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**Feeding behaviour of South American camelids**

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*For my family  
with love and  
gratitude*



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## LISTS OF ABBREVIATIONS

-	minus
%	percentage
*	multiply
~	circa
+	plus
°C	degree centigrade
♀	female animals
♂	male animals
2 <sup>nd</sup>	second
2 <sup>ter</sup>	zweiter
70s	seventies
80s	eightieth
ADF <sub>OM</sub>	organic acid-detergent fibre
BCS	body condition score
BW	body weight
C1	compartment 1
C2	compartment 2
C3	compartment 3
CA	crude ash
CL	crude lipids
CP	crude protein
CPI	crude protein intake
d	day
DLG	Deutsche Landwirtschaftsgesellschaft
DM	dry matter
DMI	dry matter intake
e.g.	exempli gratia
EI	energy intake
etc.	et cetera
g	gramm
GLD	grazing lying down
GSU	grazing standing up
h	hour
ha	hectare
HFT	Hohenheimer Futterwerttest
HGT	Hohenheimer Gas Test
i.a	inter alia
kg	kilogram
KGW	Körpergewicht
KJ	kilojoule

KJ ME	kilojoule metabolizable energy
l	litre
LD	lying down
LDL	lying down lateral
LS means	last squares means
m	meter
m <sup>2</sup>	square meter
mBW	metabolic body weight ( $BW^{0.75}$ )
MJ ME	megajoule metabolizable energy
mKGW	metabolisches Körpergewicht ( $KGW^{0.75}$ )
ml	millilitre
n	numbers
N	nitrogen
NDF <sub>OM</sub>	organic neutral-detergent fibre
NRC	National Research Council
Ø	average
pH	pondus Hydrogenii
RLD	ruminating lying down
RPM	rising plate meter
RSU	ruminating standing up
S	standing
SAC	South American camelid
SEM	standard error of the mean
TS	Trockensubstanz
vs.	versus
XA	Rohasche
XL	Rohlipide
XP	Rohprotein



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**CHAPTER 1**  
**Introduction**

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## **Introduction**

### *Taxonomy, distribution and use of South American camelids*

South American camelids, together with the species Old World camel (dromedary and the two-humped camel), belong to the suborder *Tylopoda*. The domesticated South American camelid species are llamas (*Lama glama*) and alpacas (*Vicunja pacos*), who originated in the wild form guanaco (*Lama guanicoe*) and vicunja (*Vicunja vicunja*) respectively (Fowler, 2010). Crosses of the four species are fertile offspring (Gauly et al., 2011).

Alpacas can be divided into the two breeds Huacaya and Suri, which differ in the wool quality. Huacaya fibre is shorter than Suri and it is crimped and spongy. The Suri, on the other hand, has long fibres without crimps and it hangs down alongside the body in ringlets (Fowler, 2010). Being larger in size than alpacas, llamas have a wide variation in size and weight and differ in their fibre volume. There exists a more woolly variety, one with middle fibre amounts, one with less fibre on the neck, extremities and body, as well as the Suri-type variety (Fowler, 2010).

The point of origin is the High Andes of Peru and Chile. Nowadays, South American camelids have their original habitat in South America countries like Peru, Bolivia, North of Chile and Argentina. Since the late 70s to early 80s, the number of llamas and alpacas increased in countries outside of South America. They are found in large numbers in the USA, Australia and Central Europe (Gauly et al., 2011). In these countries, they are raised for a number of purposes, including pets or companion animals, fibre production, show animals, draught, breeding, meat etc. (Cebra et al., 2014).

### *Situation in Europe*

In Central Europe, especially in Germany, South American camelids are mostly to be found in small farming systems with two to six animals each. Most of the animals are raised as pets or companion animals. For this reason, there is not an exact stock number existing (Gauly et al., 2011). Scientifically based nutritional requirements are not available for camelids that are raised under Central European conditions. The calculations of the nutritional requirement are mainly based on the knowledge from their native countries of South America, or are simply adapted from other livestock, mainly from small ruminants. Both derivations are in need for extensive analysis. It is critical to compare Europe with South America, because of the different climatic conditions and the wide range between the farming management systems. Furthermore the anatomy and physiology varies considerably between South American camelids and true ruminants.

*Difference in the digestive anatomy and physiology of South American camelids and true ruminants*

South American camelids are ruminants in the strict sense of the word that is they chew a cud but there are some important differences especially in the digestive anatomy and physiology between camelids and true ruminants.

The forestomach system of true ruminants like sheep, are three independent hollow organs (rumen, reticulum and omasum) with the attached glandular stomach (abomasum) (von Engelhardt and Breves, 2005; Loeffler and Gäbel, 2013). In contrast, camelids have only three distinct compartments (C1, C2 and C3) associated with the foregut and stomach (Vallenas et al., 1971). The first two compartments (C1 and C2) and the first four-fifths of the third compartment (C3) are representative of the reticulorumen and have the function of a fermentation chamber hosting a microbiological flora and fauna. The last fifth of the elongated tubular C3 is similar to the glandular stomach (abomasum) of true ruminants (Wang et al., 2000).

To digest the cellulose, fibre and dry matter (DM) of their feed, both species (true ruminants and South American camelids) are dependent on these microbiological flora and fauna in their foreguts and compartments (Van Saun, 2006; Gauly et al., 2011). Ruminating animals have developed a speciality for digesting feed rich in celluloses (von Engelhardt and Breves, 2005; Van Saun, 2006). The camelids flora exhibits a higher level of activity, which may be the reason to a greater digestive efficiency (San Martin, 1987; Dulphy et al., 1997; Sponheimer et al., 2003). Tichit and Genin (1997) found in an *in sacco* dry matter digestibility study that the digestibility was indeed higher in llamas than in sheep. Therefore, the best symbiotic relationship between microbial population and host animal is found in the South American camelids (Cebra et al., 2014). It can be concluded that a combination of greater degree of degradability coupled with an increased microbial yield provides llamas and alpacas with an increased advantage in dealing with coarse, low quality feed compared to other ruminants and herbivores (Van Saun, 2006).

Another difference between true ruminants and South American camelids is the size of their gastrointestinal tract and the particulate outflow rate. These camelids have smaller stomach compartments and a slower particulate outflow rate (San Martin, 1987). This slower outflow rate will lead to a longer retaining time of the food particles and in a longer fermentation time in the camelid foregut than in the ruminant one (Heller et al., 1986; Dulphy et al., 1994). The hydrolysis of cell wall components by certain microbial enzymes is working all in all slowly;

hence, the time in which the ingesta is available for the microbes is very important for the efficiency of the digestion (von Engelhardt and Breves, 2005)

Another outstanding anatomy feature of South American camelids is the specific upper lip. It is adjusted to select the better parts of the feed. Smaller than the lower lip it is divided by a median groove. Both lips are more mobile than the ones from other herbivores, what allows a high selective ability (Cebra et al., 2014).

All the differences in anatomy and physiology of the digestive tract between South American camelids and true ruminants may influence the DM-intake (DMI) and the selective behaviour of the different animals, which may require a different feeding approach for the camelids.

### *Nutrition value and diet composition*

The key element for an efficient and sustainable animal production is a proper diet composition. The precondition is the knowledge of both diet composition and total intake for preparing a proper feed ration. Many different factors influence the feed intake by both grazing and browsing ruminants (NRC, 2007), such as the season (Newman and Paterson, 1994), the digestive system morphology and anatomy (Vallenas et al., 1971), the digesta retention time of the feed, the selectivity of the animal (San Martin, 1987), the size of the body (Kleiber, 1961; Demment and Van Soest, 1985) and the digestibility and quality of the forage (Meissner and Paulsmeier, 1995). When the animals are kept under controlled conditions or on pasture, the diet formula has to be based on animal requirements (NRC, 2007). As a rough guide, it may be accepted that with increasing diet quality, animals have to ingest less of their feed because their requirements are satisfied by smaller amounts (Meyer et al., 2010).

#### Dry matter intake

By definition, the DM includes every substance left after drying at 103 °C; volatile substances are lost during this drying process (Meyer et al., 2009). The DMI is generally measured in % of body weight (BW) of the specific species and is dependent on different energetic situations of the animal like gestation, lactation and growth as well as environmental factors like coldness (Meyer et al., 2009). The influence of the diet composition, season and species on the DMI has been studied extensively in various ruminants including sheep or cows (i.a. Celaya et al., 2007; Meyer et al., 2010). A result of the experiment performed by Celaya et al. (2007) is that the dietary overlaps of cattle, sheep and goats increased from late summer to winter as the mean sward height decreased under a certain height. They also claim that sheep have the best and cattle the worst performance during the year and goats are the best complementing species with

others. In the review created by Meyer et al. (2010), they affirm that animals compensate for a decreasing diet quality with an increasing feed intake. The review also says that a coarser, more fibrous feed leads to a mechanical intake limitation in ruminating animals. Meyer et al. (2010) have compared the feed intake of herbivores and detected that in general camelids have a lower intake per kg metabolic BW (mBW) than other ruminating animals with comparable fibre contents in the forage. For South American camelids, information about intake, diet composition and feeding behaviour is rare (San Martin and Bryant, 1989; Genin and Tichit, 1997; Dulphy et al., 1998; Fraser, 1998). San Martin and Bryant (1989) summarize a large number of intake data for llamas and alpacas of the Andean region. They show an average DMI of 2.0 % (llama) and 1.8 % (alpaca) of BW. The NRC (2007) expect a DMI of 1.0 % and 1.5 % of BW, respectively, which are lower than the detected numbers of San Martin and Bryant (1989). Dumont et al. (1995) found under grazing conditions a lower DMI of 0.8 to 1.3 % of BW. Similarly, Ordoñez (1994) found a DMI of 1.7 kg per day, equivalent to 1.6 % of BW assuming 110 kg BW also in free grazing animals. In these previous studies, the DMI is measured based on one single hay quality or averaged over a wide range of qualities. The main focus was on the DMI. It is still unclear how the feed composition, gender or species are affecting intake. Furthermore, it is proven more complicated to compare results of grazing studies with studies under controlled housing conditions. Van Saun (2006) even asserted, that the exact DMI can only be detected under strict controllable housing circumstances.

The large difference in the quality of the forage used may also lead to a wide range of DMI results (Cebra et al., 2014). Like mentioned before, ruminating animals like South American camelids are increasingly limited in their food intake capacity as diet quality decreases and have a typical drop in intake with increasing fibre content (Meissner and Paulsmeier, 1995). This is due to the fact that more fibrous feed has to be ruminated upon for a longer time before it can clear the rumen which causes a mechanical intake limitation (Meyer et al., 2010). Barboza and Hume (2006) reported in their study that herbivores may increase their feed intake on high quality food to build up energy reserves for times when feed quality is low.

#### Organic neutral-detergent fibre intake

According to the definition of the extended Weender analyses (Henneberg and Stohmann, 1860) following the method of Van Soest et al. (1991), Organic neutral detergent fibre (NDF<sub>OM</sub>) is all cell wall components of the plants. The more NDF<sub>OM</sub> content a plant has the more fibrous it is.

An early study of Hintz et al. (1973) indicate that South American camelids are twice as efficient than sheep in digesting fibre. It can be found in the literature that a recommendation of a minimum of 25 % crude fibre in the diet of ruminating animals (Van Saun, 2006; NRC, 2007; Gauly et al., 2011; Cebra et al., 2014). There is still a lack of scientifically approved numbers. Not all fibre is usable for camelids in their nutrition, but it is essential for the diet of the forestomach microbial population, which processes it for the animal itself (Van Saun, 2006). This microbial fermentation leads to a greater range of microbial protein and degradation of consumed feed (Cebra et al., 2014).

### Crude protein intake

The most common system for detecting the dietary crude protein (CP) based on the total nitrogen (N) is the Kjeldahl method (Kjeldahl, 1883). The results are expressed on a CP basis ( $N \times 6.25$ ) (Henneberg and Stohmann, 1860).

Especially in camelids, protein is an important part for the diet for both microbial and animal needs (Van Saun, 2006). Hinderer (1978) claimed that llamas are able to hydrolyse more urea per unit of time in C1 than other ruminants can do in their rumen. This would lead that llamas have more urea available for protein synthesis by microorganisms. In ruminating animals, retained nitrogen is recycled to the microbial flora and fauna as urea, which is processed to microbial protein (Van Saun, 2006)

This gives camelids the ability to use poor quality roughages of low protein content contrary to other ruminating animals. Van Saun (2006) also detected that the protein requirement in true ruminants and ruminant like animals, like South American camelids, is more complex than only digestible protein or CP. Due to the microbial flora and fauna in the forestomach or compartments, they can process highly soluble and degradable dietary protein and non protein N (Van Saun, 2006). The recommendation for dietary protein content for South American camelids varies widely and is dependent on the state of performance of the animal. It ranges from 8-14 % of the DM (Gauly et al., 2011). An overflow protein intake will lead to weight gain, increasing feed costs and a greater N excretion. (Cebra et al., 2014). In camelids and other ruminating animals, protein is needed for both microbes and animals to function properly (Cebra et al., 2014). A high CP content in the feed is set even with a higher feed quality.

### Selectivity behaviour

Ruminating animals like small ruminants or South American camelids, obtain nutrients from a variety of feed sources including protein, fat, and both structural and non-structural

carbohydrates. Ruminating animals kept on pasture will be selective on what they chose to consume. They consume primarily the easy to remove parts of the plant like leaves and husks and go for sheath only when the amounts of the more palatable parts are too low (Methu et al., 2001). In an experiment by Leonardi and Armentano (2003), cows housed in tie-stalls selected their offered hay against longer particles in favour for short, easy palatable parts.

The selection is dependent on multiple factors like the nature of the animals themselves, and the plant resources they have access to. It is essential that the management systems permits the animals to be selective (NRC, 2007). Another factor influencing the selectivity of animals is the presence of another species like in co-grazing systems (Walker et al., 1994). For example, when comparing sheep and llama in such a system, Genin et al. (1994), showed that llamas selected the more coarse grass species than sheep, though there is less tendency for this selectivity behaviour in the same system with sheep and goats.

Fraser and Baker (1998) and Fraser (1998) detected in their experiments that sheep selected the high N and low fibre food items, unlike guanacos, who selected the fractions with the higher fibrous parts of the plants. They avoided the more digestible leaves, which the sheep fed on. Fraser (1998) also said that both sheep and South American camelids were found to be selective feeders, but their choice of diet differs in composition. This difference could be used to increase overall productivity of the pasture and animal performance.

Selective behaviour can also lead to complications, for example, when diets are made of fine fibre, selection can reduce intake of long, coarse particles and decrease chewing activity and forestomach pH (Leonardi and Armentano, 2003).

Ruminating animals like South American camelids would always choose the feed with the better quality (high digestibility and protein content, few secondary compounds) than the average of the forage biomass, which can be found in the feedlots (NRC, 2007).

#### *Co-grazing South American camelids and sheep*

It is a very animal friendly husbandry to keep them on pasture or in loose barn systems. The possibility to live on pasture is the best choice for the nutrition of the animals, as well as in the aspect of animal-welfare (Gauly et al., 2011). Especially for South American camelids, which are animals needing their distance from each other and avoid physical contact with others in the herd (Gerken et al., 1997).

There is still a lack of scientifically based studies about the behaviour of South American camelids on pasture. Gauly et al. (2011) claimed a daily grazing period of 7-12 hours in several periods. They say that the feed intake is spread over the whole day with interruptions for

rumination. South American camelids are diurnal animals, which have rest and rumination times during the day. Grazing time overnight is limited for ruminants, thus they optimize nutrient intake by rumen filling during the daytime (Penning et al., 1995). They are not active in the dark (Fowler, 2010).

Usually camelids sleep in a sternal position, but they can be found lying in a lateral position. Sheep do not use this lateral position, because they cannot oversee their territory from that position, therefore they are at higher risk of predation (Hulet et al., 1987; Penning et al., 1993). In the work of Baumont et al. (2000), they said that in a loose barn or extensive pasture management system, the diet compositions and the impact of grazing on the biomass is also the result of a multiple layered relationship between the animal and nature. Free housed animal show an enterprising nature in diet and selection by taking small portions from many sources, thereby increasing the likelihood that the complex diet will satisfy its nutrient requirements (NRC, 2007).

### Grazing Behaviour

The diversity of anatomy and physiology may influence and distinguish the grazing strategy of true ruminants like sheep and South American camelids. On the other hand, co-grazing of these two species may have a positive effect for the productivity of the feedlots. Especially when there is a situation of maintaining single species herds grazing, the biomass is left unbalanced. Overgrazing of a pasture will lead to a shift in one or the other direction. The possible outcome can be an overgrowing of coarse and woody plants or desertification (NRC, 2007). It is an increasing problem that there are mainly flocks of only one species like small ruminants, which leads to a loss of valuable browse and grass species (NRC, 2007). Because co-grazing systems are very effective in terms of resource use, these could be a solution for an effective utilization of available rangeland.

However, for the equilibrium between animal needs and economic benefit in all management systems, it is important to maximize the proportion of forage in the diet to minimize feeding costs. To reach these goals, it is important to know the animal behaviour and dietary choice as well as in housing systems and on pasture (Baumont et al., 2000). Heitschmidt et al. (2004) claim that co-grazing of multiple species can effectively change the number of poorly usable plant material to a better harvestable biomass. There exists a wide range of numbers of co-grazing studies between true ruminants among themselves. For example, co-grazing small ruminants like sheep and goats are improving the vegetation conditions (Walker, 1994). Goats are a good addition to other species for the best use of occurring pasture resources. Furthermore,



multispecies grazing systems improve the spatial use of pasture (Forbes and Hodgson, 1985), parasite control (Waller, 2006) and potentially lower loss due to predation under distinct conditions (Hulet et al., 1987).

In South America, it is practiced that camelids are co-grazed with sheep (Pfister et al., 1989; San Martin and Bryant, 1989; Tichit and Genin, 1997). It would seem as if housing South American camelids together with small ruminants is possible under Central European conditions, even though the climatic terms, the pasture and the animal performance are different. For example, while sheep consume forage that came into contact with dung (Brelin, 1979), South American camelids will not touch that forage (Gauly et al., 2011). Fraser (1998) claims that with mixed grazing groups, the wastage around latrine areas of South American camelids would decrease when co-grazed with other species.

*Aim of the study*

As mentioned before, the knowledge about DMI and feeding behaviours of South American camelids kept under Central European conditions is still limited. There are scientific publications about DMI and co-grazing with other species especially done in the countries of origin. However, in previous studies, the DMI was measured either based on one single hay quality or averaged over a wide range of qualities. So it is still unclear from these studies how the feed composition, gender or species are effecting intake. There is also a lack of scientifically published studies about the behaviour of South American camelids on pasture under European conditions. It is unknown how they spent their time and how their daily routine looks like. It is questionable if co-grazing camelids with other species like sheep may affect their behaviour and their physical comfort. In the worst case, it could lead to an increase of stress and a decrease of their productivity. On the opposite side, it may lead to an increase of animal productivity and represents a benefit for the efficiency of the pasture.

Therefore it was the aim of this dissertation:

- to determine the DMI of llamas depending on the quality of the hay and its effect on the composition of a feed ratio (Chapter 2)
- to determine the DMI of llamas and alpacas studying effects of gender and hay quality, and whether selection of feed is influenced by these factors (Chapter 3)
- to assess the behaviour of the two species llama and sheep, when kept on the same pasture under Central European conditions to detect a possibility for future co-grazing systems (Chapter 4)

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**CHAPTER 2**

**Dry matter intake of South American camelids and its effects on the composition of feed rations**

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Appendix I



## **Dry matter intake of South American camelids and its effects on the composition of feed rations**

### **Abstract**

The number of South American camelids (SAC) is increasing in Germany since decades. Due to a lack of scientifically based publications the knowledge about feeding SACs is still poor. Therefore, the aim of this study was to estimate the dry matter intake (DMI) of SACs as a basis for calculations of feed rations. Previous studies proposed a DMI of up to 3 % of the body weight (BW) (Gauly et al., 2011). In the present study, eight llamas (*Lama glama*) were allocated to two groups of four animals each. The two groups were fed with hay of different qualities over a total period of ten weeks, which was decided into two runs of five weeks each. During the first run, group 1 was fed with hay 1 (15.1 % crude protein; 8.5 % crude ash; 3.1 % crude fat; 52.6 % NDF per kg DM) and group 2 with hay 2 (6.6 % crude protein; 6.2 crude ash; 2.1 % crude fat; 64.3 % NDF per kg DM). After five weeks the groups were changed and group 1 received hay 2 and group 2 received hay 1. BW was measured at the start and end of each run (week zero, five and ten). The hay quality affected the DMI, but the animals did not compensate a lower feed quality with an increased DMI. The total DMI was 1.26 % and 0.89 % of the BW for hay 1 and hay 2, respectively, which was lower than expected in both groups. In conclusion, calculations of feed rations for SACs should be adjusted to the present findings of a lower DMI capability.

**Keywords:** llama (*Lama glama*), hay quality

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**CHAPTER 3**

**Does hay quality affect dry matter intake and feed selection of llamas (*Lama glama*) and alpacas (*Vicunja pacos*) under Central European conditions?**

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## **Does hay quality affect dry matter intake and feed selection of llamas (*Lama glama*) and alpacas (*Vicunja pacos*) under Central European conditions?**

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### **Abstract**

When trying to establish feeding recommendations for South American camelids, basic information on their feeding behaviour like voluntary forage intake becomes important. Dry matter intake (DMI), intake of neutral-detergent fibre (NDF<sub>OM</sub>), crude protein (CP) and energy and feed selection were compared between male and female llamas (*Lama glama*) and male llamas and alpacas (*Vicunja pacos*). In four runs of two experiments (n=10) two hay types differing in harvesting time were offered (all DM basis): 1) early 2<sup>nd</sup> cut (9.9 MJ ME/kg; 12.3 % CP, 57.4 % NDF<sub>OM</sub>) and 2) late bloom cut in autumn (8.5 MJ ME/kg; 9.4 % CP, 63.3 % NDF<sub>OM</sub>). In experiment one, DMI of male and female llamas averaged 52.8 and 56.6 g/kg metabolic body weight (mBW) for hay 1 and 45.6 and 37.8 g/kg mBW for hay 2 (p < 0.001). The NDF<sub>OM</sub> content in the residues was 10.7 to 51.2 g/kg DM higher compared to the feed, except for a lower NDF<sub>OM</sub> content in males with hay 2. CP (5.2 to 44.7 g/kg) and energy (0.5 to 2.1 MJ ME/kg) content were lower in residues than in feed. In experiment two, DMI averaged 29.4 and 42.0 g/kg mBW for llamas and 26.5 and 43.3 g/kg mBW for alpacas for hay 1 and 2, respectively (p < 0.001). Except for alpacas fed hay 2, NDF<sub>OM</sub> content was 12.5 to 31.7 g/kg lower in residues. CP was 7.3 to 12.1 g/kg higher for hay 1 and 4.1 to 17.9 g/kg lower for hay 2. Except for alpacas fed hay 1, residues were 0.02 to 0.7 MJ ME/kg lower in energy. In conclusion, quality and harvesting time affected DMI of South American camelids, which selected in favour of feed particles rich in CP and energy and low in NDF<sub>OM</sub>, especially when coarser hay was offered.

