1 Introduction

Farm animals conventionally kept in highly developed countries have been studied intensively. There is an abundance of information about the physiology, nutrition, reproduction and the ecology of cattle, pigs and sheep. The amount of basic knowledge on for instance nutrient requirements of New World camelids is still insufficient, but essential for a sustainable development of the animal husbandry in high-Andean regions. Few detailed nutritional studies have been conducted. What is known is based on observations from feeding practices and extrapolation from data accumulated by studies of sheep, goats and cattle (FOWLER 1998).

Ever since the Spanish conquest, but especially in the last century, it was attempted to replace the domestic camels of South America by high yielding European breeds of sheep and cattle. However, these breeds were not adapted to the high altitude, the long periods of drought and the low quality of the vegetation. After short periods of adaptation, the production of these animals invariably dropped to a disappointing level (BROWMAN 1984). A lot of animals did not survive or had very low reproduction rates. After the failure of numerous introduction programs, people started to realise that the endemic species of the region are much better adapted and face fewer problems coping with their environment. In fact, the camelids seem to be the only herbivores that can keep a stable population under the harsh conditions of the Andean climate and at the same time be productive as a farm animal.

In conclusion, it can be said that the original agricultural system in the Andes was severely damaged and a lot of valuable knowledge about the ecology and management of camelids has been lost in this proces. Both the scientific and the economic aspects of these indigenous farm animals have been neglected. Only recently the emphasis of scientific and developmental programs shifted towards the improvement of camelid management.

Due to the harse climatic conditions and the character of the soil, the vegetation on native Andean patures is sparse. Also, this vegetation is characterised by a low energy and protein content (FOWLER 1998). This results in relatively large area needed for a particular group of animals. A high stocking rate would limit the food supply and result in over-grazing. In fact, for this reason a large proportion of native Andean pastures suffer erosion (BROWMAN 1984).

In this study, it was expected that the described pasture conditions have implications for the activity level of herded camelids. The sparse spatial distribution of food might lead to relatively high locomotory costs. In this study the importance of this energetic aspect of locomotor activity was studied.

A part of this study was carried out under the EC-project SUPREME, which started in 1996 and aims to investigate possibilities to improve the Andean animal production, study sustainability of the production systems and improve the market for camelid products. The project involves partners from 9 different countries and among the specified topics are nutrition, marketing, fibre and meat quality, behavioural ecology.

2 Literature overview and theoretical background

2.1. New World Camelids: their taxonomy and history

On the South-American continent, camelids are the largest wild herbivores. About two million years ago they invaded the continent from North America over the Panama bridge. South American camelids are classified together with the Old World camels in the family Camelidae, suborder Tylopoda, order Artiodactyla. The representatives in the Old World, Bactrian camel and Arabian camel, fall into one genus: *Camelus*; the New World camelids into the genera *Lama* and *Vicugna* (Table 1).

Table 1. Systematic classification of the family camelids (after WHEELER 1995).

Order	Artiodactyla Owen, 1848
Suborder	Tylopoda Illiger, 1811
Family	Camelidae Gray, 1821
Genera:	
Camelus Linnaeus, 1758	
	Camelus dromedarius Linnaeus, 1758
	Camelus bactrianus Linnaeus, 1758
Vicugna Miller, 1924	
	Vicugna vicugna Molina, 1782
Lama Cuvier, 1800	
	Lama guanicoe Müller, 1776
	Lama glama Linnaeus, 1758
	Lama pacos Linnaeus, 1758

Domestication of South-American camelids has a history of between 6,000 and 7,000 years (WING 1986; STANLEY et al. 1994). These findings are based on organic remains of

camelids in the Peruvian Andes. After a period of hunting, extensive use of vicunas started by catching and shearing. Today, two wild (vicuña and guanaco) and two domesticated species (llama and alpaca) are recognised. The ancestry of the two domesticated forms has been a topic of debate for years. On the basis of a similar incisor morphology WHEELER (1991) concluded that the alpacas is a domesticated form of the vicuña. The most recent study considers the vicuna the ancestor of the alpaca and the llama to originate from the guanaco (KADWELL et al. 1999). All four forms produce fertile offspring when crossed (GRAY 1954).

Although New-World camelids not only roam in mountainous areas, they are highly adapted to living on high altitudes. Their blood has exceptionally high amounts of haemoglobin, packed in numerous small round red blood cells, instead of bigger oval shaped cells like most other mammals (JÜRGENS et al. 1988). Secondly, New World camelids are specialists in insulation. Their fibre is considered among the finest in the animal kingdom, a trade that is gratefully used for ages in the manufacturing of wool products. Finally, the food requirements of these animals are extremely low, enabling them to feed on pastures of low quality. Presumably, they inhabit the high-Andean regions since the end of the last glacial period, about 10,000 years ago (WHEELER 1995).

The areas where camelids are kept were shifted to less favourable areas of the high Andes ever since the Spanish conquest. The majority of llamas and alpacas are kept in Peru and Bolivia (Table 2). Nowadays, New World camelids range from the Southern part of Equador through Patagonia, down to the Southern tip of the continent, living on an altitude from about sea level up to 5,000 meters. Of the two wild species, vicunas only are present in the very high regions of especially Peru, but also Bolivia, Argentina and Chile (WHEELER 1995). Their numbers declined since the Spanish conquest until the 1970's, when conservation programs were started. They are now under CITES protection and their numbers are increasing (Table 2). Guanacos range from the high regions of Southern Peru to the Patagonian lowlands. Their number also went down since the Spanish conquest, but they still number about 600,000; the majority in Argentina. Concerning the domesticated species, most llamas are kept in Bolivia and most alpacas in Peru (Table 2), especially in the area around Lake Titicaca (WHEELER 1995).

Table 2. General characteristics of South American camelids (FOWLER 1998; WHEELER 1995) and the total number of South American camelids per country (SAN MARTIN and BRYANT 1989).

	Vicuña	Guanaco	Llama	Alpaca
Adult body mass (kg)	45-55	95-120	130-150	55-90
Height at withers (cm)	86-96	110-115	102-119	76-96
Total Andean population*	92,882	602,907	3,776,793	2,811,612
Total number of camelids per country:	Peru	Bolivia	Argentina	Chile
	3,975,000	186,200	2,802,200	99,500

*Data 1991

For a long time llamas were of great importance for Andean inhabitants as pack animals. Trade lines existed between the high regions and the Amazon basis as well as the coastal areas. Trade products were wool, leather, meat from one side and corn, potato, fruit and vegetables from the other. The present use of South American camelids is mainly restricted to the production of fibre and meat. A milking tradition has never been part of the Andean animal production system (GERKEN and KING 2000).

2.2. The Andean climate and natural surroundings

The Andean climate is characterised by a low annual mean temperature and a precipitation that is concentrated in one rainy season ranging from November to April. In the Andes of Southern Peru over 85% of the precipitation falls in these six months (JOHNSON 1976). The annual rainfall is highly dependent on regions. The eastern Andes have a longer and more intense rainy season because of the vicinity of the Amazon. The (south-) western slopes are extremely dry because they lie in the rain-shadow. The annual precipitation ranges from over 1000 mm near the amazon basin to less than 200 mm in the coastal region (KESSLER and MONHEIM 1968). These extreme differences in rainfall across the Andean ridge are accompanied by the strong effects of local factors, such as the vicinity of rivers and high mountain peaks. The mean altitude of the annual 0°C isotherm is about 5000 m in the Cusco area and 4600 m near Arequipa (DORNBUSCH 1998). The diurnal fluctuation in temperature is 15 °C in January and 30 °C in August (RICHTER 1981).