Institute of Animal Production in the Tropics and Subtropics

FUNCTIONS AND SELECTION CRITERIA FOR A LLAMA POPULATION IN THE BOLIVIAN ANDES

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LIST OF ABBREVIATIONS

AnGR	animal genetic resource
ASAR	Asociación de Servicios Artesanales y Rurales
a.s.l.	above sea level
Bs	Boliviano (Bolivian currency)
CE	choice experiment
cm	centimetre
CVM	contingent valuation method
DAAD	German Academic Exchange Service
DECAMA	Sustainable development of camelid products and services marketed oriented in the Andean region (EU-Project)
DESCO	Centro de Estudios y Promoción del Desarrollo
DESEC	Centro para el Desarrollo Social y Económico
Exp	exponential function
FIDA	Fondo Internacional de Desarrollo Agrícola
ICAR	International Committee of Animal Recording
IID	independently and identically distributed
INE	Instituto Nacional de Estadística
km	kilometre
LCM	latent class model
m	metre
MNL	multinomial logit model
MXL	mixed logit model
NGO	non-governmental organisation
NW	north-west
ORPACA	Organisación Regional de Productores Agropecuarios de Calientes
OU	ovine unit
PROINPA	Fundación para la Promoción e Investigación de Productos Andinos
R^2	coefficient of determination, 'goodness of fit'

RP	revealed preference
RPL	random parameter logit
SAS	Statistical Analysis System
SD or St.Dev.	standard deviation
s.e.	standard error
SE	south-east
SP	stated preference
SUPREME	Sustainable Production of Natural Resources and Management of Ecosystems (EU-Project)
SW	south-west
UHOH	University of Hohenheim
UMSS	Universidad Mayor de San Simón
UNEPCA	Unidad Ejecutora del Proyecto Camélidos
µm	micron, micrometre
WTA	willingness to accept
WTP	willingness to pay

1 Introduction

1.1 Background and research objective

The llama (*Lama glama L.)* is historically and ecologically the most important camelid species in Bolivia. More than 60% of the 4 million heads worldwide are found in Bolivia (FIDA et al., 2002), hence also accounting for a substantial national economic importance. The husbandry and management of llamas in Bolivia is completely in the hand of smallholders and an estimated 52 thousand families (FIDA et al., 1999) take advantage and utilize this species in securing their livelihoods. Llamas are anatomically and physiologically well adapted to the fragile ecosystem of the Andes and furthermore provide a variety of functions and products in terms of dung, meat, fibre and transport. Since the time of the Incan empire until today's modern times, Andean civilizations maintained a value system that symbolically integrates llama herds, pastoral habitats and supernatural powers, thereby adding considerable cultural and ritual value to the range of functions of the animals. Up to today, llamas form a key basis of wealth and prestige within the Andean highland agro-pastoral farming systems (Webster, 1973; Goebel, 2001).

This study focuses on smallholder llama keepers in the province of Ayopaya. Ayopaya is the north-western province in the department of Cochabamba and stretches between 15° 48' and 17° 27' of southern latitude and 66° 35' and 67° 27' of eastern longitude. The province is divided into the two municipalities of Ayopaya and Morochata. Its capital is Villa Independencia. Ayopaya is located in the eastern slopes of the Bolivian Andes (*Cordillera de Cocapata*). Mountain slopes of the Eastern cordillera ascend beyond 4000m above sea level and the climate ranges from sub-humid to sub-arid (Ruthsatz, 1983). The province of Ayopaya has 60,959 inhabitants and is among the poorest of the country (INE, 2001), with higher infant mortality rates as compared to the average in rural areas, more cases of malnutrition and a low income (PAHO, 1998). More than 80% of the inhabitants in the two municipalities are working in the agricultural sector (INE, 2004). Sheep and camelid husbandry, as well as potato cultivation dominate the agricultural activities. Almost 70% of the people in Ayopaya do not have regular access to drinking water and only 12% of the households are supplied with electricity. The illiteracy rate is 35% for the province

and especially high in women. Only around 50% of the women aged 15 are able to read or write (INE, 2004).

The investigated communities in the remote and marginal northern province of Ayopaya are accessible by one single unpaved road that is not permanently passable during the rainy season. Transportation possibilities for the rural population are given by trucks that frequently oscillate between the regions' central community Calientes and the next bigger city Quillacollo. The distance is approximately 120 km and travel time by truck is 8 to 10 hours. Operating NGOs in the region approach the communities by off-road vehicles. The infrastructure of the accommodation road has improved considerably during the last 10 years. The road and path network between the peasant communities however, is quite different depending on topology and distance. While some communities are still accessible by off-road vehicles or motorbikes, others can only be reached after hours of walking, resulting in a substantially reduced market access.