**Keywords:** South American camelids, llama, alpaca, DMI, hay quality, feeding behaviour

## Introduction

South American camelids (SAC) are becoming more and more popular companion animals. In consequence, quantitative aspects of their nutrition like voluntary forage intake become increasingly relevant for adequate dietary planning. The feed intake of animals is determined by differing factors such as season (Newman and Paterson, 1994), morphology and anatomy of the digestive system (Vallenas et al., 1971), digesta retention time of the feed, selectivity of an animal (San Martin, 1987) and digestibility and quality of the forage (Meissner and Paulsmeier, 1995). Also, gender may have an influence on the feeding behaviour (Shannon et al., 2013). The effect of the diet composition was studied in various ruminants including sheep, goats and cattle (e.g. Dulphy and Demarquilly, 1994; Meyer et al., 2010), but is widely unknown for SACs.

Even though studies were conducted under conditions of South America (Genin et al., 1994; Fraser and Baker, 1998), there is far less information on nutritional requirements for animals raised under Central European condition with its different climate and environmental factors (Cebra et al., 2014). The ecosystem of South America is composed of semi-arid regions at high altitude, with seasonal droughts and sparse vegetation (Riek et al., 2007). Thus, requirements are mainly based on studies from South America, or are simply adapted from other livestock, mainly from small ruminants. However, SACs bred in Europe may have to handle extreme weather conditions ranging from extremely humid and hot periods in regions of Southern Europe to very cold winter periods in Northern Europe. In their native habitats SACs do not encounter these environmental extremes and seasonal changes (Cebra et al., 2014). Furthermore, the digestive anatomy and physiology of SACs differs distinctly from ruminants, with camelids having only three distinct compartments (C1, C2 and C3) associated with the foregut and stomach as compared to the four compartments of true ruminants (Vallenas et al., 1971). The first two compartments (C1 and C2) and about 80 % of the C3 represent fermentation chambers similar to the reticulorumen of ruminants (Cebra et al., 2014). The remaining caudal part of C3 shows similarities to the abomasum with its gastric glands secreting hydrochloric acid and acid proteases (Wang et al., 2000; Cebra et al., 2014). By way of comparison, the forestomach system of true ruminants exhibits three independent hollow organs (rumen, reticulum and omasum) with the adjacent glandular stomach (abomasum) (von Engelhardt and Breves, 2005; Loeffler and Gäbel, 2013). Like true ruminants, SACs harbour a rich fibre digesting microflora in their compartments (Van Saun, 2006; Gauly et al., 2011). In general, the stomach compartments of SACs are smaller and passage rates of feed particles tend to be slower than in true ruminants (San Martin, 1987). The combination of a greater degree of

degradability coupled with increased microbial yield may provide camelids with a distinct advantage in dealing with lower quality feed compared to other herbivores (Van Saun, 2006). An important physiological difference is also the lower energy requirement of SACs, which is estimated to be 305 KJ ME/kg metabolic body weight (mBW) (NRC, 2007) or even lower (~ 250 KJ ME/kg mBW) (Dittmann et al., 2014). In summary, differences in the anatomy and physiology between camelids and ruminants may influence the dry matter intake (DMI) and feed selection.

It is generally assumed that animals, especially herbivores, compensate a period of low food quality with increasing food intake. Within their range of forage plants, free ranging ruminants select for a diet of high digestibility and protein content and low contents of secondary compounds (NRC, 2007). Ruminating animals are increasingly limited in their food intake capacity as diet quality decreases and show a characteristic decline in intake when fibre content increases (Meissner and Paulsmeier, 1995). This is primarily caused by a mechanical intake limitation, because highly fibrous food has to be ruminated for a longer time before it passes the forestomach system (Meyer et al., 2010). However, unique metabolic and physiologic adaptations have enabled SACs to perform well in an environment that is characterized by prolonged periods with limited amounts of low quality forage. The hypothesis exists that intake is less negatively correlated to fibre levels than in true ruminants (Dulphy et al., 1998; Meyer et al., 2010; Dittmann et al., 2014).

Among others, Kleiber (1961) and Demment and Van Soest (1985) claimed that there is a correlation between body weight (BW) and diet selection. They argue that species with a larger body size have a lower mass-specific energy requirement and a more voluminous digestive tract. In consequence, they are said to have a greater efficiency of ingesting fibre rich forage, which compensates for the lower quality ingested. Body size is also distinctively different between alpaca (*Vicunja pacos*) and llama (*Lama glama*) and often for genders (the latter not being true for SACs).

Due to their lower maintenance energy requirements, a lower intake can be expected in camelids compared to ruminants in general. Examples for general suggestions are e.g. 47 for camelids in general vs. 63 g/kg mBW in ruminants (Dittmann et al. 2014). While luckily some data on voluntary DMI of SACs on European forage diets appears to accumulate during the last years (e.g. Jalali et al. 2012; Dittmann et al. 2014; Stölzl et al. 2014).

In this study, some focus was put on the influence of factors like gender or species (llama or alpaca) on intake and also selectivity. Concerning gender, a higher maintenance energy requirement on the size of + 15 % is described for male sheep or goats (NRC, 2007) and cattle

(Kirchgessner et al., 1994). While this is generally attributed to higher body protein content in males, it is unclear if this applies to SAC to the same degree. Probably even more obvious than intake, gender differences in food selectivity and in consequence ingested diet quality have been described for various wild ungulates (e.g. ibex: Gross et al., 1996; giraffe: Pellew, 1984; red deer: Clutton-Brock et al., 1982); again, it is unclear to which extent this applies to animals with less sexual dimorphism (average body mass ~ 140 kg for llama males and ~ 170 kg for females). BW is also a striking difference between alpacas (~ 65 kg) and llamas (~ 160 kg). Postulated consequences could be a higher selectivity in the smaller animal and a higher capacity to process fibrous forage in the larger. In addition, higher wool production in alpacas may lead to slightly higher maintenance requirements (maximal potential for increase: ~ 60 KJ/kg mBW, if a maximal wool production of 4 kg/year is assumed for a 60 kg animal). It was the objective of the study to investigate the effects of hay quality on DMI, intake of neutral detergent fibre (NDF<sub>OM</sub>), crude protein (CP), energy and finally feed selection in SACs, comparing male and female llamas in a first and male llamas and alpacas in a second experiment.

## **Materials and Methods**

### *Animals and management*

The study was conducted at the research farm of the Georg-August-University Göttingen in Relliehausen, Germany from September 2013 until February 2014. During this period, two experiments were conducted each lasting for 8 weeks and including 10 animals. Both experiments were divided into two 4-week periods in which the animals received two types of hay with a different harvesting time. One type was early 2<sup>nd</sup> cut and the other was late bloom cut in autumn. The chemical composition is given in Table 1. These 4-week periods consisted of a 3-week adaption period followed by one week of sampling. In experiment one, mean temperatures were 10.6 °C and 8.8 °C for the first and second period, and in the second experiment 6.3 °C and 4.4 °C, respectively.

In the first experiment five uncastrated male and five non-pregnant female llamas and in the second experiment the identical five uncastrated male llamas and five uncastrated male alpacas of the Huacaya type were used.

The male llamas aged four to 13 years (average age 9.4 years), the female llamas aged five to eight years (average age 7.6 years). The alpacas aged four to seven years (average age 5.4 years). At the start of the first run of experiment one the male llamas had an average weight of 133 kg (range 113 to 156 kg) and the female llamas had an average weight of 166 kg (range



143 to 185 kg). The average initial weights for the second run were 137 kg ranging between 115 to 160 kg for the male llamas and 174 kg ranging between 148 to 203 kg for the female animals. In the second experiment during the first run the llamas had an average initial weight of 124 kg ranging between 111 kg to 141 kg and the alpacas had an average start weight of 59 kg ranging between 52 to 67 kg. At beginning of the second run the average weight of the llamas was 125 kg (range: 114 to 145 kg) and the one of the alpacas was 64 kg (range: 56 to 72 kg).

At the beginning of the study, all animals were assessed clinically healthy by a full veterinarian health check. During the whole study the animals were housed in individual pens of 3.5 by 3.5 m with audio-visual contact to each other. Sawdust was used as bedding material and water was available ad libitum.

### *Feeding*

In experiment one, hay of the autumn cut was given during the first 4-week period and hay of the 2<sup>nd</sup> cut was given in the second 4-week period. In experiment two hay of the 2<sup>nd</sup> cut was given during the first 4-week period and hay of the autumn cut during the second period. Hay was offered for ad libitum intake and provided in 90 l containers placed on the ground. During each of the 1-week sampling periods (week four) feed intake was measured by daily weighing the supplied hay and the remains of the previous day. Feed samples of the supplied hay were taken on day 1, 3 and 5 of the sampling period following the methods of Jeroch et al. (1999). Bulk samples from all feeding containers were taken. The feed remains were sampled daily for each individual animal. The samples of the whole week of one animal were merged to a bulk sample. It was attempted to supply the animals with about 120 to 150 % of the estimated DMI; the proportion varied a bit since the first rule was to have hay available in the feeding container at all times. In the first run of experiment one (autumn cut hay) the male llamas were provided with ~126 % and the female llamas ~129 % of the estimated DMI. In the second run (2<sup>nd</sup> cut hay) the male llamas were fed with ~123 % and the female animals ~116 % of the estimated DMI. In the second experiment the amount of remaining hay in the first run (2<sup>nd</sup> cut hay) accounts for 155 % for the llamas and 164 % for the alpacas and in the second run (autumn cut hay) 132 % and 138 % for llamas and alpacas, respectively.

Table 1: Nutritional composition of early 2<sup>nd</sup> cut and late bloom autumn hay used in the different runs of the two experiments

Experiment	Run	Harvesting time	Energy (MJ ME/kg)	Crude protein (% DM)	Ash (% DM)	Ether extract (% DM)	NDF <sub>OM</sub> (% DM)	ADF <sub>OM</sub> (% DM)
1	1	Late bloom autumn hay	8.2	10.5	8.2	1.2	66.1	36.9
	2	Early 2 <sup>nd</sup> cut hay	10.2	12.5	7.4	2.4	55.9	28.1
2	1	Early 2 <sup>nd</sup> cut hay	9.6	12.1	8.0	2.4	58.8	31.9
	2	Late bloom autumn hay	8.5	8.4	7.8	1.7	60.4	33.4

### *Feed analysis*

The samples were analysed for chemical composition according to VDLUFA (2012) at the Department of Animal Sciences (Ruminant Nutrition) of the Georg-August University Göttingen. This included DM content (method 3.1; drying at 100 °C until constant weight), ash content (method 8.1; ashing at 550 °C), CP content (N\*6.25) (method 4.1.1; Kjeldahl), ether extracts (EE) (method 5.1.1), NDF<sub>OM</sub> content (without residual ash) (method 6.5.1; Ankom fiberlyzer) and ADF<sub>OM</sub> content (without residual ash) (method 6.5.2; Ankom fiberlyzer).

Additionally, the Hohenheim Gas Test (HGT) (Menke et al., 1979) was used to estimate the ME content of the hay. Rumen fluid of a fistulated steer was used. The following formula applicable for grass products was used (GfE, 2008):  $ME (MJ/kg DM) = 7.81 + 0.07599 * gas\ production\ in\ HGT (ml/200\ mg\ DM) - 0.00384 * ash (g/kg\ DM) + 0.00565 * CP (g/kg\ DM) + 0.01899 * EE (g/kg\ DM) - 0.00831 * ADF_{OM} (g/kg\ DM)$

Nutrient and energy intake of individual animals was calculated by multiplying the amount of offered hay (kg DM) and the CP content of the bulk samples and subtracting the amount of residues (in DM) multiplied by their CP content. Selection for CP, NDF<sub>OM</sub> and energy was determined by subtracting the composition of the rejected hay of every single animal with the average composition of the bulk samples of the offered hay.

### *Statistical analysis*

All statistical analyses were conducted using the Statistical Analysis System (SAS), version 9.3. Experiment 1 and 2 were analysed separately. The model statement (Proc MIXED) included the fixed effects of gender (female, male) in the first experiment and species (llama, alpaca) in the second experiment as well as hay (1, 2) and its 2-way-interaction. Day was included as repeated effect. Results are presented as least square means  $\pm$  PSE. Least squares means were separated by the probability of differences option (PDIF) with Bonferroni adjustment. The significance level was set at  $p < 0.05$ .

## **Results**

### *Experiment 1*

#### Feed intake

In experiment one, in which male and female llamas were compared, intake related to mBW differed between the two hay types ( $p < 0.001$ ), while a difference between gender was only

noticed for the autumn cut hay ( $p < 0.002$ ) (Figure 1). For the autumn cut hay, male llamas had a DMI of 45.6 g/kg mBW compared with 52.8 g/kg mBW when they received 2<sup>nd</sup> cut hay. The females had a DMI of 37.8 g/kg mBW when receiving autumn cut hay and 56.6 g/kg mBW when receiving 2<sup>nd</sup> cut hay (all LS means; SEM  $\pm$  1.3 g/kg mBW).

Concerning total protein intake per day, the male llamas had a CPI of 224.9 g/d and 277.0 g/d for the autumn cut and 2<sup>nd</sup> hay, respectively. In females, the accordant values were 215.3 g/d and 342.8 g/d (all LS means; SEM  $\pm$  7.1 g/d). Cutting time also influenced CPI/d and EI/d highly significant ( $p < 0.001$ ) in both runs. When related to mBW, intakes of crude protein and energy differed between the genders offered 2<sup>nd</sup> cut hay ( $p < 0.001$ ), but not for autumn-cut hay. For the male llamas, these are 5.8 g/kg mBW and 6.8 g/kg mBW for the autumn cut and 2<sup>nd</sup> cut hay for the male llamas, respectively ( $p < 0.001$ ) (Figure 2). For the female llamas the CPI for the two sorts of hay (autumn cut hay and 2<sup>nd</sup> cut hay) amounted to 4.7 g/kg mBW and 7.2 g/kg mBW ( $p < 0.001$ ) (all LS means; SEM  $\pm$  0.2 g/kg). The difference between the genders was only highly significant in the run with the autumn cut hay ( $p < 0.001$ ).

Total energy intakes were 15.2 MJ ME/d in the autumn cut hay run and 22.4 MJ ME/d in the 2<sup>nd</sup> cut hay run for the male animals. In females, the EI for 2<sup>nd</sup> cut hay of 27.9 MJ ME/d largely exceeded the value of the autumn cut hay (15.7 MJ ME/d) (all LS means; SEM  $\pm$  0.6 MJ ME/d). Expressed as intake in KJ ME per kg mBW, males and females had an EI of 390 KJ ME and 340 KJ ME for the autumn cut and 545 KJ ME and 582 KJ ME for 2<sup>nd</sup> cut hay, respectively (all LS means; SEM  $\pm$  11.6 KJ ME). While there was a clear difference between the hays ( $p < 0.001$ ), gender-related difference was again found only in the autumn cut hay ( $p < 0.05$ ).

The intake of NDF<sub>OM</sub> (autumn cut and 2<sup>nd</sup> cut) of the male animals was 1.2 kg/d and 1.4 kg/d; NDF<sub>OM</sub> intake of the females was 1.1 kg/d and 1.4 kg/d (all LS Means; SEM  $\pm$  41.7 g/d), respectively. The NDF<sub>OM</sub> content of the ingested hay differed highly significant ( $p < 0.001$ ) between the two sorts of hay but exhibited no difference between the genders (Figure 2). Related to BW, the NDF<sub>OM</sub> intake was 8.9 g/kg BW and 10.6 g/kg BW of the autumn cut and 2<sup>nd</sup> cut hay, respectively ( $p < 0.05$ ). The female llamas fed 6.8 g/kg BW and 8.0 g/kg BW, respectively ( $p < 0.001$ ) (all LS means; SEM  $\pm$  0.3 g/kg BW). Only the run with the 2<sup>nd</sup> cut hay showed a highly significant difference between the genders ( $p < 0.001$ ).

### Feed selection

There was a selection in favour of feed particles rich in CP and energy in both runs; for NDF<sub>OM</sub>, while females selected for better quality (low NDF<sub>OM</sub>), males apparently did not in autumn cut hay (Figure 3). In detail, the NDF<sub>OM</sub> content of the remains compared with the supplied hay in

male llamas was 17.0 g/kg DM lower for the autumn-cut hay and 10.7 g/kg DM higher for the 2<sup>nd</sup> cut hay. In females, the remains were 51.2 g/kg DM and 42.3 g/kg DM higher in NDF<sub>OM</sub> content than the hay that was supplied in both runs (all LS means; SEM  $\pm$  8.9 g/kg DM).

The CP content of the residues and the supplied feed differed highly significant ( $p < 0.001$ ) between both hay qualities. There was also a highly significant difference between genders with the autumn cut hay ( $p < 0.001$ ). The CP content of the remains compared with the supplied hay of the male animals was 44.7 g/kg DM and 7.9 g/kg DM lower for the autumn-cut hay and 2<sup>nd</sup> cut. In females, the remains were 32.1 g/kg DM and 5.2 g/kg DM lower in CP than the offered hay (all LS means; SEM  $\pm$  0.9 g/kg).

As a result of selection, the energy content in the remains was 0.7 MJ ME/kg DM lower than in the offered autumn-cut hay and 0.5 MJ ME/kg DM in the 2<sup>nd</sup> cut hay in male llamas. The remains of the female llamas were 2.1 MJ ME/kg DM and 0.7 MJ ME/kg DM lower than the offered hay in both runs (all LS means; SEM  $\pm$  0.1 MJ ME/kg). The hay quality had a highly significant influence on the selecting behaviour of the female animals ( $p < 0.001$ ). There was also a highly significant difference between the genders during run one feeding the autumn cut hay ( $p < 0.001$ ).

#### Body weight development

The male llamas had a daily weight gain of 414 g/d ( $\pm$  138 g/d) for autumn cut and 374 g/d ( $\pm$  138 g/d) for 2<sup>nd</sup> cut hay. The female animals gained 350 g/d ( $\pm$  222 g/d) when fed with hay of autumn cut and 899 g/d ( $\pm$  220 g/d) with the other type of hay. In females, the hay quality had an effect ( $p < 0.05$ ), but in males and between genders not (Figure 1).

Table 2: Core values of the two experiments: Average age in years, the harvesting time of the hay, average BW/mBW in kg, LSMMeans DMI in % of BW and DMI in g/kg mBW and the intake of DM in kg.

Experiment	Run	Harvesting time	Gender/Species	Average BW (kg) (Range)	mBW (kg) (Range)	Intake DM (kg)	DMI/BW (%)	DMI/mBW (g/kg)
1	1	late bloom autumn hay	Llama ♂	133 (113-156)	39 (34-44)	1.8 ± 0.04	1.4 ± 0.04	45.6 ± 0.13
			Llama ♀	166 (143-186)	46 (41-50)	1.8 ± 0.04	1.1 ± 0.04	37.8 ± 0.13
	2	early 2 <sup>nd</sup> cut hay	Llama ♂	142 (115-160)	41 (38-44)	2.2 ± 0.04	1.6 ± 0.04	52.8 ± 0.13
			Llama ♀	174 (148-203)	47 (42-43)	2.7 ± 0.04	1.6 ± 0.04	56.6 ± 0.13
2	1	early 2 <sup>nd</sup> cut hay	Llama ♂	124 (111-141)	37 (34-40)	1.1 ± 0.05	0.9 ± 0.06	29.4 ± 0.18
			Alpaca ♂	59 (52-70)	21 (19-23)	0.6 ± 0.05	1.0 ± 0.06	26.5 ± 0.18
	2	late bloom autumn hay	Llama ♂	125 (114-145)	37 (34-41)	1.6 ± 0.05	1.3 ± 0.06	42.0 ± 0.18
			Alpaca ♂	64 (56-72)	22 (20-24)	1.0 ± 0.05	1.5 ± 0.06	43.3 ± 0.18

*Experiment 2*

## Feed intake

In experiment two, in which male llamas and alpacas were compared, only the harvesting time of the hay influenced the DMI in g/kg mBW ( $p < 0.001$ ) (Figure 1). Fed with hay of the 2<sup>nd</sup> cut, llamas had a DMI of 29.3 g/kg mBW compared with 42.0 g/kg mBW when they received autumn cut hay. The alpacas had a DMI of 26.5 g/kg mBW when fed 2<sup>nd</sup> cut hay and 43.3 g/kg mBW when fed autumn-cut hay (all LSmeans; SEM  $\pm 1.8$  g/kg mBW). There was no significant difference in the DMI between the species.

The llamas fed 122.7 g/d of CP for 2<sup>nd</sup> cut and 132.9 g/d for autumn cut hay. Corresponding values for the alpacas were 55.9 g and 98.8 g/d for 2<sup>nd</sup> cut and autumn hay (all LSmeans; SEM  $\pm 6.2$  g/d). The CPI/d of alpacas was highly significant different ( $p < 0.001$ ) between hay types. There was no such difference for llamas (Figure 2). The intake of CP per day differed between the species in both runs highly significant ( $p < 0.001$ ). The CPI in g/kg mBW differed highly significant between the runs of the alpacas. A species applied difference was significant in the run with the autumn cut hay ( $p < 0.02$ ) and showed a tendency in the run with the 2<sup>nd</sup> cut hay ( $p < 0.08$ ). Intakes were 3.3 g/kg mBW and 3.6 g/kg mBW CP for the 2<sup>nd</sup> cut and autumn cut hay for the llamas, respectively. For the alpacas the CPI for the two sorts of hay (2<sup>nd</sup> cut and autumn cut hay) amounted to 2.7 g/kg mBW and 4.4 g/kg mBW (all LSmeans; SEM  $\pm 0.2$  g/kg mBW).

