarhet och kroppsvikt. Djuren som ingick i försöket var tretton ston utan föl och tolv ston med sina respektive föl.

Enligt litteraturen har alpackor ett torrsubstansintag på 1,25-1,5 % av kroppsvikten för underhållsbehov. Lakterande ston kan konsumera 2,0-2,75 % av kroppsvikten. I detta utfodringsförsök låg torrsubstansintaget på 1,4 % av kroppsvikten för icke-lakterande ston, respektive 1,8 % för lakterande ston. Energiintaget för icke-lakterande ston och lakterande ston var 0,14 MJ/kg kroppsvikt respektive 0,18 MJ/kg kroppsvikt, vilket är något lägre än de värden funnit tidigare i studier med lamor.

Alla stona ökade i vikt under föröksperioden. Fölen ökade dock inte alls i vikt. Endast de lakterande stona hade en liten ökning av hullpoäng under perioden. De lakterande stona hade också högre smältbarhetskoefficienter än de icke-lakterande stona, både när det gäller torrsubstans, NDF, råprotein, organisk substans och mineraler.

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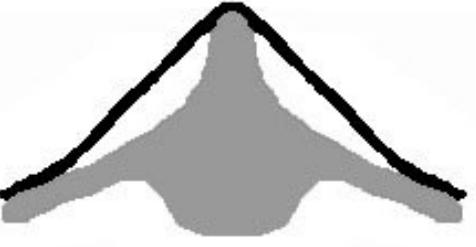
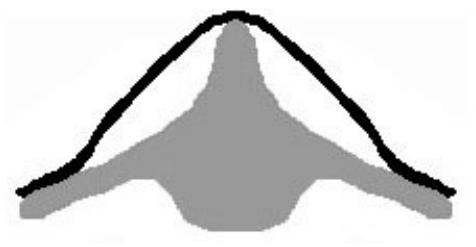
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Appendix 1. Body condition scoring sheet

Score	Description	Lumbar area
1.0	No palpable muscles at the lumbar area.	
2.0	Concave shape of the lumbar area.	
3.0	Moderate condition. 45 degree slope of lumbar area.	
4.0	Slight convex shape of the lumbar area.	
5.0	Can not feel the spine.	