The prevalent agricultural production system in the region can be categorized as agro-pastoral and subsistence-based (Nürnberg, 2005). Smallholder farmers in the region, belonging to the native Aymará and Quechua ethnics, rely on a range of agricultural activities and species diversity as a necessary part of risk minimisation. In addition to sheep and llama husbandry, potatoes are cultivated. Since seed potato production, variety development and chemical control of potato crop diseases have been intensively promoted by the NGO ASAR (Asociación de Servicios Artesanales y Rurales) in cooperation with the semi-private foundation PROINPA (Fundación para la Promoción e Investigación de Productos Andinos), potato production has become a rewarding income source for smallholders in Ayopaya (Bentley and Vazques, 1998; Fernández-Northcote et al., 1999; Thiele, 1999). Nevertheless, animal ownership and husbandry remains the principal reason mentioned by smallholders to reside in the Andean highlands (Nürnberg, 2005). The husbandry and management of the animals in such traditional systems and marginal regions appear to be rather simple and basic at first glance, but the complexity of risk-prone systems is not easily understood and contemporary Andean societies still deliberately employ substantial livestock management to secure their subsistence (Browman, 1990; Flores et al., 2007). Hence, the dependency on llamas to secure smallholders' livelihoods in the Andean highlands

seems to be crucial. Nevertheless, future threats to this valuable animal genetic resource (AnGR) are more likely to be expected than currently conceivable, because of an increasing shortage of pastures due to a restricted transhumant movement, the expansion of crop land at the expense of pasture land, a retrogressive management in terms of pasture rotation on communal land and the introduction of alpacas resulting in a deterioration of the genetic pool by an undesired hybridisation progress. As a reasonable perspective for safeguarding animal genetic resources and an efficient use of limited natural resources, the development of sustainable breeding programmes have been proposed (Smith, 1988; Chávez, 1991; Valle Zárate, 1996; Iñiguez, 1998; Sölkner et al., 1998). In particular, the inclusion of genotypes that possess high levels of adaptive fitness to specific environments in such programmes would represent an utilization strategy maintaining or even enhancing the animals' properties and thus contributing to the economy of the communities depending on them (Mueller, 2008). Because of often missing formal and properly functioning markets in developing countries and the many additional functions and roles of livestock in smallholder systems, the derivation of economic weights for traits included in the breeding objective still remains a challenge (Scarpa et al., 2003b; Ouma et al., 2004; Nielsen and Amer, 2007; Wurzinger et al., 2008).

This study attempts to evaluate important functions, roles and traditional selection criteria of llamas from the livestock keepers' point of view. The information intends to deliver the basis for an aggregate evaluation of the genetic resource, as well as to identify entry points for breeding goal definition of the local llama population in Ayopaya. The following objectives were pursued to achieve the required information:

- A relative evaluation of the multiple functions the animals fulfil for the livestock keepers in their current production environment.

- A description of traditional llama husbandry and breeding management activities.

- The compilation and relative evaluation of traditional selection criteria for llama breeding males and females.

- An assessment of important breeding male attributes by a choice experiment approach to better understand farmers' preferences and the trade-offs they are willing to make in the setting of a possible breeding programme goal.

- A comprehensive discussion on the constraints and potentials of the methodologies applied and suggestions for further research to replenish the obtained information.

In the remainder of chapter 1, the present study is put in the context of past llama research conducted in the same study region and describes the outline of the thesis.

1.2 Positioning of the study

This study is part of a collaboration project between the UHOH (University of Hohenheim, Stuttgart, Germany), the UMSS (Universidad Mayor de San Simón, Cochabamba, Bolivia), the local NGO ASAR (Asociación de Servicios Artesanales y Rurales, Cochabamba, Bolivia) and the farmers' organisation ORPACA (Organisación Regional de Productores Agropecuarios de Calientes) initiated in 1998, with the aim to jointly describe and investigate constraints and perspectives of llama husbandry in the Ayopaya region. Initially the prevalent production system was described and classified (Nürnberg and Valle Zárate, 1999; Nürnberg, 2005). A subsequent study evaluated the outstanding fibre quality of the local llama population and the national and international fibre marketing potential (Delgado, 2003). A phenotypic and genetic characterisation of growth and fibre traits of the llama population was performed (Wurzinger et al., 2005; 2006a) and alternative designs for a breeding programme were modelled and compared (Wurzinger, 2008). The local NGO ASAR is working with farmers in the field of crop production and animal health and management. Farmers in Ayopaya were assisted to form the regional farmers' organisation ORPACA in 1998 that is headquartered in the central community Calientes. Moreover, both organisations planned and constructed a central mating station in Calientes in 1999, thus providing the basis for directed matings. ASAR also gives regular training courses for farmers on different topics related to crop and livestock production. Currently 130 farmers from 7 communities are members of the farmers' organisation ORPACA.