The llamas had an EI of 10.5 MJ ME/d and 13.9 MJ ME/d for the two sorts of hay ( $p < 0.001$ ). In alpacas the corresponding values were 5.3 MJ ME/d and 8.8 MJ ME/d (all LSmeans; SEM  $\pm 0.5$  MJ ME/d) ( $p < 0.001$ ). Related to mBW, llamas and alpacas had an EI of 284 KJ ME/kg mBW and 250 KJ ME/kg mBW for the 2<sup>nd</sup> cut hay and 375 KJ ME/kg mBW and 396 KJ ME/kg mBW for 2<sup>nd</sup> cut hay, respectively (all LSmeans; SEM  $\pm 16.7$  KJ ME/kg mBW).

The NDF<sub>OM</sub> intake differed highly significant ( $p < 0.001$ ) depending on the type of hay and exhibited a significant difference between the species in run two (Figure 2). The daily NDF<sub>OM</sub> intake (2<sup>nd</sup> cut and autumn cut) of the llamas was 678 g/d and 952 g/d. The ingested NDF<sub>OM</sub> amount of the alpacas was 357 g/d and 574 g/d, respectively (all LSmeans; SEM  $\pm 31.7$  g). The llamas fed 5.5 g/kg BW and 7.7 g/kg BW of the 2<sup>nd</sup> cut hay and autumn cut hay, respectively ( $p < 0.001$ ), while the alpacas fed 6.1 g/kg BW and 9.2 g/kg BW respectively ( $p < 0.001$ ) (all LSmeans; SEM  $\pm 0.4$  g/kg BW). There was also a significant difference between the species during run one feeding the autumn cut hay ( $p < 0.001$ ).

### Feed selection

The hay remains of the llamas were lower in NDF<sub>OM</sub> than the supplied feed in both runs (Figure 3). This led to a decrease of the NDF<sub>OM</sub> content of 31.7 g/kg for 2<sup>nd</sup> cut hay and 12.5 g/kg for autumn cut hay ( $p < 0.04$ ) in the leftovers. The alpacas only selected for high NDF<sub>OM</sub> contents in the first run with hay of 2<sup>nd</sup> cut (- 29.1 g/kg), but not in the second run with the autumn cut hay (all LSmeans; SEM  $\pm$  5.1 g/kg). This result is highly significant different ( $p < 0.001$ ). The use of autumn cut hay reveals also a highly significant difference between the species, but feeding the 2<sup>nd</sup> cut hay showed no differences.

Neither llamas nor alpacas selected for particles with high CP content when offered 2<sup>nd</sup> cut hay, whereas for autumn cut hay the CP content was 4.1 g/kg lower in the residues than in feed in llamas and 17.9 g/kg lower for alpacas (all LS means; SEM  $\pm$  2.4 g/kg). Consequently the quality and the harvesting time have a significant ( $p < 0.002/0.001$ ) influence on the CP selection of the animals. There is also a highly significant difference visible in the run with the autumn cut hay between the species ( $p < 0.001$ ).

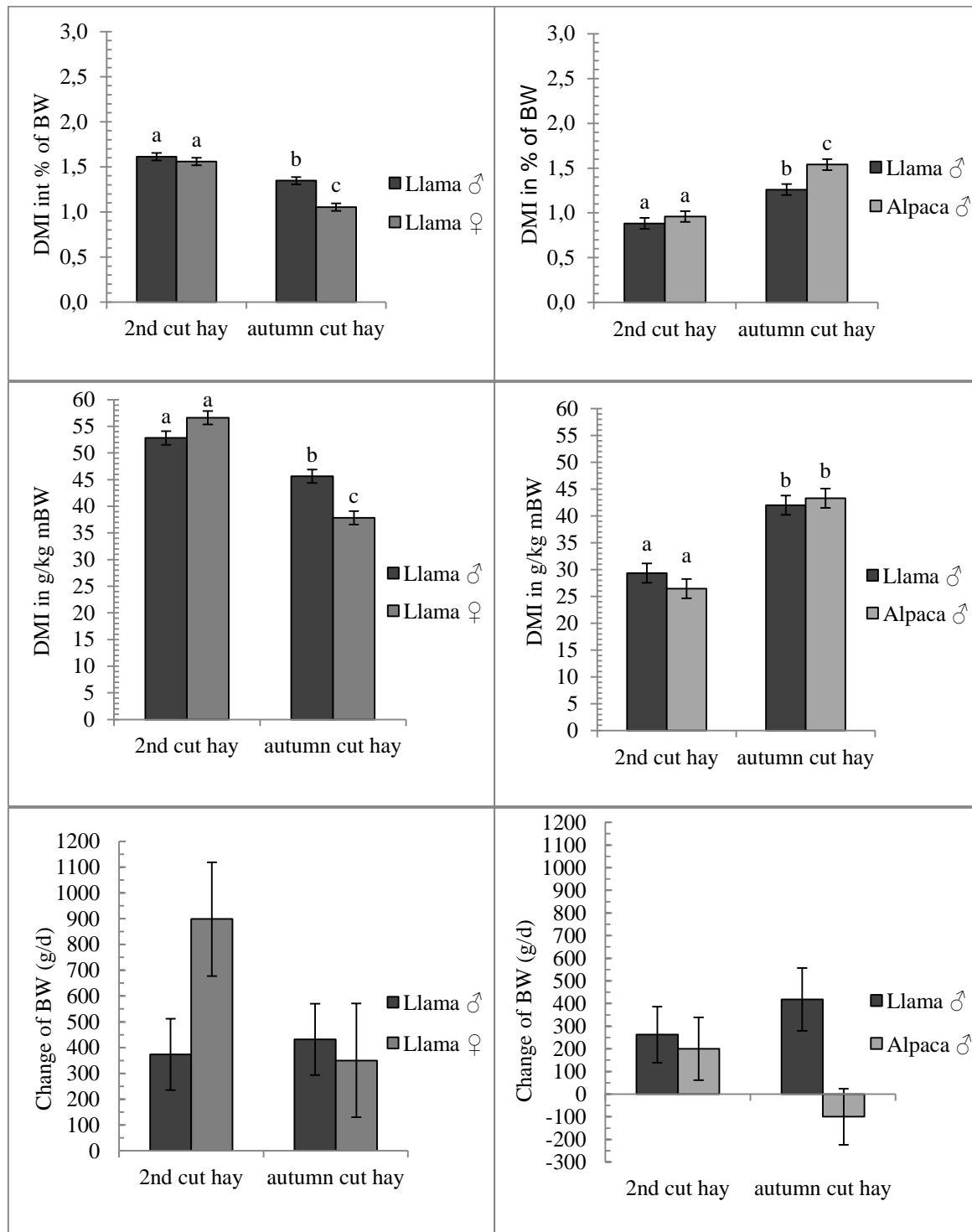
Resulting from the selection, the energy content of the remains of the llamas was 0.02 MJ ME/kg DM and 0.3 MJ ME/kg DM lower for 2<sup>nd</sup> and autumn cut hay, respectively. The residues of alpacas were 0.1 MJ ME/kg DM higher in the first run with the 2<sup>nd</sup> cut hay and 0.7 MJ ME/kg DM lower in the second run with the autumn cut hay (all LSmeans; SEM  $\pm$  0.1 MJ ME/kg DM). There was a highly significant influence in the energy- selection of quality only in the runs with the alpacas and in the autumn cut run between the species ( $p < 0.001$ ).

### Body weight development

The llamas had a daily weight gain of 263 g/d ( $\pm$  124 g/d) for 2<sup>nd</sup> cut and 418 g/d ( $\pm$  139 g/d) for autumn cut hay. The alpacas gained when fed with hay of 2<sup>nd</sup> cut 200 g/d ( $\pm$  139 g/d) and lost 100 g/d ( $\pm$  124 g/d) with the autumn cut hay. None of the runs did differ significantly, neither between the species nor between the cutting-time of the hay (Figure 1).

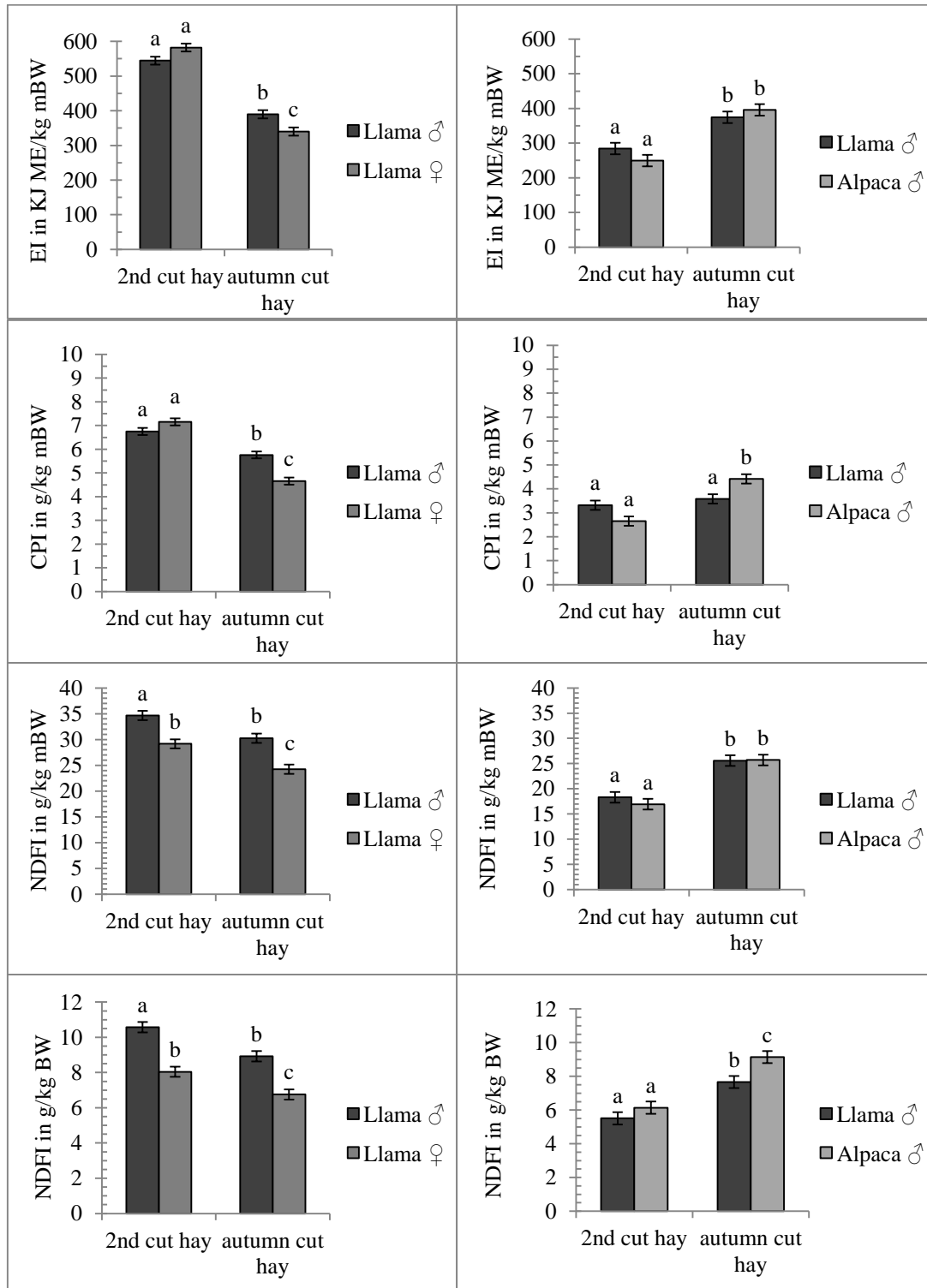


Figure 1: DMI expressed as % of BW and g per kg mBW and daily weight gain (g/d) of male and female llamas in experiment 1 (left) and male llamas and alpacas in experiment 2 (right) in dependence of the two different hay qualities (2nd cut vs. autumn cut)



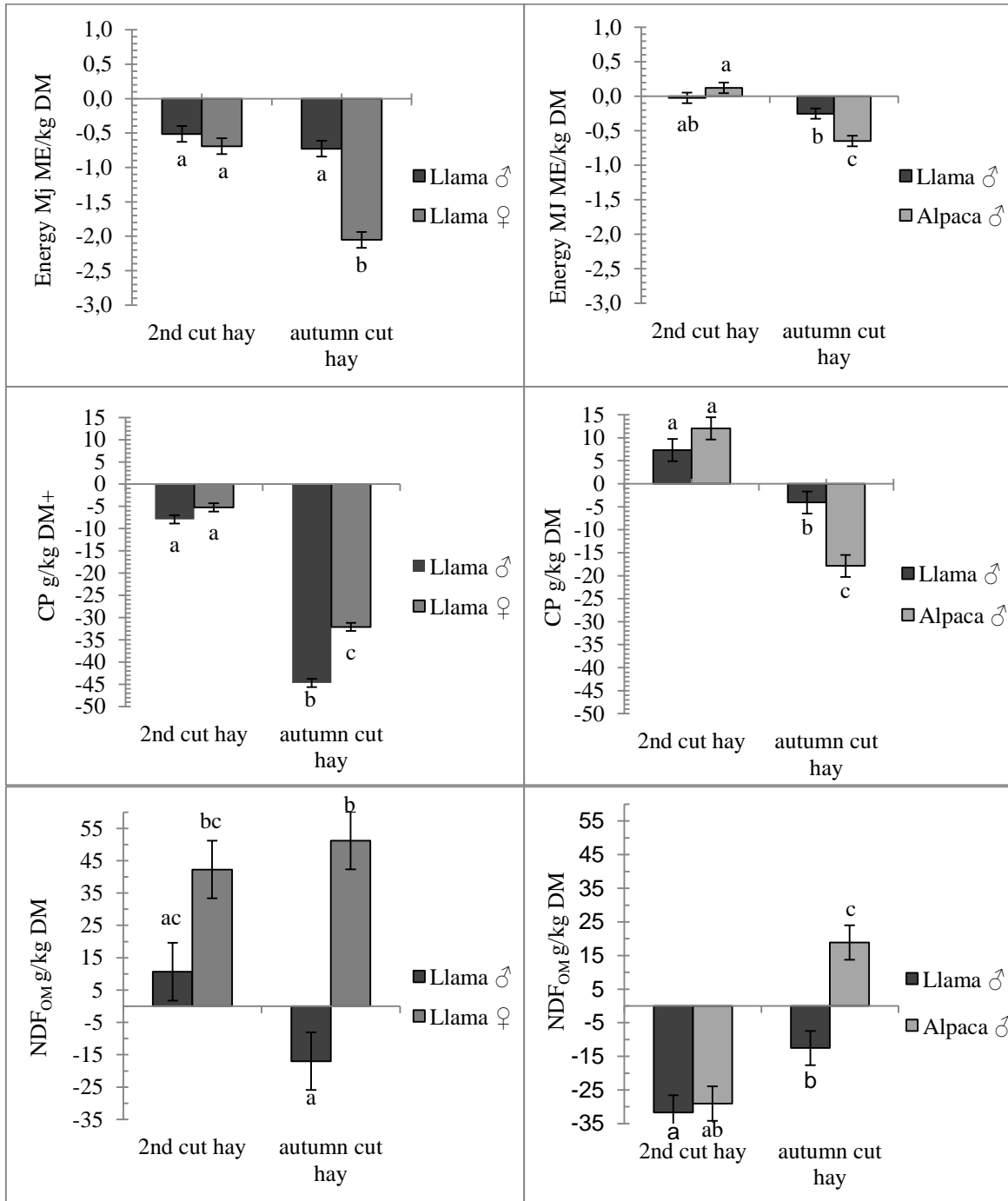
abc = p < 0.05

Figure 2: Intake energy (EI), crude protein (CPI) and neutral detergent fibre (NDF<sub>OM</sub>) of male and female llamas in experiment 1 (left) and male llamas and alpacas in experiment 2 (right) in dependence of the two different hay qualities (2<sup>nd</sup> cut vs. autumn cut)



abc = p < 0.05

Figure 3: Difference between supplied feed and feed residues in energy, crude protein (CP) and NDF<sub>OM</sub> content of male and female llamas in experiment 1 (left) and male llamas and alpacas in experiment 2 (right) in dependence of the two different hay qualities (2<sup>nd</sup> cut vs. autumn cut)



abc = p < 0.05

## Discussion

By using examples for hays in Menke and Huss (1987), the two hay types used in this study can be characterized as hay of good quality (2<sup>nd</sup> cut hay) and hay between low and middle quality (autumn cut hay). Early 2<sup>nd</sup> cut hay, which was characterised by a higher CP and lower NDF<sub>OM</sub> content, lead to a higher EI per kg mBW and CPI per kg mBW of the llamas compared with late bloom autumn hay in experiment one. In experiment two a reversed result was obtained. Furthermore, feeding selectivity in favour of high CP and energy content was less pronounced when 2<sup>nd</sup> cut hay was offered in all animals.

Experiments one and two differed in DMI related to mBW, since in the comparison of genders, a higher DMI with 2<sup>nd</sup> cut hay was found, while animals in experiment two had a higher DMI in the run with hay cut in autumn. Cebra et al. (2014) suggested a DMI at maintenance requirements to be in a desired range of about 38 to 54 g/kg mBW and Fraser and Baker (1998) reported a daily intake of 44 to 56 g/kg mBW. The animals of the first experiment were all perfectly within this range. However, in the first run (2<sup>nd</sup> cut) of the second experiment all the animals fed less than 30 g/kg mBW. On a long term, such an amount could lead to undersupply of the animals.

While DMI related to mBW may be considered the best option if accurately meeting energy requirements or comparisons of animals differing in BW (like llama vs. alpaca) are major goals, DMI expressed as % BW is still popular in the community of SAC husbandry practitioners and due to its calculatory ease has its definite advantages as long as animals are all within a rather close BW spectrum, e.g. only adult llamas. A large body of literature uses this way to express DMI: In a previous study using mixed gender groups of castrated male and non-pregnant female llamas, a DMI of 1.26 % of BW for llamas for hay rich in energy and CP and 0.89 % of BW for hay of increased NDF<sub>OM</sub> and reduced CP content was found (Stölzl et al., 2014), both similar to the present study. Dumont et al. (1995) found a similar DMI of 0.8 to 1.3 % of BW under grazing conditions. Reviewing a large number of studies on intake, San Martin and Bryant (1989) found an average DMI for llamas of 2.0 % of BW which is a bit higher than the results of this study. Nevertheless, it is difficult to compare grazing studies with studies under controlled housing conditions. Van Saun (2006) insisted that the exact DMI can only be detected under those controlled housing circumstances as used in the study presented here. In previous studies so far, the DMI was mainly measured either based on one single hay quality or averaged over a wide range of qualities. Neither the male llamas nor the female llamas or the male alpacas could reach a DMI the level of 3 % of BW that was described by Gauly et al. (2011) as a possible maximum intake.

The highly increasing intake of the females when receiving hay with higher CP content following a period in which CP was low might have been influenced by some physiological feedback. Similarly as described for other herbivores by Barboza and Hume (2006), SACs may increase their food intake on high quality food to build up energy reserves for a period where only feed of lower quality is available. This can be ascribed to the area of origin (Altiplano of Peru and Bolivia) where it usually rains only between December and March, followed by a long period of total drought. During this dry season, SACs may face a severe constraint of their nutritional needs (Cebra et al., 2014). Wild-living animals match their nutritional requirements between periods of nutritional excess and nutritional deficits at a timescale varying greatly (Barboza and Hume, 2006).

Compared to llamas, the nutritional requirements of alpacas are even less known. The negative correlation between feed intake and coarse fibrous feed contents as found by López et al. (1998) was contrasted by the finding of our second experiment in which animals fed more when autumn cut hay with a higher NDF<sub>OM</sub> content was offered. Generally, DMI values for alpacas varied from 1.2 to 2.4 % of BW (Fernandez-Baca and Novoa, 1963–1966; Florez and Valdivia, 1973), which are close to what was found here with 1.0 % of BW for hay of high and 1.5 % of BW for hay of low protein content. Also, Reiner et al. (1987) had similar results in their study. There the alpacas fed more from the oat hay with less protein (1.25 % of BW) and less of the ryegrass with a higher protein content (1.18 % of BW). However, like in our study the alpacas lost weight in the run with the hay lower in protein.

A surprising result of the study was the low DMI especially in the llamas of the first run of experiment two. While the intake of the animals of the three other runs was close to estimates by a camelid intake prediction equation based on NDF content of hay (Meyer et al., 2010) (measured 42, 55 and 43 g/kg mBW vs. predicted 45, 49 and 47 g/kg mBW), intake in this run (28 g/kg mBW) was well below the predicted 48 g/kg mBW. While nutrient composition can be excluded as explanation, different factors must be considered. E.g., animals show less preferences for feed produced with higher levels of N fertilization or soil-contamination (Reid and Jung, 1965; Dulphy and Demarquilly, 1994). Ruminating animals are also very sensitive to changes in pH and osmotic pressure in their foreguts (Dulphy and Demarquilly, 1994), and are therefore able to adjust their feeding habits. Sheep, for example, feed on forage rich in fibre to prevent rumen disorders, even when energy-rich feed is available (Cooper et al., 1995). Furthermore, it has to be considered that herbivores show some adaption of the digestive tract after a prolonged experimental period. This might have led to the decreased DMI of the male

llamas that were used in both experiments (Karasov and McWilliams, 2005) although it should be excluded by the three week adaption period of each run.

The NDF<sub>OM</sub> content of the ingested hay in both experiments was much higher than the suggested range of 30-35 % NDF<sub>OM</sub> as minimum dietary fibre content in the work of Van Saun (2006). The amount of NDF<sub>OM</sub>-intake per day in g especially in the first experiment was similar to the NDF<sub>OM</sub>-intake of the llamas in the study of Dulphy et al. (1997). The results of this study indicated that there is a significant influence of the gender on the NDF<sub>OM</sub> intake and that female llamas have a more pronounced tendency to prefer less coarse forage. A similar result indicated the study of Leonardi and Armentano (2003) where milking cattle frequently consumed tender and shorter feed parts than offered. San Martin and Bryant (1989) and Florez and Valdivia (1973) claim that SACs appear to be better adapted than other animals on the lower quality forage found in the drier regions of South America. They suggested that the physiological features and the longer retention time in forestomach confer a greater digestive efficiency especially for fibrous low quality feed. Results of Van Soest (1994) and López et al. (1998) also suggest a more efficient fermentation of forages high in NDF<sub>OM</sub> content compared with other ruminants. This was also supported by the weight gain which emphasized that the llamas compensated for the lower hay quality and did not lose weight except for the alpacas when autumn-cut hay was offered. This could be confirmed by the fact that with a larger body size the mass-specific energy requirements are decreasing. Large herbivores can easier reach their nutritional requirements with low quality feed (Kleiber, 1961; Demment and Van Soest, 1985) By implication, the smaller SAC species alpaca may have a higher diet quality requirement than the bigger llamas. Another argument for the probable higher basic need of alpacas compared to llamas may be that alpacas are wool producing animals with a finer type of fibre (Cebra et al., 2014). An alpaca producing between 0.9 to 4.0 kg fibre a year needs about 314.0 to 1507.3 KJ ME per day more energy additional to the maintenance requirement (NRC, 2007; Cebra et al., 2014). The studies of Newman and Paterson (1994) and Russel and Redden (1997) show that high quality nutrition has a positive effect on fibre growth and guarantees a high fleece quality. In the latter study, male alpacas were either fed a low or high energy and CP diet. The animals with the high energy diet had a higher clean fleece weight, fibre length and length to diameter ratio compared to the other group. Furthermore, it might be harder for them to balance a period with low quality food which in consequence leads to weight loss. Especially for animals producing wool at higher levels, the additional requirement should be considered to some extent.

To measure the energy content of feed, the HGT (Menke et al., 1979) is a valuable method. This test is normally performed using rumen fluid of fistulated cattle. The energy content (MJ ME) can be estimated using the formula for grass products (G4) of the GfE (2008). Considering the use of rumen fluid from cattle, values estimated here have to be taken with caution as the ability to digest fibre differs to some extent between ruminants and SACs (Dulphy et al., 1994; Van Soest, 1994; López et al., 1998). Generally, it is assumed that ME values from tables for cattle may underestimate the available energy for SACs by 3-5 % (NRC 2007; page 238), probably especially when fed with low quality forages. Nevertheless, the estimation of energy content of feeds based on in vitro fermentation with inoculum from true ruminants is considered as a feasible estimation for SACs. The results of the EI of our llamas are widely above the numbers (256 KJ ME per kg mBW per day) of von Engelhardt and Schneider (1977) or 305 KJ ME/kg mBW (NRC, 2007) for maintenance energy requirements.

The animals of experiment one had a higher CPI per kg mBW when the hay with higher CP content was fed. Contrarily, in experiment two the animals had a higher CPI per kg mBW when the hay of the lower CP content was offered. Again, this may indicate an attempt of compensating the phase with forage of lower quality. The llamas of experiment one were considerably oversupplied with CP if the numbers of the NRC (2007) were used as benchmark (75-158 g/d for maintenance). The alpacas nearly doubled their CPI with the autumn cut hay. As mentioned before, this may be due to the reduced energy and increased NDF<sub>OM</sub> content, which in turn resulted in compensation in terms of an increased absorption of CP. However, the compensation did not substantiate BW. The statement of San Martin and Bryant (1989) seems to be confirmed, that llamas are better adapted than alpacas to subsist on lower quality forage. NRC (2007) claimed, that ruminants with a free choice what to fed, will always be selective when choosing what to consume. They will select a feed with a better quality (higher digestibility and protein content) than the average of the plant biomass on offer. This fact we could confirm in both experiments. All animals selected for forage parts rich in CP and energy, especially in the run with the autumn cut hay. This is in contrast to the results of Leonardi and Armentano (2003), who claimed that in their case cows do not select more when only low quality hay is offered.

Somehow surprisingly, especially the male llamas selected the parts with the high NDF<sub>OM</sub> content. That result corresponds with the outcomes of the study of Fraser and Baker (1998) where male guanacos selected parts of the plants with a higher NDF and ADF content, too. It can be speculated if this behaviour is specific for male SACs. The male alpacas only preferred the hay-parts high in fibre in the runs with the tender 2<sup>nd</sup> cut hay. SACs are anatomical

predestined for selecting their feed. Their upper lip exhibits a labial cleft or philtrum, which splits it in two parts. Each part can move independently and is very sensible for investigating potential feed sources, while the lower lip is in one part and not that mobile or sensitive (Cebra et al., 2014).

### **Conclusion**

The present findings indicated that forage quality affects DMI of SACs significantly. Overall, llamas were better able to cope with hay high in NDF<sub>OM</sub> and low in CP content than alpacas. Especially female llamas tried to compensate the period of reduced feed quality with an increased intake afterwards. Apart from the hay composition, differences between male and female llamas were most pronounced when autumn cut hay was fed. The differences between male llamas and alpacas in the second experiment were lower but also most obvious for the autumn cut hay.

Further studies are desirable to continue to adjust nutritional requirements of SAC to activity level, reproduction status or exposure to extreme environmental conditions.



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**CHAPTER 4**

**Grazing behavior and dry matter intake of llamas (*Lama glama*) and German blackhead mutton sheep (*Ovis orientalis forma aries*) under Central European conditions**

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Appendix II

**Grazing behavior and dry matter intake of llamas (*Lama glama*) and German blackhead mutton sheep (*Ovis orientalis forma aries*) under Central European conditions****Abstract**

The aim of the present study was to assess the behaviour of llamas (*Lama glama*) and sheep (*Ovis orientalis forma aries*) when kept under Central European grazing conditions. In total, six adult female sheep and six adult female llamas were observed by direct observation during one week, in which each group was observed for a total time of 24 h. The animals were kept on the same pasture, but the species were raised in separate plots. Forage height before and after the experimental period were determined using a rising plate meter to calculate the average daily dry matter intake (DMI). Llamas had a daily DMI of 0.85 %/BW and sheep of 1.04 %/BW, respectively. The following behaviours were recorded by direct observation: grazing standing up, grazing lying down, ruminating standing up, ruminating lying down, lying down, lying down lateral and standing. Both species grazed for more than 50 % of the time. Ruminating was predominantly performed while standing and lying by sheep (about 50 % of the night and 12 % of the day) and while lying by llamas (54 % of the night and 10 % of the day). In conclusion, sheep and llamas differed in grazing behaviour and daily biorhythm. These differences indicate that sheep and llamas may not synchronize their behaviour when co-grazed, though particularly in co-grazing studies the observation period should be extended

**Keywords:** Llama, German blackhead mutton sheep, grazing behaviour, dry matter intake



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**CHAPTER 5**  
**General Discussion**

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## General Discussion

### *Dry matter intake and selectivity dependent on hay quality, gender and species*

Study 1 (Chapter 2) and study 3 (Chapter 3) were similar constructed with small differences. This can be attributed to the fact that study 1 was done to determine the DMI of the species South American camelid with the influence of different hay qualities and building on that, deriving a statement for their nutritional requirement. The objective in study 3 was to study the effects of hay quality on the DMI, intake of NDF<sub>OM</sub>, CP, energy and feed selection in South American camelids, comparing male and female llamas in a first experiment and male llamas and alpacas in a second.

In both studies, two groups of animals were simultaneously used per trial. In study 1, four animals per group (mixed groups with castrated male llamas and non-pregnant female llamas) and in study 3, five animals per group (male llamas, non-pregnant female llamas or male alpacas per group; n=10) were available. All of them got fed an alternating hay of different harvesting time and due to that a different quality. The outcomes of the two studies were condensed and calculated in different ways, which may have influenced the results. In the first study, the outcomes were calculated for the mean value of all eight animals and did not examine the two different groups separately. As distinct from the third study, in which the animals were strictly separated in female and male llamas (experiment 1) or male llamas and male alpacas (experiment 2). There the two groups of each experiment were always directly compared to each other.

In study 3, the quality, the harvesting point in time and the ingredients of the hay had a highly significant ( $p < 0.001$ ) influence on the DMI in % of BW of the South American camelids; whereas, this was not the case in study 1. The DMI in % of BW in both studies were similar. In study 1, an average DMI of 0.89 % ( $\pm 0.21$ ) to 1.26 % ( $\pm 0.23$ ) of BW were calculated for hay low and high in quality. A similar result showed the DMI in study 3 with a range of 0.9 % ( $\pm 0.06$ ) to 1.6 % ( $\pm 0.04$ ) of BW for the llamas. Other authors (Ordoñez, 1994; Dumont et al., 1995) found similar numbers for the DMI of 0.8 to 1.6 % of BW for llamas. But these obtained numbers were collected under grazing and free-ranging conditions. Nevertheless, it is proven complicated to compare result of grazing studies with studies under controlled housing conditions. Van Saun (2006) even asserted that the exact DMI can only be detected under strict controllable housing circumstances. San Martin and Bryant (1989) reviewed a larger number of different studies about the DMI of South American camelids and found an average DMI for llamas of about 2.0 % of BW. In previous studies, the dates of the DMI were collected based

on a single feed quality or averaged over a wider range of qualities, mostly under grazing conditions. The effect of gender, species and hay quality was not clearly determined. While it is still popular in the community of South American camelids husbandry practitioners to express the DMI in % of BW, the DMI in g/kg metabolic BW (mBW) may be considered to be the best option if accurately meeting energy requirements or comparisons of animals differing in BW (like llama and alpaca). For this reason, this study additionally calculated the DMI in g/kg mBW for a better comparability of female and male animals and the two different species in the third study. The harvesting time and the quality, which can be attributed to that point, had again a highly significant influence ( $p < 0.001$ ) on the DMI in g/kg mBW in both experiments of study 3. Experiments one and two differed in the outcome, since in the comparison of genders, a higher DMI with 2<sup>nd</sup> cut hay was found, while animals in experiment two had a higher DMI in the run with hay cut in autumn. Cebra et al. (2014) suggested a DMI at maintenance requirements to be in a desired range of about 38 to 54 g/kg mBW and Fraser and Baker (1998) reported a daily intake of 44 to 56 g/kg mBW. The animals of the first experiment were all perfectly within this range. In the second experiment of study 3, the animals had a lower DMI in g/kg mBW with the 2<sup>nd</sup> cut hay, than in experiment one, although they got nearly the same quality during these runs. The hay was visually without any negative notations and the animals were clinically healthy. While nutrient composition can be excluded as explanation, different factors must be considered. Most animals show less preference for hay contacted with high amounts of N fertilization or soil contaminations (Reid and Jung, 1965; Dulphy and Demarquilly, 1994; Peyraud and Astigarraga, 1998). Another explanation could be the theory that ruminating animals show some adaption of the digestive tract after a prolonged experimental period (Dulphy and Demarquilly, 1994). As already been stated, the male llamas were used in both experiments, which may have led to the decreased DMI (Karasov and McWilliams, 2005), although it should be excluded by the three week adaption period of each run of study 3. Indistinguishable health problems with their foreguts could be another cause for the lower DMI. Ruminants are very sensitive to changes in osmotic pressure and pH in their forestomach. They will try to change their diet to react on physiological variations before they conduct any obviously visible health problems (Dulphy and Demarquilly, 1994). Cooper et al. (1995) observed that sheep feed on plants rich in fibre to prevent rumen disorder even when there was a possibility to consume a more concentrated feed. The animals got the same quality during the same season with only a minimal change of temperature. Therefore, the seasonal or temperature impact (Newman and Paterson, 1994) can be excluded.

The nutritional requirements and feeding behaviours of alpacas are even less described compared to llamas. Already conducted studies about the DMI of alpacas showed a variation of 1.2 to 2.4 % of BW (Fernandez-Baca and Novoa, 1963–1966; Florez and Valdivia, 1973; San Martin and Bryant, 1989). The results of the third study with 1.0 % of BW for hay of high protein and 1.5 % of BW for hay of low protein content fit in this range. The result that the animals fed more when autumn cut hay was offered stands in contrast with the findings of López et al. (1998), who claimed that there exists a negative correlation between feed intake and coarse fibrous feed content. But Reiner et al. (1987) also showed a related result in their study, in which the alpacas fed less (1.18 % of BW) from the ryegrass with a higher protein content than from the oat hay with less protein (1.25 % of BW). The alpacas in the study of Reiner et al. (1987) lost weight in the run with hay lower in protein, as was the outcome of this study. However in summary, it can be claimed that South American camelids have a DMI around 0.9 % to 1.6 % of their BW in housed and controlled conditions. These are numbers other studies have shown before, most of them for South American conditions or on pasture. Neither the male animals nor the female llamas of both studies increased their feed intake to a number near the 3 % of BW which was proposed previously as a possible intake in times of energy loss (e.g. Gauly et al., 2011; Duncanson, 2012).

The consumption of NDF<sub>OM</sub> in both experiments of study 3 was higher than Van Saun (2006) suggested: 30-35 % NDF in the diet as a minimum dietary fibre content in the feed of South American camelids. The results of this study also indicate that there is a significant influence of the gender on the NDF<sub>OM</sub> intake and that female llamas have a more pronounced tendency to prefer less coarse forage. Gender differences in food selectivity is probably even more obvious than intake and in consequence ingested diet quality have been described for various wild ungulates (e.g. ibex: Gross et al., 1996; giraffe: Pellew, 1984; red deer: Clutton-Brock et al., 1982).

Several authors (e.g. Florez and Valdivia, 1973; San Martin and Bryant, 1989) claimed that it can be assumed that South American camelids seemed to be better adapted than other herbivores on lower quality forage. The ecosystem of South America is composed of semi-arid regions at high altitude with seasonal droughts and sparse vegetation (Riek et al., 2007). Florez and Valdivia (1973) and San Martin and Bryant (1989) asserted that the reason of this adaptation is that these animals have a greater digestive efficiency especially for rough feed with low quality. This is allegedly because of special physiological features and the slower outflow rate of the forestomachs. After an *in sacco* dry matter digestibility study, Tichit and Genin (1997) came to the conclusion that the digestibility is indeed higher in llamas than in sheep. This can

be attributed to the fact that South American camelids disposed over a more efficient fermentation of highly fibrous forage than other ruminating animals (Van Soest, 1994; López et al., 1998). The slower passage rate results in an extended time for the microbial population in the compartments to ingest the cell wall fractions of the biomass. Dittmann et al. (2014) generally suggested a lower maintenance energy requirement which lead to a lower intake of 47 g/kg mBW for camelids in general vs. 63 g/kg mBW in ruminants.

These assumptions can be confirmed by the weight gain of the llamas in study 3. However, all animals of study 1 and the alpacas of study 3 during the trial with the fibrous hay containing a high NDF<sub>OM</sub> percentage, lost weight. Like mentioned before, the alpacas and as well as the alpacas of Reiner et al. (1987) lost weight in these trials even though they had an increased DMI. This indicates that a feed lower in energy may be more outbalancing for alpacas than it is for llamas. Alpacas, as wool producing animal with a finer type of fibre, may have a higher basic nutritional requirement than llamas (Cebra et al., 2014). An alpaca producing between 0.9 to 4.0 kg fibre a year needs about 314.0 to 1507.3 KJ ME per day more energy additional to the maintenance requirement (NRC, 2007; Cebra et al., 2014). Studies show that high quality nutrition has a positive effect on the fibre production and ensure such a high fleece quality (Newman and Paterson, 1994; Russel and Redden, 1997). It can be assumed that especially for wool producing animals it is necessary not to be in a negative energy rating. Especially for animals producing wool at higher levels, the additional requirement should be considered to some extent.

In study 1, the llamas lost weight no matter if they got high or low quality hay. Since a health problem could be excluded, the weight loss may be due mainly because of the available diet. It is worth noting that only a small number of animals were available and the average weight of mixed groups was used. The llamas in the third study did not lose weight, which may be confirmed by statements of Kleiber (1961) and Demment and Van Soest (1985) that with a larger body size the mass-specific energy requirements are decreasing. That could be the reason why larger animals may reach their nutritional requirements easier with a low-energetic diet. In both studies, a much higher variation of daily weight gain was anticipated, in particular a weight loss in the runs with the more fibrous hay higher in NDF<sub>OM</sub> and lower in protein.

To measure the energy content of feed, the HGT (Menke et al., 1979) is a valuable method. This test is usually performed using rumen fluid of fistulated cattle. The energy content (MJ ME) can be estimated using the formula for grass products (G4) of the GfE (2008). Considering the use of rumen fluid from cattle, values estimated here have to be taken with caution as the ability to digest fibre differs to some extent between ruminants and SACs (Dulphy et al., 1994;

Van Soest, 1994; López et al., 1998). In general, it is assumed that ME values from tables for cattle may underestimate the available energy for SACs by 3-5 % (NRC 2007; page 238), probably especially when feed with low quality forages. Nevertheless, the estimation of energy content of feeds based on in vitro fermentation with inoculum from true ruminants is considered as a feasible estimation for SACs. The results of the EI of the llamas in study 3 are widely above the numbers (256 KJ ME per kg mBW per day) of von Engelhardt and Schneider (1977) or 305 KJ ME/kg mBW (NRC, 2007) for maintenance energy requirements.

In the first study, the llamas did not show any selective behaviour. This could be the reason for the weight loss in both trials. The situation is different in study 3, where this did not happen. It may be presumed that the llamas managed to compensate these times of low available energy with selectivity. NRC (2007) affirms that ruminating animals will always select their feed for a diet of high digestibility and protein content and low contents of secondary compounds when they have the free choice. This evidence was confirmed in both experiments of study 3. This is in contrast to the results of Leonardi and Armentano (2003), who claimed that in their case cows do not select more when only low quality hay is offered. Somehow, surprisingly, the male llamas selected the parts with the high NDF<sub>OM</sub> content. That result corresponds with the outcomes of the study of Fraser and Baker (1998) where male guanacos (*Lama guanicoe*) selected parts of the plant with a higher NDF and ADF content. It can be speculated that this behaviour is specific for male South American camelids.

South American camelids are anatomically predestined for selecting their feed. Their lower lip is more mobile and the upper lip is smaller and divided by a median groove or philtrum, which splits it into two parts. Each part of the upper lip is able to move independently and is more sensitive for examining potential feed sources. This allows a high selective ability (Cebra et al., 2014). It can be assumed that for female animals it is essential to build up reserves for physiological needs of more energy like lactation or pregnancy. The results may confirm this assumption. The female animals of study 3 showed a significant selective behaviour in dependence of the hay quality. The high increasing intake of the females when receiving hay with higher CP content following a period in which CP was low might have been influenced by some physiological feedback. Similar to what Barboza and Hume (2006) described for other herbivores, SACs may increase their food intake on high quality food to build up energy reserves for a period where only feed of lower quality is available. This can be ascribed to the area of origin (Altiplano of Peru and Bolivia) where it usually rains only between December and March, followed by a long period of total drought. During this dry season, SACs may face a severe constraint of their nutritional needs (Cebra et al., 2014). Wild-living animals match

their nutritional requirements between periods of nutritional excess and nutritional deficits at a greatly varying timescale (Barboza and Hume, 2006).

*Grazing behaviour and dry matter intake of llamas (Lama glama) and German black head mutton sheep (Ovis orientalis forma aries) under Central European conditions*

Both llamas and alpacas are important members of the agricultural sector of South America. The housing of these animals take place traditionally in small flocks mixed with sheep (*Ovis orientalis aries*) (Pfister et al., 1989). This concept could be efficient under Central European conditions, but their behaviour and grazing strategies are widely unknown in European latitudes. It is questionable if it is practical to transmit the South American knowledge, because of the huge difference between the countries in pasture productivity, performance of animals and climatic conditions. However, before it is useful to co-graze the two species standardly in Central Europe, it is necessary to understand the grazing behaviour in order to impose that the presence of other livestock disturbs or even changes the behaviour of the individual animal species (Brown et al., 2010).

The anatomy and physiology are the most striking differences between South American camelids and sheep like mentioned before. As a consequence the grazing strategy may differ largely. The third presented study (Chapter 4) shows the apparent differences in the grazing behaviour of llamas and sheep on pasture. Even though the main grazing time of both species happens during the day-hours, the sheep activity varied more between night and day than the llama activity. This may be due to the fact that sheep are in a higher risk of predation (Hulet et al., 1987; Lima and Dill, 1990; Penning et al., 1993) and cover only very short distances in the dark (Lin et al., 2011). Llamas on the other hand have a natural aggression toward canines and are not much endangered to become a victim of predators (Cavalcanti and Knowlton, 1998). Concluding, the grazing time during the daylight hours reflects the total daily grazing time for sheep, which confers widely with the 65 % mentioned by Bojkovski et al. (2014). It is reported that llamas graze in a cycle several times during the day (Gauly et al., 2011), what matches the outcome of this study. Llamas had a greater total grazing time than sheep like in the study of Pfister et al. (1989). Because the animals spent most of the daytime grazing it can be taken for granted that the rumination time was significantly higher in both flocks during the night time. Llamas prefer to separate ruminating and forage intake like cows (Schirmann et al., 2012). Sheep were often observed ruminating between two bites. These facts made it easier to capture the ruminating time of llamas than the one of sheep. The time-sampling method used in this

experiment may not be well suitable to capture the exact rumination time of the animals, since it is a snapshot in time.

Unlike sheep, llamas did not rest often simultaneously. This proves the claims of Gerken et al. (1997) that South American camelids are distance-animals, which avoid physical contact with each other. Like in the before mentioned study of Pfister et al. (1989), the sheep rested more than the llamas, but on the other hand llamas ruminated more often in a lying position. The animals may use this time for resting and relaxation. Resting in a lateral position is a behaviour only shown by llamas. A reason could be that sheep are in a higher risk of predation, because while lying in a lateral position they do not have the possibility to observe their environment (Hulet et al., 1987; Lima and Dill, 1990; Penning et al., 1993). In agreement with other studies (Pokorna et al., 2013; Bojkovski et al., 2014), the animals of this study had a very low frequency of standing without any other action, because they usually feed or perform other activities when standing.

It is questionable if the animals would synchronize themselves according to others, like Brown et al. (2010) indicate for herds with different livestock species in it. It is debatable if South American camelids and sheep really would disturb each other. It can be the case that the different foraging behaviour may be an important issue of resource partitioning between South American camelids and sheep. Another advantage of llamas can be that they function as an active or passive guard against canids or other predators, because of the appearance of a bond with sheep shown in the study of Cavalcanti and Knowlton (1998). An advantage of sheep grazing in llama flocks could be that South American camelids refuse to graze around their latrine area. They defecate and urinate in one particular spot, where long refused vegetation will develop. Fraser (1998) showed in his study that sheep feed from those areas around the latrine spot. This result claims that the wastage of good retained grazing places may decrease in co-grazing-systems.

Pfister et al. (1989) and San Martin (1987) suggest that co-grazing of sheep and South American camelids may exploit species-specific differences in behaviour on pasture. The different behaviour of the animals in this study submits the same result.



### **General conclusion**

The results of both studies (Chapter 2 and 3), but especially the one of study 3 indicate that the harvesting time and leading back to that the quality of the hay have a significant effect on the DMI of South American camelids. Apart from the hay composition, differences between male and female llamas were most pronounced when autumn cut hay was fed. The differences between male llamas and alpacas in the second experiment were lower, but most obvious for the autumn cut hay. The introduced studies 1 and 3 indicate that llamas are better adapted to hay quality with a high crude fibre proportion and a lower CP content than alpacas. Especially female llamas increase their feed intake by availability of lower hay quality and select components that were high in protein, and energy and low in fibre.

The theoretical calculations of study 1 show that llamas are commonly over-supplied with protein and energy and that alpacas are faster in a situation of energy deficiency. They will lose weight and show a bad body-condition (BCS 1 and 2 of 5), like they did in the second experiment of study 3. Alpacas were not able to cope as good as llamas with hay low in protein and high in NDF<sub>OM</sub>.

Study 2 (Chapter 4) showed that sheep and llamas have a different behaviour on pasture and a different daily biorhythm. It is questionable if the animals would synchronize their behaviour in a co-grazing situation or to the contrary, disturb each other. Co-grazing systems may be very effective in terms of resource usage, since overgrazing of one species can ruin a pastureland and may result in loss of useful forbs and grass species (NRC, 2007).

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## Summary

Anna Maria Stölzl

### Feeding behaviour of South American camelids

The feed intake of herbivores is affected by many different influences like season or anatomy of the gastrointestinal tract. Also the quality of the feed has an effect on the intake of various ruminating animals (e.g. Dulphy and Demarquilly, 1994; Meyer et al., 2009). Due to a lack of scientifically based publications surrounding South American camelids in Central Europe, the knowledge about nutrition physiology, behaviour and interaction with other species is still poor. The calculations of the nutritional requirements still are mainly based on the knowledge from South America and/or are simply adapted from other livestock, especially small ruminants. Using this knowledge is highly debatable, since among others, the performance and climatic conditions differ between South America and Europe and the anatomy and physiology of South American camelids and small ruminants varies considerably. Unlike other true ruminants, the stomach of the camelids is divided into three parts: the so-called compartments (C1, C2 and C3). There is also a hint about a lower energy-requirement existing.

South American camelids possess, like other ruminating animals, a microbial population in their compartments, which digest the fibrous parts of their feed (Gauly et al., 2011; Cebra et al., 2014). It is partially assumed that the combination of better digestive captivity and a higher level of microbial digestibility is an advantage in times only when low quality food is available (San Martin, 1987). Additionally, they have a better possibility to select their feed because of the split upper lip (Cebra et al., 2014).

Therefore, the aim of this study is to estimate the dry matter intake (DMI) of llamas (*Lama glama*) depending on different hay qualities under accurately controlled, experimental conditions (Chapter 2). Additionally, the derivation for the consequences of the nutrient supply of the animals is theoretically attempted. The objective is to study the effects of hay quality on DMI, crude protein intake and intake of fibrous parts (NDF<sub>OM</sub> content in ingested hay). Another objective is to compare feed selection between male and female llamas in one experiment and between male llamas and alpacas (*Vicunja pacos*) in a second experiment (Chapter 3). Another scientific issue discussed in this dissertation is to assess the 24 h behaviour of llamas and German blackhead mutton sheep (*Ovis orientalis forma aries*) when kept under Central European grazing conditions (Chapter 4).

In study 1 (Chapter 2), eight llamas, two geldings and six non-pregnant mares, born between 2004 and 2006 were used. The animals were divided randomly into two groups of four animals each with each group consisting of one gelding and three females of approximately the same weight. The study was conducted at the research farm of the Georg-August-University Göttingen (Lehr- und Versuchsgut Relliehausen). During the whole study, the animals were housed in individual pens of 10 m<sup>2</sup> with audio-visual contact to each other. The total study period lasted for 10 weeks (July to August 2010), divided into two 5-week periods. The two groups were fed with hay of two different qualities. Each of the two 5-week study periods consisted of a 4-week adaptation period followed by a sampling period of seven days. During this latter period, hay was weighed daily in order to calculate the daily amount of feed supplied. The remains of the previous day (including the ones on the ground) were weighed, too. The difference is defined as the feed intake. During the first five weeks, group one was fed with hay 1 (15.1 % crude protein (CP); 8.5 % crude ash (CA); 3.1 % crude lipids (CL) and 52.6 % neutral detergent fibre (NDF<sub>OM</sub>) per kg DM) and group two with hay 2 (6.6 % CP, 6.18 % CA, 2.1 % CL and 64.3 % NDF<sub>OM</sub> per kg DM). After five weeks group one was fed with hay 2 and group two with hay 1. The hay quality did not significantly affect the DMI and therefore, the animals did not compensate for a lower feed quality with an increased DMI. The total average DMI was 1.26 % and 0.89 % of the bodyweight (BW) for hay 1 and hay 2, respectively, which is lower than expected in both groups. Subsequently, in theory, the nutrient requirement of llamas is calculated and the nutrient requirement of alpacas is estimated. The results suggest that llamas have to feed about 0.9 % of their BW to cover their nutrient requirements with low-quality hay. In general with European standards, it occurs that llamas have an over-supply of energy and protein whenever they are fed ad libitum with the most common basic forages. In consequence, the animals become obese. This situation is different for alpacas. According to our estimates, the animals may quickly become energy deficit. In consequence, alpacas often show a poor body condition score (BCS 1 to 2 out of 5) in cases where only forages of an average quality are offered. Because the nutrient requirements of the alpacas are only estimated from the requirements of the llamas more exact numbers should be determined in another study (Chapter 3). Additionally to the effects of hay quality on DMI, the objective is to study the crude protein intake and intake of fibrous parts (NDF<sub>OM</sub> content in ingested hay) and to compare feed selection in South American Camelids. Study 3 (Chapter 3) is conducted similarly to study 1 (Chapter 2), however, with small differences. Again, the study is conducted on the research farm of the Georg-August-University Göttingen in Relliehausen, Germany from September 2013 until February 2014. During this period, two experiments including 10 animals each were



conducted. Both experiments were divided into two four-week periods in which the animals received two sorts of hay. The hay types differed in the time of harvesting and therefore, also in the composition of the ingredients: 1) early 2<sup>nd</sup> cut hay (9.9 MJ ME/kg; 12.3 % CP; 7.7 % CA; 2.4 % CL; 57.4 % NDF<sub>OM</sub>; 30.0 % acid-detergent fibre (ADF<sub>OM</sub>)) and 2) late bloomed hay cut in autumn (8.5 MJ ME/kg; 9.4 % CP; 8.0 % CA; 1.5 % CL; 63.3 % NDF<sub>OM</sub>; 35.2 % ADF<sub>OM</sub>). In the first experiment, five uncastrated male llamas (average age 9.4 years; range: 4-13 years) and five non-pregnant female llamas (average age 7.6 years; range: 5-8 years) and in the second experiment, five uncastrated male llamas and five uncastrated male alpacas (average age 5.4 years; range: 4-7 years) of the breed Huacaya were used. During the whole study, the animals were housed on sawdust in individual pens of 3.5 to 3.5 m with audio-visual contact to each other, and with hay and water available ad libitum. Each of the 4-week study periods per hay quality consisted of a 3-week adaptation period followed by a sampling period of seven days. The animals got hay of the autumn cut in the first trial and 2<sup>nd</sup> cut hay in the second trial during experiment one. In experiment two, the animals were fed in reverse. During each of the 1-week sampling periods, feed intake was measured by daily weighing the supplied hay and the remains of the previous day (including those on the ground). The difference is defined as the feed intake like we did in study 1 (Chapter 2). Both offered and rejected hay was analysed for the chemical compositions CP, CL, CA, NDF<sub>OM</sub>, ADF<sub>OM</sub> and ME (*Hohenheim Gas Test*).

While in experiment 1, the DMI of male llamas in the run with the autumn cut hay amounted to 1.4 % of the BW, the female llamas only fed 1.1 % of their BW ( $p < 0.001$ ). In the run with the 2<sup>nd</sup> cut hay, the DMI was 1.6 % of the BW for both sexes. Additionally, we calculated the DMI in g per kg metabolic BW (mBW) to have a better comparability of sex and species. The DMI in g per kg mBW of male and female llamas respectively averaged 52.8 and 45.6 g per kg mBW for the male llamas (2<sup>nd</sup> cut and autumn cut hay) and 56.6 and 37.8 g per kg mBW for the female animals. There is also a high significant difference in the DMI between in dependence of the hay quality and between the sexes in the run with the autumn cut hay ( $p < 0.001$ ). The feed residues (autumn cut/2<sup>nd</sup> cut) had a lower concentration of CP ( $\sigma^7$ : - 44.7/- 7.9 g/kg DM;  $\sigma^8$ : - 32.1/- 5.2 g/kg DM) and energy ( $\sigma^7$ : - 0.7/- 0.5 MJ ME/kg DM;  $\sigma^8$ : - 2.0/- 0.7 MJ ME/kg DM). The NDF<sub>OM</sub>-content in the residues is higher in both runs of the female animals ( $\sigma^8$ : + 51.2 und + 42.3 g/kg DM) and in the autumn cut run of the male llamas ( $\sigma^7$ : + 10.7 g/kg). The average change of bodyweight was in the run with the autumn cut hay and 2<sup>nd</sup> cut hay 414 g/d and 374 g/d for the male llamas and 350 g/d and 899 g/d for the female llamas respectively. It can be assumed that the animals selected their feed in favour for parts with

higher quality and were able to compensate especially in the run with the hay lower in quality a potential deficiency situation.

In the second experiment of this study, DMI averaged 0.9 % and 1.3 % of BW for llamas and 1.0 and 1.5 % of BW for alpacas (2<sup>nd</sup> cut and autumn cut hay, respectively) ( $p < 0.001$ ). An impact of the species was only detectable in the run with the autumn cut hay ( $p < 0.05$ ).

Like in the first experiment of this study, we calculated the DMI in g per kg mBW to have a better comparability of the two groups. The results show a DMI of 29.4 and 42.0 g per kg mBW for llamas and 26.5 and 43.3 g per kg mBW for alpacas for 2<sup>nd</sup> cut and autumn cut hay, respectively ( $p < 0.001$ ). The feed residues also have lower/higher concentrations of NDF<sub>OM</sub> (L: - 31.7/- 12.5 g/kg DM; A: - 29.1/+ 18.7 g/kg DM), CP (L: + 7.3/- 4.1 g/kg DM; A: + 12.1/- 17.9 g/kg DM) and energy (L: - 0.02/- 0.3 MJ ME/kg DM; A: + 0.1/- 0.7 MJ ME/kg DM) as the offered hay. This suggests that the animals partly selected their feed. By comparison of llamas and alpacas during the period with the autumn cut hay, the alpacas were not able to compensate as good as the llamas with hay low in protein and high in NDF<sub>OM</sub> with an increased selection of CP or energy. Thus, they lost weight ( $\emptyset$  100 g/d). The statement of Johnson (1994) “*Llamas make their own pellets and therefore do not really need any*” could be qualified at least for alpacas raised under practical conditions. The DMI in this study is comparable with the intakes of the older studies including the first study of this dissertation (Ordoñez, 1994; Dumont et al., 1995; Stölzl et al., 2014). The results of both studies indicate that the harvesting time, and leading back to that, the quality of the hay have a high effect on the DMI of South American camelids. Apart from the hay composition, differences between the sexes and the species are perceptible in the runs with the more fibrous hay (autumn cut).

The aim of the second study (Chapter 4) is to assess the behaviour of six non-pregnant female llamas and six non-pregnant female German blackhead mutton sheep. The animals were kept on the same pasture, but the species were raised in separate plots and were directly observed over a period of one week also on the research farm of the Georg-August-University Göttingen in Relliehausen, Germany in August 2013. Forage height before and after the experimental period were determined using a rising plate meter (Castle, 1976) to estimate the average daily DMI. Llamas had a daily estimated DMI of 0.85 % of BW and sheep of 1.04 % of BW. The following behaviours were recorded by direct observation: grazing standing up (GSU), grazing lying down (GLD), ruminating standing up (RSU), ruminating lying down (RLD), lying down (LD), lying down lateral (LDL) and standing (S). Both species grazed (GSU and GLD) for more than 50 % of the time. Ruminating is predominantly performed while standing and lying down by sheep (about 50 % of the night and 12 % of the day) and while lying down by llamas (54 %

of the night and 10 % of the day). The study may also indicate that the llamas separate ruminating and forage intake. It also can be assumed that llamas are using their time ruminating during lying down for relaxation; otherwise, they have shorter relaxation times than the sheep. Nevertheless, we assume that ruminating is a behaviour that cannot be exactly captured with the direct observation method. Especially sheep were often observed ruminating between two bits, which made it difficult to capture it with this method of behaviour analysis. This reflects the very short rumination time in sheep in this experiment. Lying down in a lateral position to rest is a phenomenon practiced especially by llamas.

In conclusion, sheep and llamas differed in grazing behaviour and daily biorhythm. However, it can also be the case that the different foraging behaviour may be an important issue of resource partitioning between South American camelids and sheep. Baumont et al. (2000) claimed that in an extensive pasture farming system the food intake, feed composition and the impact of grazing on the vegetation is the result of a multi-layered relationship between the animal and the vegetation. Another advantage of llamas can be that the function as an active or passive guard against canids or other predators because of their natural aggression against canids and the appearance of a bond with sheep shown in the study of Cavalcanti and Knowlton (1998). An advantage of co-grazing sheep and llamas is that South American camelids refuse to graze around their latrine area and sheep feed from those areas around the latrine spot. All in all, co-grazing systems are very effective in term of resource usage, protection of animals and an improvement of the diet since overgrazing of one species can ruin a pastureland and results in loss of useful forbs and grass species (NRC, 2007).

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## Zusammenfassung

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### Fressverhalten von südamerikanischen Kameliden

Die Futteraufnahme von Herbivoren wird von verschiedenen Faktoren (u.a. Saison und Anatomie des Verdauungstraktes) beeinflusst. Ebenso wurden Auswirkungen der Futterqualität auf verschiedene Wiederkäuerarten nachgewiesen (e.g. Dulphy und Demarquilly, 1994; Meyer et al., 2009). Für Neuweltkameliden sind die Kenntnisse in diesem Bereich gering. Bei der Zusammenstellung der Futterrations und der Berechnung der Bedarfswerte wird in der Regel auf Erkenntnisse aus Südamerika, dem Herkunftsgebiet der Neuweltkameliden, zurückgegriffen oder es werden Werte von anderen Nutztieren, vor allem von kleinen Wiederkäuern, abgeleitet. Durch unterschiedliche klimatische Bedingungen und Haltungssysteme sind die südamerikanischen Daten allerdings nur schwer auf europäische Haltungsbedingungen zu übertragen. Weiterhin ist es durchaus problematisch, einen direkten Vergleich zum Wiederkäuer zu ziehen, da sich dieser anatomisch und physiologisch vom Neuweltkamel unterscheidet. Anders als die echten Wiederkäuer weisen diese nur ein dreiteiliges Magensystem, bestehend aus drei Kompartimenten (C1, C2 und C3), auf. Neuweltkamele besitzen, wie andere wiederkäuende Arten, eine Mikrobenpopulation in ihren Kompartimenten, die für die Verdauung der faserhaltigen Futterbestandteile verantwortlich ist (Gauly et al., 2011; Cebra et al., 2014). Es wird teilweise angenommen, dass die Kombination aus größerem Verdauungsvermögen und höherem Grad an mikrobieller Verdaulichkeit den Neuweltkamelen einen Vorteil bei geringer Futterqualität gegenüber anderen Pflanzenfressern verschafft (San Martin, 1987). Hinzu kommt die durch eine gespaltene Oberlippe anatomisch erleichterte Möglichkeit zur Futterselektion (Cebra et al., 2014)

Ziel der vorliegenden Dissertation ist es die Trockensubstanzaufnahme (TS-Aufnahme) und ihre Abhängigkeit von unterschiedlichen Qualitäten Heu bei Lamas (*Lama glama*) unter kontrollierten experimentellen Bedingungen zu ermitteln (Kapitel 2). Anschließend wird daraus die Nährstoffversorgung von Lamas und Alpakas (*Vicunja pacos*) theoretisch abgeleitet. Weiterführend sollte der Einfluss von Geschlecht (männliche und weibliche Tiere) und den zwei domestizierten Arten, Lama und Alpaka, auf die TS-Aufnahme und das Selektivitätsverhalten in Abhängigkeit von verschiedenen Heuqualitäten bestimmt werden

(Kapitel 3). Darüber hinaus sollte das Verhalten von Lamas und Schafen (*Ovis orientalis aries*) auf der Weide unter zentraleuropäischen Bedingungen ermittelt werden (Kapitel 4).

In Versuch 1 (Kapitel 2) standen acht Lamas auf dem Lehr- und Versuchsgut Relliehausen der Georg-August-Universität Göttingen zur Verfügung. Dabei handelte es sich um zwei Kastraten, sowie sechs güste Stuten, die zwischen 2004 und 2006 geboren worden sind. Die Tiere wurden in zwei Gruppen zu je vier Tieren eingeteilt (je ein Kastrat und drei Stuten) und in 10 m<sup>2</sup> große Boxen, einzeln mit Sichtkontakt und Möglichkeiten zur Lautäußerung zueinander aufgestellt. Die Datenaufnahme betrug insgesamt 10 Wochen im Juli und August 2010, die in je zwei fünfwochige Perioden geteilt wurde. In dieser Zeit erhielten die Tiere je eine Sorte Heu. Jede der fünf Wochen Perioden gliederte sich in eine vierwöchige Adaptionsperiode, auf die eine siebentägige Messperiode folgte. Zur Berechnung der täglichen Futteraufnahme wurde das Heu in dieser Periode täglich abgewogen und übergebliebene Reste zurückgewogen. Die Differenz zwischen Ein- und Auswaage wurde als Futteraufnahme definiert. Während der ersten fünf Wochen wurde Gruppe 1 mit Heu 1 (15,1 % Rohprotein (XP); 8,49 % Rohasche (XA); 3,1 % Rohlipide (XL); 52,6 % organische Neutral-Detergenzien-Faser (NDF<sub>OM</sub>: enthält Lignin Zellulose und Hemizellulose) pro kg Trockensubstanz (TS)) und Gruppe 2 mit Heu 2 (6,6 % XP; 6,18 % XA; 2,1 % XL; 64,3 % NDF<sub>OM</sub> pro kg TS) gefüttert. Danach wurden die Gruppen getauscht und Gruppe 1 erhielt Heu 2 und Gruppe 2 erhielt Heu 1. Die Heuqualität beeinflusste die TS-Aufnahme nicht signifikant. Die Tiere glichen die schlechtere Heuqualität nicht mit einer erhöhten TS-Aufnahme aus. Die durchschnittliche TS-Aufnahme betrug 1.26 % des Körpergewichts (KGW) für Heu 1 und 0.89 % des KGW für Heu 2 und fiel in beiden Gruppen damit niedriger aus als erwartet. Anschließend wurde mit den gewonnenen Ergebnissen die Versorgungssituation von Lamas theoretisch berechnet und die von Alpakas geschätzt. Demnach sollten Lamas über 0,9 % ihres KGW aufnehmen, um mit Heu von geringerer Qualität ihren Bedarf abzudecken. Da unter europäischen Bedingungen vorwiegend qualitativ hochwertigere Futtermittel verwendet werden, ist die Gefahr einer Energiemangelsituation bei Lamas selten vorhanden. In der Regel besteht eine Überversorgung mit Energie und Eiweiß, die zu Adipositas bei den Tieren führen kann. Bei Alpakas ist die Situation anders; sie würden nach unseren Schätzungen schneller in ein Energiedefizit kommen. Bei einer Versorgung mit durchschnittlicher bis geringer Heuqualität zeigen sich in der alltäglichen Praxis vermehrt Alpakas mit einem schlechten Body Condition Score (BCS 1-2 von 5). Da die Angaben für die TS-Aufnahme für die Alpakas in diesem Versuch von denen der Lamas abgeleitet worden sind, wurden präzise Zahlen in einer weiteren Studie (Kapitel 3) ermittelt. Zusätzlich zu den Effekten der Heuqualität auf die TS-Aufnahme sollten XP-Aufnahme und Aufnahme von den

faserhaltigen Anteilen ( $\text{NDF}_{\text{OM}}$  im aufgenommenen Futter) festgestellt werden. Außerdem wurde ermittelt, ob es zu einer Selektion des Futters durch die Neuweltkameliden kommt. Versuch 3 (Kapitel 3) war im Aufbau vergleichbar mit dem ersten Versuch. Die Untersuchungen fanden von September 2013 bis Februar 2014 auf dem gleichen Versuchsgelände statt. In diesem Zeitraum wurden zwei Experimente mit je zehn Tieren durchgeführt. Jedes Experiment dauerte zweimal vier Wochen, in denen die Tiere jeweils eine unterschiedliche Qualität Heu erhielten. Zur Verfügung stand ein im zweiten Schnitt geerntetes, eiweißreiches und rohfaserarmeres Heu ( $9,9 \text{ MJ ME/kg}$ ;  $12,3 \% \text{ XP}$ ;  $7,7 \% \text{ XA}$ ;  $2,4 \% \text{ XL}$ ;  $57,4 \% \text{ NDF}_{\text{OM}}$ ;  $30,0 \% \text{ Säure-Detergenzien-Faser (ADF}_{\text{OM}}$ : enthält Lignin und Zellulose) pro kg TS) und ein im Spätherbst geschnittenes, eiweißarmes und rohfaserreiches Heu ( $8,5 \text{ MJ ME/kg}$ ;  $9,4 \% \text{ XP}$ ;  $8,0 \% \text{ XA}$ ;  $1,5 \% \text{ XL}$ ;  $63,3 \% \text{ NDF}_{\text{OM}}$ ;  $35,2 \% \text{ ADF}_{\text{OM}}$  pro kg TS). Im ersten Experiment wurden fünf Lamahengste (Durchschnittsalter: 9,4 Jahre; Spanne: 4-13 Jahre) und fünf güste Lamastuten (Durchschnittsalter: 7,6 Jahre; Spanne: 5-8 Jahre), im zweiten Experiment dieselben fünf Lamahengste und fünf Huacaya-Alpakahengste (Durchschnittsalter: 5,4 Jahre; Spanne: 4-7 Jahre) verwendet. Die Tiere wurden in Einzelboxen ( $3,5 * 3,5 \text{ m}$ ) mit Sichtkontakt und Möglichkeit zur Lautverständigung auf Sägespäne aufgestellt. Heu und Wasser standen ad libitum zur Verfügung. In jedem Durchgang folgte nach einer dreiwöchigen Adaptionsperiode eine einwöchige Messphase. In Experiment 1 bekamen die Tiere im ersten Durchgang das im Spätherbst und im zweiten Durchgang das im 2<sup>ten</sup> Schnitt geerntete Heu. Im zweiten Experiment erfolgte die Gabe in umgekehrter Reihenfolge. Während der Messperiode wurde die Futteraufnahme durch Wiegen des verabreichten Heus, sowie der Futterreste ermittelt. Sowohl das angebotene als auch das nicht aufgenommene Heu, wurde im Hinblick auf XP, XL, XA,  $\text{NDF}_{\text{OM}}$ ,  $\text{ADF}_{\text{OM}}$  und metabolisierbare Energie (ME) (*Hohenheimer Futterwerttest*) analysiert. Während in Experiment 1, beim Einsatz des Heus aus dem Spätherbst, die männlichen Lamas mit  $1,4 \% \text{ des KGW}$  mehr TS aufnahmen als die weiblichen mit  $1,1 \% \text{ (} p < 0,001 \text{)}$ , erreichten beide Geschlechter beim Heu des zweiten Schnittes einen Wert von  $1,6 \% \text{ des KGW}$ . Zusätzlich wurde in dieser Studie die TS-Aufnahme in g/kg metabolischem Körpergewicht (mKGW) berechnet, um die Geschlechter und Arten besser miteinander vergleichen zu können. Die männlichen Lamas nahmen  $52,8$  und  $45,6 \text{ g pro kg mKGW}$  im zweiten Schnitt zubereiteten Heus und von im Spätherbst geschnittenem Heu zu sich. Die weiblichen Tiere fraßen  $56,6$  und  $37,8 \text{ g pro kg mKGW}$ . Hier konnte ein hoch signifikanter Einfluss des Heuschnittes auf die TS-Aufnahme ( $p < 0,001$ ), sowie des Geschlechtes im Durchgang mit dem im Spätherbst geschnittenen Heu festgestellt werden. Die Futterreste (Spätherbst/2<sup>ter</sup> Schnitt) hatten eine niedrigere Konzentration an XP ( $\text{♂: } - 44,7/- 7,9 \text{ g/kg TS}$ ;  $\text{♀: } - 32,1/- 5,2 \text{ g/kg TS}$ ) und Energie



(♂: - 0,7/- 0,5 MJ ME/kg TS; ♀: - 2,1/- 0,7 MJ ME/kg TS) und eine höhere Konzentration an NDF<sub>OM</sub> in den beiden Durchgängen der weiblichen Tiere (♀: + 51,2 und + 42,3 g/kg TS) und im Durchgang mit dem Spätherbstheu bei den männlichen Lamas (♂: + 10,7 g/kg TS). Die durchschnittliche tägliche Änderung des Körpergewichts betrug bei Fütterung von Heu vom Spätherbstschnitt bzw. 2<sup>ten</sup> Schnitt 414 g/d bzw. 374 g/d bei den männlichen und 350 g/d bzw. 899 g/d bei den weiblichen Lamas. Daraus lässt sich folgern, dass die Tiere ihr Futter zu Gunsten der Anteile mit höherer Qualität selektiert haben und so vor allem im Durchgang mit dem qualitativ geringwertigeren Heu eine mögliche Mangelsituation ausgleichen konnten. Im zweiten Experiment dieser Studie betrug die TS-Aufnahme 0,9 bzw. 1,3 % des KGW für die Lamas und 1,0 bzw. 1,5 % des KGW für die Alpakas bei Fütterung von Heu aus dem 2<sup>ten</sup> Schnitt bzw. Spätherbst. Der Einfluss des Schnittzeitpunktes war bei beiden Arten hochsignifikant ( $p < 0,001$ ). Wie schon im ersten Experiment war ein Einfluss der Art auf die TS-Aufnahme nur im Durchgang mit dem im Spätherbst geschnittenen Heu zu beobachten ( $p < 0,05$ ). Bei der Berechnung der TS-Aufnahmen in g/kg mKGW, um die Gruppen besser miteinander vergleichen zu können, ergaben sich 29,4 (2<sup>ter</sup> Schnitt) bzw. 42,0 g/kg mKGW (Spätherbst) für die männlichen Lamas und 26,5 bzw. 43,3 g pro kg mKGW (2<sup>ter</sup> Schnitt bzw. Schnitt im Spätherbst) für die männlichen Alpakas ( $p < 0,001$ ). Auch hier hatten die Futterreste (2<sup>ter</sup> Schnitt/Spätherbst) niedrigere bzw. höhere Konzentrationen an NDF (L: - 31,7/- 12,5 g/kg TS; A: - 29,1/+ 18,7 g/kg TS), XP (L: + 7,3/-4,1 g/kg TS; A: + 12,1/-17,9 g/kg TS) und Energie (L: - 0,02/- 0,3 MJ ME/kg TS; A: + 0,1/- 0,7 MJ ME/kg TS) verglichen mit dem angebotenen Futter. Daraus lässt sich auch hier auf eine partielle Selektion durch die Tiere schließen. Im Vergleich zu Lamas konnten die Alpakas bei Fütterung von Heu aus dem Spätherbst die aufkommende Energiemangelsituation nicht mit vermehrter Aufnahme und erhöhter Rohprotein- und Energieselektion ausgleichen und verloren folglich an Körpergewicht (Ø -100 g/Tag). Damit hat sich die von Johnson (1994) getroffene Aussage „*Llamas make their own pellets and therefore do not really need any*“ zumindest für das Alpaka bereits relativiert. Insgesamt sind die TS-Aufnahmen vergleichbar mit Ergebnissen älterer Studien (Ordoñez, 1994; Dumont et al., 1995; Stölzl et al., 2014). Die Ergebnisse der beiden für diese Dissertation durchgeführten Studien deuten darauf hin, dass bei Neuweltkameliden der Schnittzeitpunkt und die damit zusammenhängende Qualität und Zusammensetzung des Heus einen signifikanten Effekt auf die TS-Aufnahme haben. Ein Einfluss des Geschlechts und der Art konnte vor allem in den Durchgängen mit dem rohfaserreicherem Heu beobachtet werden (Schnitt im Spätherbst). In der Studie des vierten Kapitels wurde das Verhalten von sechs weiblichen güsten deutschen Schwarzkopfschafen und sechs weiblichen güsten Lamas für eine Woche mittels direkter

Beobachtung erfasst. Die Tiere wurden dafür auf derselben Weide, aber in getrennten Gattern gehalten. Der Versuch fand ebenfalls auf dem Lehr- und Versuchsgut Relliehausen der Georg-August-Universität Göttingen im August 2013 statt. Zur Abschätzung der täglichen TS-Aufnahme wurde vor und nach der experimentellen Periode die Grashöhe mithilfe eines Rising Plate Meters (Castle, 1976) erfasst. Diese wurde bei den Lamas auf 0,84 % des KGW und bei den Schafen auf 1,04 % des KGW geschätzt. Vor Beginn des Versuches wurden die folgenden sieben Verhaltensmuster definiert: stehend Grasens (GSU), liegend Grasens (GLD), stehend Wiederkauen (RSU), liegend Wiederkauen (RLD), Liegen (LD), seitlich Liegen (LDL) und Stehen (S). Die Ergebnisse dieser Studie zeigen, dass beide Tiergruppen mehr als 50 % des Tages mit Grasens (GSU und GLD) verbringen. Wiederkauen wurde vom Schaf vor allem im Liegen und Stehen beobachtet (ca. 50 % der Nachtaktivität und 12 % während des Tages). Im Gegensatz zum Lama, das vor allem liegend wiederkaut (54 % in der Nacht und 10 % während des Tages) und getrennt von jeglicher anderen Aktion. Es kann angenommen werden, dass die Neuweltkamele diese Zeit zum Ausruhen nutzen, da sie ansonsten kürzere Liegezeiten als die Schafe aufwiesen. Es ist zu vermuten, dass die genauen Wiederkauaktivitäten nur schwer mit der Methode der direkten Beobachtung festzuhalten sind. Vor allem Schafe wurden des Öfters beobachtet, wie sie zwischen zwei Bissen wiederkauten. Diese Art von Wiederkauen ist schwer mit der in diesem Versuch angewendeten Methode der Verhaltensanalyse einzufangen. Dies spiegelt sich ebenfalls in den kurzen Wiederkauzeiten der Schafe wieder. Im Gegensatz zu den Lamas konnte bei den Schafen nicht beobachtet werden, dass sie in seitlicher Position liegen. Zusammenfassend zeigten Schafe und Lamas ein unterschiedliches Grasungsverhalten und einen unterschiedlichen täglichen Biorhythmus. Diese Unterschiede im Weideverhalten, in Verbindung mit der Präferenz einer anderen Futterzusammensetzung, lassen sich eventuell bei gemeinschaftlicher Haltung von Neuweltkameliden und Schafen ausnutzen und somit die Weideproduktivität verbessern. In der Studie von Baumont et al. (2000) wurde festgestellt, dass in einem extensiven Haltungssystem die Futteraufnahme, die Futterzusammensetzung und der Einfluss der grasenden Tiere auf die Vegetation ein Ergebnis einer vielschichtigen Beziehung zwischen Tier und Vegetation ist. Ein weiterer Vorteil, der durch die Vergesellschaftung von Schafen und Lamas entsteht, ist, dass unter anderem die natürliche Aggression von Kameliden gegen Kaniden als Schutz für die Schafherde dienen könnte (Cavalcanti und Knowlton, 1998). Umgekehrt könnten Schafe die Latrinenstellen der Lamas abweiden, da diese von den Neuweltkamelen gemieden werden. Die Vergesellschaftung von verschiedenen Tierarten auf der Weide kann sich zusammenfassend als ein effektives Mittel gegen die Verschwendung von

Ressourcen, als Schutz der Tiere, eine Verbesserung der Futterzusammenstellung je Tier und dadurch eine Minimierung der Kosten herausstellen (NRC, 2007).

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**Appendix I**

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## Zusammenfassung

## Summary

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# Trockensubstanzaufnahme von Neuweltkameliden und deren Bedeutung für die Rationsgestaltung

## *Dry matter intake of South American camelids and its effects on the composition of feed rations*

Anna Maria Stölzl, Christian Lambertz, Eva Moors, Jennifer Stiehl, Matthias Gauly

Die Privathaltung von Neuweltkameliden gewinnt in Deutschland bereits seit Jahrzehnten an Bedeutung. Durch das Fehlen von wissenschaftlichen Publikationen ist das Wissen über deren Ernährungsphysiologie jedoch nach wie vor gering. Das Ziel dieser Studie war es daher, die Trockensubstanzaufnahme abzuschätzen, um eine Basis für Futterrationsberechnungen zu schaffen. Vorangegangene Studien schlagen eine Trockensubstanzaufnahme (TS-Aufnahme) von bis zu 3 % des Körpergewichtes (KGW) vor (Vaughan und Gauly, 2011).

In der vorgestellten Studie wurden acht Lamas (*Lama glama*) in zwei Gruppen zu je vier Tieren eingeteilt. Diese zwei Gruppen wurden mit Heu unterschiedlicher Qualität über einen Zeitraum von zehn Wochen gefüttert, der in zwei Durchgänge von je fünf Wochen unterteilt war. Im ersten Durchgang wurden Gruppe 1 mit Heu 1 (15,1 % Rohprotein; 8,5 % Rohasche; 3,1 % Rohfett; 52,6 % NDF pro kg TS) und Gruppe 2 mit Heu 2 (6,6 % Rohprotein; 6,2 % Rohasche; 2,1 % Rohfett; 64,3 % NDF pro kg TS) gefüttert. Nach fünf Wochen wurden die Gruppen gewechselt und Gruppe 1 erhielt Heu 2 und Gruppe 2 Heu 1. Das Körpergewicht wurde vor und nach jedem Durchgang erfasst (Wochen null, fünf und zehn). Die Heuqualität beeinflusste die TS-Aufnahme und die Tiere glichen eine schlechtere Futterqualität nicht mit einer erhöhten TS-Aufnahme aus. Die TS-Aufnahme betrug 1,26 bzw. 0,89 % des Körpergewichtes für Heu 1 und Heu 2 und fiel in beiden Gruppen niedriger aus als erwartet. Folglich sollten Rationsberechnungen für Neuweltkameliden an diese niedrigeren TS-Aufnahmekapazitäten angepasst werden.

**Schlüsselwörter:** Lama (*Lama glama*), Heuqualität

The number of South American camelids (SAC) is increasing in Germany since decades. Due to a lack of scientifically based publications the knowledge about feeding SACs is still poor. Therefore, the aim of this study was to estimate the dry matter intake (DMI) of SACs as a basis for calculations of feed rations. Previous studies proposed a DMI of up to 3% of the body weight (BW) (Vaughan und Gauly, 2011). In the present study, eight llamas (*Lama glama*) were allocated to two groups of four animals each. The two groups were fed with hay of different qualities over a total period of ten weeks, which was divided into two runs of five weeks each. During the first run, group 1 was fed with hay 1 (15.1% crude protein; 8.5% crude ash; 3.1% crude fat; 52.6% NDF per kg DM) and group 2 with hay 2 (6.6% crude protein; 6.2% crude ash; 2.1% crude fat; 64.3% NDF per kg DM). After five weeks the groups were changed and group 1 received hay 2 and group 2 received hay 1. BW was measured at the start and end of each run (week zero, five and ten). The hay quality affected the DMI, but the animals did not compensate a lower feed quality with an increased DMI. The total DMI was 1.26% and 0.89% of the BW for hay 1 and hay 2, respectively, which was lower than expected in both groups. In conclusion, calculations of feed rations for SACs should be adjusted to the present findings of a lower DMI capability.

**Keywords:** llama (*Lama glama*), hay quality

## Einleitung

Die Privathaltung von Neuweltkameliden nimmt seit Ende der siebziger, Anfang der achtziger Jahre kontinuierlich zu. Mittlerweile hat sich die Haltung in Deutschland etabliert (Nickolmann et al., 2008; Schwalm et al., 2008). Bei der Zusammenstellung der Futtermittelliste und der Berechnung der Bedarfswerte wird nach wie vor auf Erkenntnisse zurückgegriffen, die entweder aus den Ursprungsländern dieser Tierart stammen oder von anderen Nutztieren, überwiegend kleinen Wiederkäuern, abgeleitet wurden. Vor allem die aus Südamerika stammenden Daten sind unter anderem aufgrund der verschiedenen klimatischen Einflüsse nur bedingt auf die Haltungsumwelt in Europa übertragbar. Auch die Vergleichbarkeit zu den kleinen Wiederkäuern ist limitiert, da sich Anatomie und Physiologie von Neuweltkameliden davon unterscheiden. Somit sind Erkenntnisse nicht unmittelbar von Schafen und Ziegen auf Lamas und Alpakas übertragbar.

Engelhardt (1978) und Hinderer (1978) verfassten die ersten Studien über den Nährstoffbedarf von Lamas bereits in den siebziger Jahren. Später folgten einige Untersuchungen in anderen europäischen Ländern (Adam, 1990). Insgesamt ist die Anzahl wissenschaftlich belastbarer Publikationen zum Thema Ernährungsphysiologie von Neuweltkameliden allerdings sehr gering.

Es kann angenommen werden, dass die Tiere an Futtermitteln mit einem hohen Rohfaseranteil und vergleichsweise niedrigen Nährstoffgehalten angepasst sind, da sie aus Ländern mit sehr widrigen Umweltbedingungen stammen. Folglich können sie rohfaserreiche und vergleichsweise nährstoffarme Futtermittel besser verwerten als andere domestizierte Wiederkäuer, wie z. B. Schafe oder Rinder (Schneider et al., 1974; Moseley, 1993). Der größte Unterschied zwischen dem Verdauungssystem von Neuweltkameliden und echten Wiederkäuern beruht auf anatomischen Merkmalen. Neuweltkameliden weisen im Gegensatz zu Wiederkäuern mit einem viergliedrigen Magensystem nur drei sogenannte Kompartimente (C1 bis C3) auf (Vallenas et al., 1971). Trotz existierender Unterschiede bei der Aufnahmefähigkeit des Vormagensystems ähnelt sich die Zusammensetzung des aufgenommenen Futters. Von größerer Bedeutung ist jedoch die Passage rate durch das Vormagensystem. Vergleichende Studien zwischen Neuweltkameliden und echten Wiederkäuern zeigen, dass das aufgenommene Futter viel langsamer durch das Kompartiment C1 der Neuweltkameliden als durch den Pansen der echten Wiederkäuer fließt (Florez, 1973; Clemens und Stevens, 1980; San Martin, 1987). Die reduzierte Passage rate führt zu einer verlängerten Verweildauer des Futters in den Gärkammern. Somit können Neuweltkameliden Zellwandfraktionen besser aufspalten und verdauen (Florez, 1973; Hintz et al., 1973; San Martin et al., 1986; San Martin 1987, 1991; Cordesse et al., 1992; Genin et al., 1994; Genin und Tichit, 1997; Hospinal, 1997; Lopez et al., 1998). Gegenwärtig wird von einem täglichen Energieerhaltungsbedarf von etwa 0,03 MJ metabolisierbare Energie (ME) pro kg metabolischem Körpergewicht ausgegangen (Schneider et al., 1974). Bei vermehrter Bewegung und/oder bei sehr niedrigen Temperaturen, z. B. nach der Schur, müssen bis zu 50 % mehr veranschlagt werden. Ein ausgewachsenes Alpaka (70 kg KGW) hat demnach einen Energieerhaltungsbedarf von ca. 7–8 MJ ME (Carmean et al., 1992; Van Saun, 2006) und ein Lama (150 kg KGW) von ca. 11–12 MJ ME (Vaughan und Gauly, 2011). Der Proteinbedarf liegt bei etwa

8–10 % der TS (Davies et al., 2007). Trächtige und laktierende Tiere benötigen einen Proteinanteil von 12–14 %; Jungtiere haben einen etwas höheren Bedarf, der durch die Milch der Muttertiere abgedeckt wird. In den Tabellen 1 und 2 sind Energie- und Proteinbedarfswerte von Neuweltkameliden in verschiedenen Leistungsstadien nach Vaughan und Gauly (2011) angegeben.

Zur Aufrechterhaltung der Funktionsfähigkeit des Vormagensystems (C1–C3) müssen 20–25 % der Ration aus strukturierter Rohfaser bestehen (Gauly und Vaughan, 2011). Für eine angepasste Rationsgestaltung muss neben dem Nährstoffbedarf der Tiere auch deren maximale TS-Aufnahme bekannt sein. Dies ist vor allem unter Bedingungen, bei denen das Tier eine erhöhte Leistung erbringt, oder bei ad libitum Fütterung wichtig. In der Literatur sind maximale TS-Aufnahmen von bis zu 3 % des Körpergewichtes angegeben, wobei diese von anderen Tierarten abgeleitet wurden (Vaughan und Gauly, 2011). Demnach kann z. B. ein 150 kg schweres Lama bis zu 4,5 kg TS aufnehmen, was z. B. 5,0 kg Heu bei einem TS-Gehalt von 92 % oder 30 kg Gras bei einem TS-Gehalt 15 % entspräche (Tab. 3). Andere Autoren gehen von TS-Aufnahmen von 1,8–2,0 % des Körpergewichtes aus, wobei auch hier keine Exaktversuche durchgeführt wurden (Fowler, 1992).

Als einen wesentlichen Einflussfaktor auf die TS-Aufnahme nennen Lopez et al. (1998) die Qualität des Futtermittels, welche entscheidend durch die Verdaulichkeit bestimmt wird. Variierende TS-Aufnahmen in Abhängigkeit der Rohproteingehalte wurden bereits an anderen Tierarten, wie z. B. Rindern, beschrieben (Broderick, 2003; Van Dung et al., 2013).

Da es nach Kenntnis der Autoren keine Studien zu diesem Thema für Neuweltkameliden gibt, war es das Ziel dieser Studie, die TS-Aufnahme in Abhängigkeit von der Grundfutterqualität zu messen und darauf aufbauend Konsequenzen für deren mögliche Nährstoffversorgung abzuleiten. Schließlich kann nur eine tiergerechte Fütterung zu einem angepassten Wachstum von Fohlen, guten Reproduktionsergebnissen, qualitativer und hoher Wollproduktion und einer optimalen Körperkondition in allen Lebensabschnitten führen.

**TABELLE 1:** Energiebedarf für die Erhaltung bei Neuweltkameliden in Abhängigkeit vom Körpergewicht nach Vaughan und Gauly (2011)

Körpergewicht (kg)	ME (MJ) (+ 10 %)	ME (MJ) (+ 20 %)
50–80	5,3–7,5	5,8–8,2
80–100	7,5–8,9	8,2–9,7
100–130	8,9–10,8	9,7–11,8
> 130	> 10,8	> 11,8

**TABELLE 2:** Rohproteinbedarf für die Erhaltung bei Neuweltkameliden in Abhängigkeit vom Leistungsstadium nach Vaughan und Gauly (2011)

Leistungsstadium	Rohproteinbedarf (%)
Erhaltung	8–10
Trächtigkeit (erste zwei Drittel)	10–12
Trächtigkeit (letztes Drittel)	12–14
Laktation	13–15
Wachstum < 9 Monate	14–16
Wachstum 9–18 Monate	12–14

## Material und Methoden

Für die Untersuchungen standen acht Lamas (*Lama glama*) auf dem Lehr- und Versuchsgut Relliehausen der Georg-August-Universität Göttingen zur Verfügung. Es handelte sich um zwei Kastraten sowie sechs nichttragende Stuten. Alle Tiere wurden zwischen 2004 und 2006 geboren, zu Versuchsbeginn tierärztlich untersucht und für klinisch gesund befunden. Die Tiere wurden in zwei Gruppen zu je vier Tieren aufgeteilt, wobei jede Gruppe jeweils einen Kastraten und drei Stuten umfasste. Die Tiere wurden nach ihrem Gewicht in die beiden Gruppen aufgeteilt, sodass die Gesamtgewichte der beiden Gruppen nahezu gleich waren. Das Körpergewicht betrug in Gruppe 1 im Mittel 144,3 kg und variierte zwischen 113,5 und 184,0 kg, in Gruppe 2 im Mittel 145,0 kg und variierte zwischen 110,0 und 169,5 kg. Die Versuchsdauer betrug zehn Wochen (Juli bis August 2010), die sich in zwei Durchgänge mit jeweils fünf Wochen aufteilte. Alle Tiere wurden jeweils zu Beginn und Ende der beiden Durchgänge gewogen.

Die beiden Gruppen wurden mit Heu zweier Qualitäten gefüttert. In den ersten fünf Wochen bekam Gruppe 1 Heu 1 und Gruppe 2 Heu 2 zu fressen. Im zweiten Durchgang wurden die Gruppen getauscht, sodass Gruppe 1 Heu 2 und Gruppe 2 Heu 1 erhielt. Jede der beiden Fünf-Wochen-Perioden beinhaltete eine vierwöchige Adaptationsperiode, auf die eine siebentägige Sammelperiode folgte. Während der letztgenannten Periode wurde Heu täglich gewogen und in 90-l-Containern angeboten, die auf dem Boden platziert wurden. Die tägliche Futteraufnahme wurde berechnet, wobei die

zum Zeitpunkt der nächsten Fütterung verbliebenen Futtermengen inklusive der Reste am Boden der Box täglich zurückgewogen wurden. Die im Versuch eingesetzten Futtermittel wurden zu Beginn des Versuchs in Anlehnung an die Methodik von Jeroch et al. (1999) beprobt und anschließend mittels Weender Analyse (Henneberg und Stohmann, 1860) am Department für Nutztierwissenschaften, Abteilung für Tierernährungsphysiologie der Georg-August-Universität Göttingen, untersucht. Die Ergebnisse sind in Tabelle 4 dargestellt. Aus den ermittelten Werten wurde nach der DLG-Futterwerttabelle (DLG, 2005) ein Energiegehalt von 9,7 bzw. 7,7 MJ ME unterstellt. Die Tiere waren während des Versuchszeitraums in Einzelboxen mit einer Fläche von 10 m<sup>2</sup> mit Sichtkontakt zueinander auf Sägespäne aufgestellt.

Die statistische Auswertung der Daten erfolgte mittels des Programmpaketes SAS. Für die Analyse der Futteraufnahme wurde folgendes Modell verwendet:

$$Y_{ijkl} = \mu + FM_i + W_j + T_k + e_{ijkl}$$

- $\mu$  = Mittelwert der Gesamtprobe
- $FM_i$  = fixer Effekt des i-ten Futtermittels
- $W_j$  = fixer Effekt der j-ten Woche
- $T_k$  = fixer Effekt des k-ten Versuchstages
- $e_{ijkl}$  = zufälliger Restfehler

## Ergebnisse und Diskussion

### Futter- und Trockensubstanzaufnahme

Die TS-Aufnahmeraten betragen 2,15 kg pro Tag in der Gruppe, die das Heu der guten Qualität erhielt, und 1,79 kg pro Tag für das Heu von der schlechteren Qualität, wobei dieser Unterschied nicht signifikant ( $p > 0,05$ ) unterschiedlich war (Tab. 5). Im Gegensatz zu früheren Studien mit anderen Nutztieren (Broderick, 2003; van Dung et al., 2013) stieg die Futteraufnahme beim Angebot von schlechterer Heuqualität nicht an. Insgesamt ergab sich eine TS-Aufnahme von nur 0,89 % des Körpergewichtes beim Heu der schlechteren Qualität (Heu 2) und 1,26 % bei der guten Qualität (Heu 1). Dies ist insofern bemerkenswert, da beide Gruppen weit unter der Maximalaufnahme von 3 % des Körpergewichtes an TS lagen, die u. a. Vaughan und Gauly (2011) sowie Duncanson (2012) angegeben hatten.

### Gewichtsentwicklung

Das durchschnittliche Körpergewicht am Anfang und Ende des ersten Durchgangs betrug 148,2 kg ( $\pm 27,7$ ) und 143,1 kg ( $\pm 27,7$ ) für die Gruppe, die Heu 1 erhielt, sowie 146,2 kg ( $\pm 26,8$ ) und 137,3 kg ( $\pm 26,1$ ) für die Gruppe, der Heu 2 gefüttert worden war. Das Körpergewicht veränderte sich während der Durchgänge nicht signifikant ( $p > 0,05$ ). Tendenziell verloren die Tiere beider Gruppen während der Studie an Gewicht, unabhängig von der Heuqualität. Der Gesundheitszustand kann als Ursache für diesen starken Gewichtsverlust während der Versuchsperiode ausgeschlossen werden. Somit wird die Gewichtsentwicklung im Wesentlichen auf die Fütterung zurückgeführt. Es wird darauf hingewiesen, dass eine relativ geringe Tieranzahl untersucht wurde; entsprechend ist die Gewichtsentwicklung mit Vorsicht zu betrachten. In weiteren Studien sollte die Körpergewichtsentwicklung in Abhängigkeit von der Fütterung jedoch anhand einer größeren Tieranzahl validiert werden.

**TABELLE 3:** Trockensubstanz- und Wassergehalt verschiedener Futtermittel für Neuweltkameliden (Moran, 1996)

Futtermittel	Trockensubstanzgehalt (%)	Wassergehalt (%)
Weidegras vor Blüte	10–20	90–80
Weidegras nach Blüte	25–35	75–65
Grassilage	25–55	75–45
Weideheu	75–95	25–5
Getreide/Kraftfutterpellets	85–92	15–8

**TABELLE 4:** Zusammensetzung der eingesetzten Futtermittel nach Weender Analyse (in % TS)

Heu	Rohprotein	Rohfett	Rohasche	Rohfaser	NDF <sup>1</sup>
1	15,1	3,1	8,49	3,1	52,6
2	6,6	2,1	6,18	2,1	64,3

<sup>1</sup> Neutrale Detergenzienfaser (Lignin, Zellulose und Hemizellulose)

**TABELLE 5:** Körpergewichte, TS-Gehalte sowie Futter- und Trockensubstanzaufnahmen für die beiden im Versuch eingesetzten Heuqualitäten (LS Means  $\pm$  SD)

Variable	Heu 1	Heu 2
Körpergewicht (kg) <sup>1</sup>	145,7	141,8
TS-Gehalt (%)	84,8	85,4
Futteraufnahme (kg) ( $\pm$ SD)	2,15 $\pm$ 0,46	1,79 $\pm$ 0,37
Futteraufnahme (kg TS)	1,82	1,53
Futteraufnahme (% KGW) ( $\pm$ SD)	1,49 $\pm$ 0,27	1,22 $\pm$ 0,25
TS-Aufnahme (%) ( $\pm$ SD)	1,26 $\pm$ 0,23	0,89 $\pm$ 0,21

<sup>1</sup> Mittelwert aus Beginn und Ende der jeweiligen Versuchsperiode

**Bedarfsdeckung in Abhängigkeit der Futtermittel**

In Ergänzung zur Nährstoffzusammensetzung der im Versuch eingesetzten Heuqualitäten sowie der gemessenen TS-Aufnahme wurden Literaturangaben verwendet, um die Versorgungssituation für Lamas (*Lama glama*) und Alpakas (*Vicugna pacos*) zu kalkulieren. Die Auswirkungen von verschiedenen TS-Aufnahmen auf die Versorgung mit Energie und Rohprotein sind in Tabelle 6 aufgeführt. Die Schätzungen basieren auf den Ergebnissen unserer Studie, in der TS-Aufnahmen in Höhe von 0,9 bzw. 1,3 % des KGW festgestellt wurden, und Literaturangaben, die von max. 3 % des KGW ausgehen (Vaughan und Gaulty, 2011). Unter Annahme der Nährstoffzusammensetzung, wie sie für Heu 1 im vorliegenden Versuch gemessen wurde, ergibt sich in Abhängigkeit der TS-Aufnahme eine Rohproteinübersversorgung von 44–281 % für Alpakas und 36–202 % für Lamas. Bei der im vorliegenden Versuch gemessenen TS-Aufnahme von 1,3 % des KGW bei den Lamas kommt es zudem zu einer Übersversorgung mit Energie von 18,9 %. Werden die für Heu 2 analysierten Nährstoffzusammensetzungen für die Versorgungsbeurteilung zugrunde gelegt, führt dies in Abhängigkeit der TS-Aufnahme zu einer Unterversorgung mit Rohprotein von 27–41 % und Energie von 4,9–10,4 %.

Zusätzlich wurde die Versorgungssituation für Lamas und Alpakas kalkuliert, wenn die Tiere ad libitum mit Grünland oder Heu versorgt werden (Tab. 7). Für diese Kalkulation wurde die Nährstoffzusammensetzung für Grünland und Heu nach der DLG-Futterwerttabelle gewählt. Zumindest beim Alpaka ergaben sich Situationen mit energetischer Unterversorgung sowie Eiweißmangel. Auch hier wird eine weitere Überprüfung in Studien mit größerer Tieranzahl empfohlen. Aus den angeführten Kalkulationen lässt sich ableiten, dass in Deutschland beim Einsatz praxisüblicher Futtermittel bei Lamas Energie- und Proteinübersversorgungen häufiger vorzufinden sind als -unterversorgungen.

**Konsequenzen für die Nährstoffversorgung in der Praxis**

Der Energie- und Nährstoffbedarf muss mit dem angebotenen und aufgenommenen Futter gedeckt werden. Bei den meisten unter deutschen Bedingungen eingesetzten Futtermitteln, die im Durchschnitt eine sehr gute Qualität aufweisen, sind dafür ca. 1 kg an TS-Aufnahme notwendig (Sponheimer et al., 2003). Bei Ad-libitum-Angebot kommt es tatsächlich bei den meisten eingesetzten Grundfuttermitteln eher zur Übersversorgung mit Energie und Eiweiß bei Unterstellung einer TS-Aufnahme von 1,3 % des KGW. Die Folge ist eine Verfettung der Tiere, wobei die Gewichtsentwicklung der untersuchten Tiere dafür keine Anzeichen zeigte. Duncanson (2012) unterstützt die Aussage dieser Studie, dass eine Übersversorgung und die daraus resultierende Verfettung bei Lamas praxisrelevant sind. Diese Voraussetzungen sind jedoch beim Einsatz von qualitativ schlechterem Heu nicht mehr gegeben. Ein Ergebnis der vorliegenden Studie ist unter anderem, dass die Tiere schlechte Futterqualität nicht mit vermehrter TS-Aufnahme ausgleichen. Diese Erkenntnis ist neu, da bisher davon ausgegangen wurde, dass die Tiere bis zu 3 % ihres KGW an TS aufnehmen, insbesondere in Energiemangelsituationen (Vaughan und Gaulty, 2011). Unter deutschen Bedingungen werden jedoch vorwiegend qualitativ hochwertige Futtermittel eingesetzt. Somit sind die meisten Lamas eher über- als unterkonditioniert. Bei Alpakas ist die Situation häufig anders. Hier wird in der Praxis bei Fütterung von

Heu durchschnittlicher Qualität meistens ein schlechter Body Condition Score beobachtet (Vaughan und Gaulty, 2011). Aus den Kalkulationen, die Ergebnisse der vorliegenden Untersuchung sowie Literaturangaben zum Erhaltungsbedarf von Lamas und Alpakas berücksichtigt haben, lässt sich ableiten, dass Alpakas entweder einen grundsätzlich höheren Bedarf, schlechtere Verwertungskoeffizienten, d. h. Verdaulichkeiten, aufweisen oder durchschnittlich sogar noch weniger TS aufnehmen können als Lamas. Deshalb werden dringend weitere Studien benötigt, die tragende Stuten und wachsende Tiere mit einschließen. Bei tragenden Stuten muss dabei

**TABELLE 6:** Kalkulation der Versorgungssituation von Alpakas und Lamas mit metabolisierbarer Energie (ME) und Rohprotein bei unterschiedlicher TS-Aufnahme, basierend auf Ergebnissen des Versuchs (Nährstoffzusammensetzung Heu 1: 151,1 g Rohprotein, 9,7 MJ ME/kg TS; Heu 2: 66 g Rohprotein, 7,7 MJ ME/kg TS) und Literaturangaben zum Erhaltungsbedarf (Alpaka, 70 kg KGW: 7,5 MJ ME, 70 g Rohprotein; Lama, 150 kg KGW: 11 MJ ME, 150 g Rohprotein) nach Vaughan und Gaulty (2011)

	TS-Aufnahme (% KGW)	TS-Aufnahme (kg)	ME (MJ) (% Über- bzw. Unterversorgung)	Rohprotein (g) (% Über- bzw. Unterversorgung)
<b>Heu 1</b>				
Alpaka	0,9	0,63	6,1 (-19)	95,2 (+44)
	1,3	0,91	8,8 (+17)	137,5 (+108)
	3,0	2,10	20,4 (+172)	317,3 (+281)
Lama	0,9	1,35	13,1 (+19)	204,0 (+36)
	1,3	1,95	18,9 (+72)	294,7 (+95)
	3,0	4,53	43,7 (+297)	453,3 (+202)
<b>Heu 2</b>				
Alpaka	0,9	0,63	4,9 (-35)	41,6 (-27)
	1,3	0,91	7,0 (-3)	60,1 (-9,4)
	3,0	2,10	16,2 (+131)	138,6 (+110)
Lama	0,9	1,35	10,4 (-5)	89,1 (-41)
	1,3	1,95	15,2 (+38)	128,7 (-14)
	3,0	4,53	34,7 (+216)	297,0 (+98)

**TABELLE 7:** Kalkulation der Versorgungssituation von Alpakas und Lamas mit metabolisierbarer Energie (ME) und Rohprotein bei unterschiedlicher TS-Aufnahme von Grünland und Heu (Energie- und Rohproteingehalt laut DLG-Futterwerttabelle) und Literaturangaben zum Erhaltungsbedarf (Alpaka, 70 kg KGW: 7,5 MJ ME, 70 g Rohprotein; Lama, 150 kg KGW: 11 MJ ME, 150 g Rohprotein) nach Vaughan und Gaulty (2011)

	TS-Aufnahme (% KGW)	TS-Aufnahme (kg)	ME (MJ) (% Über- bzw. Unterversorgung)	Rohprotein (g) (% Über- bzw. Unterversorgung)
<b>Grünland<sup>1</sup></b>				
Alpaka	0,9	0,63	7,1 (-5,3)	113,4 (+62)
	1,3	0,91	10,3 (+37)	163,8 (+134)
	3,0	2,10	23,8 (+217)	378,0 (+440)
Lama	0,9	1,35	15,3 (+39)	243 (+62)
	1,3	1,95	22,0 (+100)	351 (+134)
	3,0	4,50	50,9 (+363)	810 (+440)
<b>Heu<sup>2</sup></b>				
Alpaka	0,9	0,63	5,7 (-24)	66,8 (-4,6)
	1,3	0,91	8,3 (+11)	96,5 (+38)
	3,0	2,10	19,1 (+155)	222,6 (+218)
Lama	0,9	1,35	12,3 (+12)	143,1 (-4,6)
	1,3	1,95	17,8 (+62)	206,7 (+38)
	3,0	4,50	41,0 (+273)	477,0 (+218)

<sup>1</sup> Grünland, grasreich, zwei bis drei Nutzungen, 1. Aufwuchs, volles Ährenschieben (180 g Rohprotein, 11,3 MJ ME/kg TS) (nach DLG-Futterwerttabelle)

<sup>2</sup> Heu, grasreich, zwei bis drei Nutzungen, 1. Aufwuchs, volles Ährenschieben (106 g Rohprotein, 9,11 MJ ME/kg TS) (nach DLG-Futterwerttabelle)

zusätzlich beachtet werden, dass deren TS-Aufnahme vor allem in den letzten beiden Trächtigkeitsdritteln relativ stark eingeschränkt ist, da sich das Vormagenvolumen aufgrund der großen Fruchtausdehnung verkleinert. Dementsprechend muss diesen Tieren eine gute Futterqualität, also Futter mit höherer Energiedichte, angeboten werden.

## Schlussfolgerung

Die Ergebnisse der vorliegenden Studie zeigen, dass Lamas eine schlechte Futterqualität nicht mit vermehrter TS-Aufnahme ausgleichen. Dadurch ist eine Energie- und Eiweißübersorgung wesentlich weiter verbreitet als eine Unterversorgung. In weiteren Untersuchungen sollten für die Bewertung des TS-Aufnahmeverhaltens von Neuweltkameliden auch weitere Einflussfaktoren wie Alter und Trächtigkeit bewertet werden.

## Conflict of Interest

Es bestehen keine geschützten, finanziellen, beruflichen oder anderen persönlichen Interessen an einem Produkt, Service und/oder einer Firma, welche die im oben genannten Manuskript dargestellten Inhalte oder Meinungen beeinflussen könnten.

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**Appendix II**

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## Summary

## Zusammenfassung

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# Grazing behaviour and dry matter intake of llamas (*Lama glama*) and German blackhead mutton sheep (*Ovis orientalis forma aries*) under Central European conditions

## Weideverhalten und Trockensubstanzaufnahme von Lamas (*Lama glama*) und deutschen Schwarzkopfschafen (*Ovis orientalis forma aries*) unter zentraleuropäischen Bedingungen

Anna Maria Stölzl<sup>1</sup>, Christian Lambertz<sup>2</sup>, Matthias Gauly<sup>2</sup>

The aim of the present study was to assess the behaviour of llamas (*Lama glama*) and German blackhead mutton sheep (*Ovis orientalis forma aries*) when kept under Central European grazing conditions. In total, six adult female sheep and six adult female llamas were observed by direct observation during one week, in which each group was observed for a total time of 24 h. The animals were kept on the same pasture, but the species were raised in separate plots. Forage height before and after the experimental period were determined using a rising plate meter to calculate the average daily dry matter intake (DMI). Llamas had a daily DMI of 0.85%/BW and sheep of 1.04%/BW, respectively. The following behaviours were recorded by direct observation: grazing standing up, grazing lying down, ruminating standing up, ruminating lying down, lying down, lying down lateral and standing. Both species grazed for more than 50% of the time. Ruminating was predominantly performed while standing and lying by sheep (about 50% of the night and 12% of the day) and while lying by llamas (54% of the night and 10% of the day). In conclusion, sheep and llamas differed in grazing behaviour and daily biorhythm. These differences indicate that sheep and llamas may not synchronize their behaviour when co-grazed, though particularly in co-grazing studies the observation period should be extended.

**Keywords:** Llama, German blackhead mutton sheep, grazing behaviour, dry matter intake

Das Ziel dieser Studie war es, das Weideverhalten von Lamas (*Lama glama*) und deutschen Schwarzkopfschafen (*Ovis orientalis forma aries*) unter mitteleuropäischen Bedingungen zu untersuchen. Dafür wurden sechs weibliche ausgewachsene deutsche Schwarzkopfschafe und sechs weibliche ausgewachsene Lamas mittels Direktbeobachtung eine Woche beobachtet, wobei jede Tiergruppe für insgesamt 24 Stunden erfasst wurde. Die Tiere wurden auf derselben Weide in getrennten abgeäunten Bereichen gehalten. Vor und nach der experimentellen Periode wurde die Grashöhe mithilfe eines Rising Plate Meters erfasst, um die durchschnittliche tägliche Trockensubstanzaufnahme zu berechnen. Diese betrug im Durchschnitt bei den Lamas 0,85 % des Körpergewichts und bei den Schafen 1,04 %. Die folgenden Verhaltensweisen wurden durch Direktbeobachtung erfasst: stehend Grasens, liegend Grasens, stehend Wiederkauen, liegend Wiederkauen, Liegen, seitlich Liegen und Stehen. Beide Tiergruppen verbrachten mehr als 50 % der Zeit mit Grasens. Wiederkauen wurde beim Schaf vor allem im Liegen und Stehen (50 % nachts und 12 % tagsüber) und beim Lama vor allem liegend (54 % nachts und 10 % tagsüber) beobachtet. Zusammengefasst unterschieden sich Schafe und Lamas im Weideverhalten und zeigten einen unterschiedlichen Tagesrhythmus. Diese Ergebnisse lassen annehmen, dass Schafe und Lamas ihr Verhalten auf der Weide nicht synchronisieren, wobei vor allem bei Studien zur Mischbeweidung die Beobachtungsperiode verlängert werden sollte.

**Schlüsselwörter:** Lama, Deutsches Schwarzkopfschaf, Weideverhalten, Trockenmasseaufnahme

## Introduction

Co-grazing of South American Camelids and sheep (*Ovis orientalis aries*) is widely practiced under South American conditions (Pfister et al., 1989b; Tichit and Genin, 1997) and might be an efficient way under Central European conditions, too. Nevertheless, the grazing strategy of these two species when raised under comparable grazing conditions is widely unknown. In general, conditions in South America and Central Europe differ largely in pasture productivity, animal performance and climatic conditions.

In order to optimize co-grazing systems it is necessary to understand the grazing behaviour, especially because it is hypothesized that the presence of other livestock causes behavioural changes of the individual animal species (Brown et al., 2010). Only a very limited number of behavioural assessments that included South American Camelids is available and nearly all were conducted in the USA or South America, and thus under differing conditions when compared to Central Europe (Raedeke, 1980; Reiner and Bryant, 1986; Pfister et al., 1989a; San Martin and Bryant, 1989). Comparisons between South American Camelids and sheep were not conducted, yet.

First of all, the anatomy and physiology of South American Camelids varies considerably to true ruminants such as sheep. The most striking difference is the anatomy of the digestive tract. Camelids have only three distinct compartments (C1 to C3) associated with the foregut and stomach as compared to the four compartments of ruminants (Vallenas et al., 1971). The retention time of digesta in the reticulo-rumen and compartments one and two, respectively, is also longer in camelids than in sheep, which increases the potential degradation of plant particles through fermentation (Dulphy et al., 1994). San Martin (1987) proposed that camelids are less selective grazers because of their larger body size. Thus, South American Camelids are able to utilize feed more efficiently than sheep. As a consequence of the varying anatomy and physiology, the grazing strategy of sheep and South American Camelids may differ largely.

A co-grazing system is very effective in terms of resource use. All in all, it is important to maximize the proportion of forage in the diet to minimize feeding costs in all production systems. However, an efficient utilization of forage resources and control of animal impacts on vegetation require knowledge on the animal behaviour and dietary choices (Baumont et al., 2000). Baumont et al. (2000) described in an extensive pasture farming system, feed intake, feed composition and the impact of grazing on the vegetation is also the result of a multi-layered relationship between the animal and the vegetation. Overgrazing of all small ruminants is an increasing concern and results in the loss of valuable browse and grass species (National Research Council, 2007). When rangeland grazing is left unbalanced, particularly by maintaining single species herds, overgrazing will occur and result in desertification or noxious weed or woody plant overgrowth (National Research Council, 2007). Multispecies grazing in a controlled fashion can effectively alter the amounts of poorly usable plant material to a more harvestable biomass (Heitschmidt et al., 2004). Benefits of co-grazing sheep and goats, for example, are mainly based on the management and improvement of vegetation conditions (Walker, 1994), and consequently in enhancing plant and animal biodiversity (El Aich and

Waterhouse, 1999). Furthermore, multispecies grazing systems improve the spatial use of pasture (Forbes and Hodgson, 1985), parasite control (Waller, 2006) and potentially lower losses due to predation under distinct conditions (Hulet et al., 1987). Celaya et al. (2007) also found the performance of cattle and sheep being dependent on the sward height. In comparison to these two species, goats were found to be the best complements to other species and made the optimal use of resources. Benefits of raising South American Camelids together with small ruminants are probable, too. While sheep consume forage that got into contact with dung (Brelin, 1979), South American Camelids do not (Gauly et al., 2011).

Even though co-grazing of South American Camelids and sheep is widely practiced under South American conditions (Pfister et al., 1989b; Tichit and Genin, 1997), the differing conditions in Central Europe might have an effect on the system. Not only the pastures are characterized by varying productivity, but also the animal performance and the climatic conditions are different. Therefore, the aim of the present study was to assess the behaviour of these two species when kept under the same grazing conditions.

## Material and Methods

### Study site and experimental setup

The study was conducted on seven consecutive days at the experimental farm Relliehausen of the Department of Animal Science of the Georg-August-University Göttingen in August 2013.

In total, six adult female German blackhead mutton sheep (*Ovis orientalis forma aries*) and six adult female llamas (*Lama glama*) were used. The animals of each species were similar in terms of age, size and weight. At the time of the study the animals were not pregnant. The llamas aged from seven to nine and sheep from four to six years. The mean weights of the sheep and llamas accounted 80.5 kg ( $\pm 7.0$  kg) and 167 kg ( $\pm 13.7$  kg), respectively. Three days prior to the study, the llama and sheep groups were raised next to the pasture areas that were used for the observation period. Thus, the feed was not changed at the beginning of the study. At the beginning of the behavioural observations, llamas and sheep were allocated to two separate pasture areas, which size was calculated based on the metabolic weight of the animals. Accordingly, the pasture area for sheep sized 328 m<sup>2</sup> and for llamas 552 m<sup>2</sup>. The pasture was mainly composed of the following five grass species: common bent grass (*Agrostis capillaris*), meadow fescue (*Festuca pratensis*), common velvet grass (*Holcus lanatus*), perennial ryegrass (*Lolium perenne*), common meadow grass (*Poa pratensis*) and the herb species: common mouse-ear chickweed (*Cerastium holosteoides*) and the legume species: tufted vetch (*Vicia cracca*). Water was provided ad libitum and shelter trees and bushes were available, though the animals were not able to feed from the trees and bushes.

Forage heights before and after the experimental period were determined using a rising plate meter. The tool used in the present study had a disc diameter of 0.3 m, an area of 0.07 m<sup>2</sup> and weighed 0.2 kg (Castle, 1976). The height of the forage was recorded at 50 randomly chosen points on the sheep paddock and 70



**TABLE 1:** Definitions of recorded behaviours

Behaviour	Abbreviation	Definition
Grazing standing up	GSU	Head touching the ground ingesting forage while standing or walking
Grazing lying down	GLD	Head touching the ground ingesting forage while lying
Ruminating standing up	RSU	Clearly visible masticatory movement while standing
Ruminating lying down	RLD	Clearly visible masticatory movement while lying
Lying down	LD	Lying without any other activity
Lying down in lateral position	LDL	Lying in lateral position without any other activity
Standing	S	Standing without any other activity

**TABLE 2:** Average compressed pasture height (cm) and vegetation biomass (kg DM/ha) before and after the experimental period and daily DMI per animal (kg) and kg body weight (%) at the beginning and end of the experimental period in llamas and sheep

Species	Time-point	Average compressed pasture height (cm)	Vegetation biomass (kg DM/ha)	DMI/animal (kg)	DMI/animal (% of BW)
Llama	Start	13.39	2374.6		
	End	5.71	1299.4	1.41	0.85
Sheep	Start	12.07	2189.8		
	End	4.38	1113.2	0.84	1.04

points on the llama paddock. Based on this, the average compressed forage height was calculated. For determination of DM content, ten forage samples, five above and five lower than the average height within the sheep paddock, and 16 samples, eight above and eight lower than the average, within the llama paddock were collected. The DM content was determined by weighing the samples before and after oven drying at 60°C for 48 h. The amount of DM/ha was estimated according to the following formula (Lile et al., 2001): Average compressed pasture height × 140 (multiplier for the average biomass growth) + 500 = kg DM/ha.

With these values the DM amount on the pasture areas before and after the study period was calculated, and accordingly the DMI per animal and day.

The daily mean temperature during the experimental period was 17.9°C (±2.2°C), ranging from 15.3°C to 21.4°C. Slight rain occurred on four days and total precipitation was 16 mm.

### Behavioural observations

The behaviour of the animals was recorded by direct observation using the scan-sampling method at five minute intervals as defined in Table 1. Sheep were marked individually and could be identified from everywhere in the paddock. The appearance of the llamas was different in colour and shape allowing animal identification. The animals were observed by direct observation during one week, in which each group was assessed for a total time of 24 h. Observations were done by one single person according to the time schedule as given in the following. At day one and six the observation began at 08:00 and ended at 22:00, while at day two it began at 06:00 and ended at 00:00. At day five the observation

took place from 22:00 to 04:00. At day three the animals were observed from 00:00 to 05:00, while at day four observations were done for two hours at 00:00 and 04:00. At the last day the animals were observed continuously between 05:00 and 08:00 and again from 10:00 to 20:00. After each two hours observation period, a two hours break followed, except for day 3. This resulted in each animal group being observed during the seven days for a total period of 24 h. The hours 6:00 to 21:00 were defined as day time and 21:00 to 6:00 as night time. Results are expressed as percentage in which the respective behaviour was performed during day and night time, respectively; and are also presented as absolute time given the different length of day and night time. During the observations, the observer stood either outside, in front of the paddock or in a caravan distanced 50 m from the paddocks by using a binocular. During the night a torch was used to observe the animals' behaviour. Prior to the experiment, the observer spent 24 h together with the animals, so that they habituated to the presence of the person and the use of the torch.

### Statistical analysis

All statistical analyses were conducted using the Statistical Analysis System, version 9.3. For the behavioural traits, namely the proportion of animals performing each of the behaviours grazing standing up, grazing lying down, ruminating standing up, ruminating lying down, lying down, lying down lateral and standing, the paddock was defined as the experimental unit. To adjust data for normality they were arcsine square root transformed prior to analysis. The model statement included the fixed effects of animal species (llama, sheep), time (day time, night time) and its 2-way-interaction. Results are presented as untransformed least square means ± pooled standard error. Least squares means were separated by the probability of differences option (PDIF) with Bonferroni adjustment with a significance level of  $p < 0.05$ .

## Results

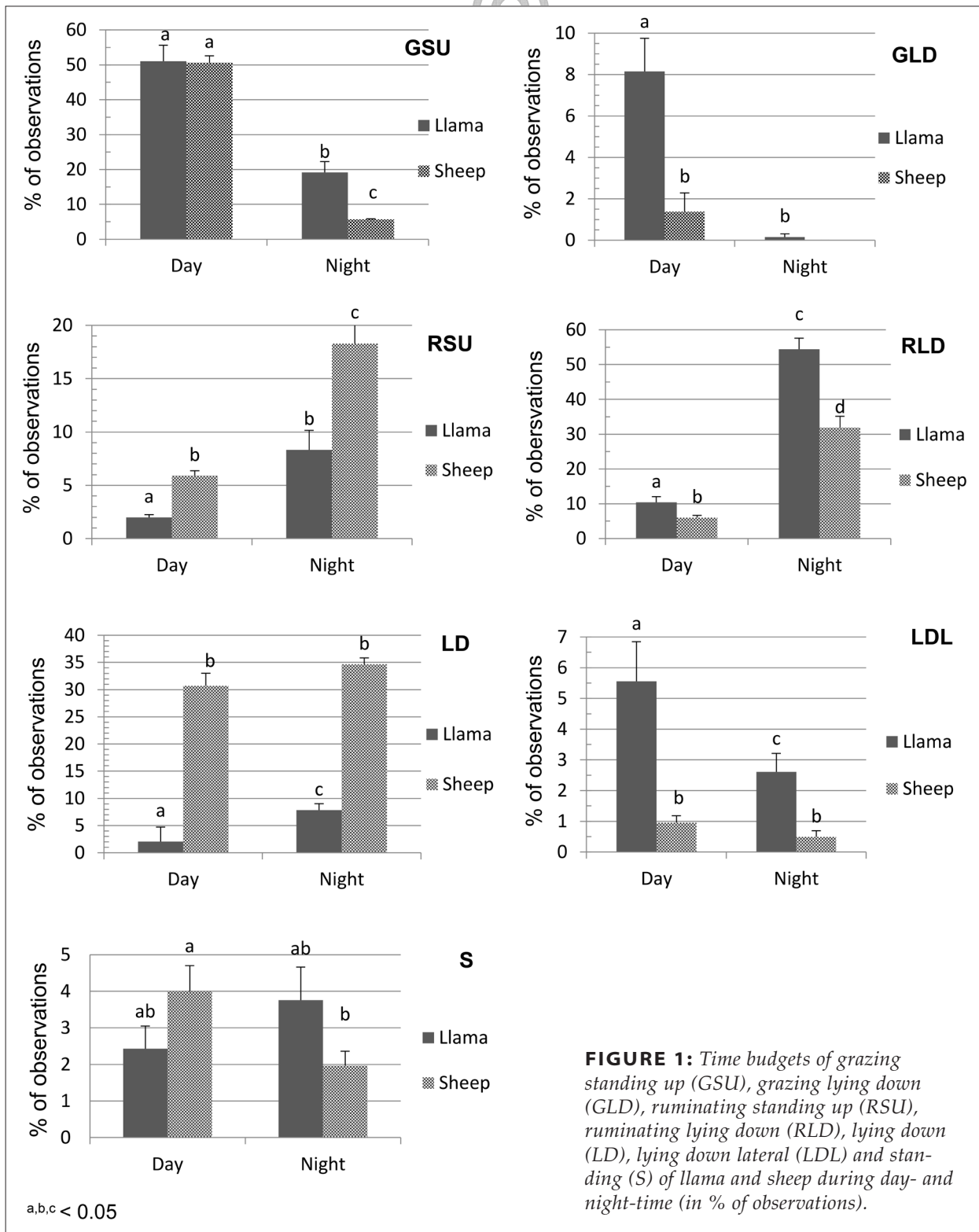
### Grazing

The proportions in which the different behaviours were performed during day- and night-time are presented in Figure 1. Grazing standing up was found especially during day-time and less often during the night ( $p < 0.05$ ). Both species spent more than 50%, which corresponds to 8 h, of their time grazing standing up. At night, llamas with about 20%, corresponding to 1.7 h, spent significantly more time grazing than sheep (6% or 0.5 h,  $p < 0.05$ ).

Grazing lying down was observed at relatively low frequencies and mainly during day time accounting for about 8% (1.2 h) in llamas and less than 2% (0.2 h) in sheep ( $p < 0.05$ ). This behaviour did not have any relevance in both species during night-time. In summary, grazing was the predominant behaviour which was performed for more than 60% in llamas and 50% in sheep, respectively.

### Ruminating

In contrast to grazing, ruminating in a standing or lying position was shown more often during night- than during day-time in both species ( $p < 0.05$ ) (Fig. 1). In



**FIGURE 1:** Time budgets of grazing standing up (GSU), grazing lying down (GLD), ruminating standing up (RSU), ruminating lying down (RLD), lying down (LD), lying down lateral (LDL) and standing (S) of llama and sheep during day- and night-time (in % of observations).

detail, llamas spent about 8% (0.8 h) of the night and 2% (0.3 h) of the day for ruminating standing up; and further 10% (1.6 h) and 54% (4.9 h) of day- and night-time for ruminating lying down, respectively. In sheep, ruminating standing up was recorded at rates of 6% (0.3 h) during day- and 18% (1.7 h) during night-time. The respective values for ruminating lying down were 6% and 32%, corresponding to 0.9 and 2.9 h, for day and night (Fig. 1).

**Lying down and standing**

The lying behaviour differed significantly between sheep and llamas (p < 0.05). While sheep were lying about one third of the day- (3.1 h) and night-time (4.6 h), llamas spent only 8% (0.7 h) of the night- and 2% (0.3 h) of the day-time lying down (p < 0.05) (Fig. 1). Lying down in a lateral position for resting was mainly shown by llamas, which performed this behaviour at frequencies of 6% and 2% (0.8 and 0.2 h) of the day- and night

time, respectively. Standing without any other activity was observed at low proportions of less than 4% in both species.

### Body weight and dry matter intake

The body weight at the beginning and the end of the trial averaged 167.0 kg ( $\pm 13.7$ ) and 167.6 kg ( $\pm 16.0$ ) for the llamas and 80.5 kg ( $\pm 7.0$ ) and 78.6 kg ( $\pm 4.4$ ) for the sheep, respectively.

The pasture that was allocated to the llama flock had a vegetation biomass of 2374.6 kg DM/ha at the beginning and 1299.4 kg DM/ha at the end of the experimental period, respectively (Tab. 2). The accordant biomass of the sheep pasture was 2189.8 kg DM/ha at the beginning and 1113.2 kg DM/ha DM at the end of the study. Consequently, the daily DMI was estimated at 1.41 kg for llamas and 0.84 kg for sheep. Expressed in relation to the BW of the animals, llamas had a DMI of 0.85% and sheep of 1.04% of BW.

## Discussion

The present study clearly shows differences in the behavioural pattern under pasturing conditions of llamas and German blackhead mutton sheep. Although the animals were only observed during one week, findings present a clear view on differences between the studied species. In both, llamas and sheep, grazing was the predominant behaviour accounting for more than 50% of the total time. Recorded mainly during night time, ruminating was predominantly performed while standing and lying by sheep and while lying by llamas. Sheep were lying for about one third of day- as well as night-time, whereas llamas were mainly lying in a lateral position and more often during the day than the night. The estimated daily DMI of llamas was 0.85% of BW and 1.04% of BW for sheep, respectively.

Even though both species had their main grazing activity during day-time, the behaviour of the sheep varied more between day- and night-time than the pattern of the llamas. Owing to these results and the fact that sheep only cover very short distances during darkness (Lin et al., 2011), probably due to the risk of predation (Hulet et al., 1987; Lima and Dill, 1990; Penning et al., 1993), the grazing time observed during the day in this study reflects the total daily grazing time for sheep. The overall grazing time confers widely with the values of 65% observed by Bojkovski et al. (2014). In another study, sheep spent also most of their active time foraging during the day (Ruckstuhl, 1998). For llamas, in contrast, a total grazing time of 7 to 12 h per day in a multi-period cycle is generally reported (Gauly et al., 2011), which concurs with a total grazing time of about 10.6 h for the llamas in this experiment. The adaptation of the feed intake of llamas to the ambient temperature and their response of short lying and long activity or feed intake periods to low temperatures may explain the comparatively high number of grazing periods during night-time (Gauly et al., 2011).

When rumen fill is increasing with indigestible material, animals increase the number of meals and the time spent ruminating per kg ingested feed (Baumont et al., 1990). This stimulation of rumination behaviour, related to increased stimulation of tactile receptors in the rumen wall, speeds up digesta outflow and tends to reduce

rumen fill (Baumont et al., 2000). Both species had a significantly higher ruminating rate at night than during the day in our study. This implies that the animals spent most of the day-time grazing. In contrast to other studies, sheep in this study spent more time ruminating while lying down than standing. In our as well as in the study of Pokorna et al. (2013), sheep spent about half of the ruminating time while standing and the other half while lying. During the night, the proportion of ruminating in a lying position increased and that in a standing position decreased considerably.

Our study may also indicate that the llamas separate ruminating and forage intake. Thus, these activities should be clearly distinguished when the behaviour of llamas is assessed. The study of Schirmann et al. (2012) showed also a strong negative association between rumination and DMI in dairy cows. Nevertheless, we assume that ruminating is a behaviour that cannot be exactly captured with the scan-sampling method. Especially sheep were often observed ruminating between two bits, which is difficult to capture with this method of behaviour analysis. This reflects the very short rumination time in sheep in this experiment. In llamas masticatory movements are clearly visible. To the current knowledge of the authors, there are no comparable studies for ruminating time and behaviour in llamas.

The recorded lying pattern is widely in agreement with the study of Pfister et al. (1989a). In that study, the sheep spent about twice as much time resting as camelids did. This difference can mainly be explained by the fact that sheep were often observed to rest near to each other and simultaneously. Llamas, in contrast, were never observed to lie close to each other and were always spread over the whole grazing area. Other than sheep, llamas were also observed less often to rest simultaneously. This concurs with the statement of Gerken et al. (1997), that South American Camelids are animals which need their distance from each other and are avoiding physical contact with others in the herd. The study of Penning et al. (1993) showed that for sheep a higher number of animals in a herd is important, because animals in smaller flocks have shorter grazing times and gained less weight. On the other hand, Brown et al. (2010) indicate that the presence of another livestock species in a herd causes that the animals synchronize their behaviour according to the others.

Lying down in a lateral position to rest is a phenomenon practiced especially by llamas. Because sheep are at high risk of predation (Hulet et al., 1987; Lima and Dill, 1990; Penning et al., 1993), they rarely lie on the side, so that they can observe their environment. Furthermore, it is impossible for ruminants and camelids to eructate when lying on the side. This may explain why sheep were not strictly separating ruminating and other activities.

The relatively low frequency of standing without any other activity in both species might be due to the fact that they usually graze or perform other activities when standing. This widely agrees with other studies (Pokorna et al., 2013; Bojkovski et al., 2014).

The estimated daily DMI of the llamas of 1.41 kg per head and 0.85% of BW, respectively, is widely in agreement with other previous reports. Ordoñez (1994) found a daily DMI of llamas under natural grazing conditions of 1.7 kg per animal. The llamas in the study of Dumont et al. (1995) had a DMI ranging from 0.9 kg to

1.4 kg. In an earlier study, Stölzl et al. (2014) calculated a DMI of 1.26% of BW for hay of good quality and 0.89% of BW for hay of reduced protein and increased fibre content for llamas. Although llamas may be more efficient grazers, sheep present some advantages such as a higher reproductive rate and an advanced market for their products (Tichit, 1995). San Martin and Bryant (1989) summarized feed intake data from a number of experiments using South American Camelids and sheep under pasturing and raised in paddocks. The authors suggested a DMI of 1.8 to 2.0% of BW for llamas, which was more than 30% lower than for sheep. Other studies also suggested a lower intake of llamas based on BW while compared to sheep (Dulphy et al., 1997; Fraser and Baker, 1998). However, the values calculated here are lower than the predicted DMI of 1.5 to 2.0% of BW of sheep suggested by the National Research Council (2007). It has to be mentioned, that the DMI measurement was based on the RPM estimates. This technique has been proven to be suitable for estimating the average vegetation mass on pasture (Lile et al. (2001). The low DMI in this study compared to others where animals were housed indoors might be partly explained by the RPM estimation.

Generally, there are two ways to control intake. While better digestible feed is restricted by metabolic processes and the nutritional need of the animals, low energy feed is especially restricted by the limited size of the gastrointestinal tract (Waldo, 1984). Similarly to true ruminants, South American Camelids need a microbiological flora in their compartments to digest cellulose (Gauly et al., 2011). The high level of activity may also be the reason for the greater digestive efficiency of llamas because of their higher level of activity (Dulphy et al., 1997).

Other studies (San Martin and Bryant, 1989; Graham and Åman, 1991; Van Soest, 1994) described that the DMI is negatively correlated with the retention time of the forestomach and positively correlated with the volume and feed digestibility of the forestomach. Nevertheless, measuring the DMI for an animal is difficult when it is not housed individually (Van Saun, 2006) and other factors like breed, age, temperature and humidity, day length and body condition may also affect the appetite of the animals (Dulphy and Demarquilly, 1994). In an extensive pasture farming system the feed intake, feed composition and the impact of grazing on the vegetation is also the result of a multi-layered relationship between the animal and the vegetation (Baumont et al., 2000). Baldi et al. (2004) discussed that guanacos, the wild relatives of the llamas, and sheep are intermediate feeders who are able to change their diets seasonally. As generalist herbivores both species use a wide range of plant species. The behaviour is different on pasture where the animals have to search for appropriate feed than it is in a stable where the feed is provided (Baumont et al., 2000). Baumont et al. (2000) also proposed that the vegetation characteristics, the distance to water and a shelter and the herd itself as social factor will influence their feeding place choice.

In conclusion, German blackhead mutton sheep and llamas showed different grazing behaviours and a different daily biorhythm. These distinct differences indicate that sheep and llamas may not synchronize their behaviour when co-grazed, though particularly in co-grazing studies the observation period should be extended.

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## Conflict of interest

The authors declare that no competing interests exist.

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## **Erklärung**

Hiermit erkläre ich, dass ich die Dissertation „Feeding behaviour of South American camelids“ (Fressverhalten von südamerikanischen Kameliden) selbstständig verfasst habe. Alle Hilfen Dritter sind in der Dissertation aufgeführt.

Ich habe keine entgeltliche Hilfe von Vermittlungs- bzw. Beratungsdiensten (Promotionsberater oder andere Personen) in Anspruch genommen. Niemand hat von mir unmittelbar oder mittelbar entgeltliche Leistungen für Arbeiten erhalten, die im Zusammenhang mit dem Inhalt der vorgelegten Dissertation stehen.

Ich habe die Dissertation an folgenden Institutionen angefertigt:

1. Department für Nutztierwissenschaften, Abteilung Produktionssysteme der Nutztiere, Fakultät für Agrarwissenschaften der Georg-August-Universität Göttingen
2. Physiologisches Institut, Stiftung Tierärztliche Hochschule Hannover

Die Dissertation wurde bisher nicht für eine Prüfung oder Promotion oder für einen ähnlichen Zweck zur Beurteilung eingereicht.

Ich versichere, dass ich die verstehenden Angaben nach bestem Wissen vollständig und der Wahrheit entsprechend gemacht habe.

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Anna Maria Stözl