Fieldwork for this study was conducted in the central community Calientes, the more remote communities Cajas, Milluni and Putucuni and the very remote communities Escalerani, Huayllas, Lagunas and Pulchentas. The communities are situated within a radius of 15 to 20km from the central community Calientes, but are characterized by different accessibility and therefore different market access. The communities were selected based on the catchment area of the farmers' organisation ORPACA. However, households within the communities were selected at random and hence also non-members of ORPACA were screened. Data was collected from June 2005 to May 2006 and July to November 2007 via repeated farm visits, during ORPACA reunions taking place once per month, and during the mating season in the central mating station. Data collection methods comprised semi-structured household interviews, a ranking approach with functions of llama keeping presented by illustrations, a choice experiment approach and llama registers.

Following the research objectives mentioned in Chapter 1.1, 75 farmers from 6 communities took part in the ranking approach to evaluate the functions of llamas within the production system. Relative importance of functions was investigated by paired *t*-test statistics based on ranks for all pair-wise comparisons. The factors gender and village provenance were considered by the non-parametric Wilcoxon rank-sum test.

Information for the description of traditional llama husbandry and breeding management activities was derived from semi-structured interviews conducted in 47 households in 3 communities and partly cross-checked with information from 21 llama registers put up in August 2007. The evaluation of important selection criteria for male and female breeding llamas enquired and compiled by open-ended questions within the semi-structured questionnaires was performed by a ranking based on the sum of frequencies and a ratio-scaled evaluation.

The choice experiments were based on 5 selected criteria for male llamas from the evaluation results. 8 choice sets (16 pairs) were presented by means of pictorial presentations to a total of 159 randomly selected farmers from 7 communities. Results were displayed by a mixed logit model (MXL) with interactions.

1.3 Structure of the thesis

Chapter 2 of the thesis corresponds to "Stated preferences of llama keeping functions in Bolivia", published in Livestock Science 124, 2009, and introduces the multiple functions llamas fulfil in the productive, social and cultural life of smallholders in Andean highland farming systems. A relative evaluation of the functions was performed by presenting 10 important functions to each respondent, who subsequently ranked his or her preferred reason for keeping llamas. The results and the methodology are critically discussed.

Chapter 3 of the thesis, corresponding to "Traditional llama husbandry and breeding management in the Ayopaya region, Bolivia", published in Tropical Animal Health and Production 42, 2010, presents traditional llama husbandry and management activities in the Ayopaya region. The findings are compared with information from other studies and past camelid research in the same study region. Furthermore, traditional selection traits for male and female llamas are documented and assessed by a ranking and a ratio-scaled evaluation. Similarities and differences of the prevalent farming system in Ayopaya region and the dominant herd management applied by the livestock keepers are discussed in comparison to information from other studies conducted in the same and other Bolivian highland regions. The strengths and shortcomings of the methodology applied to collect and evaluate selection criteria are demonstrated.

Chapter 4 corresponds to "Estimation of farmers' preferences for llama traits: A stated choice experiment", submitted to Agricultural Economics. Important traits of llama breeding males are assessed by a choice experiment model that allows a systematic investigation of the single attributes of a bundled good. Welfare measures were calculated for statistically significant characteristics based on the coefficients of the MXL model, thereby presenting economic values for different llama attributes. The empirical results are discussed and limitations, as well as implications, also for further research, are given.

2 Stated preferences of llama keeping functions in Bolivia

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2.1 Abstract

Bolivia accounts for approximately 63% of the South American llama population. Llamas keep playing an important role in the subsistence of smallholdings in the Andean regions fulfilling various functions in the productive, social and cultural life of the people. The present study evaluates functions of llama keeping as a prerequisite to the formulation of a community-driven breeding programme. A ranking approach was applied with 75 farmers in 6 villages. Sampling considered the factors gender and central versus remote communities. The different functions were presented visually. Each farmer was asked to arrange the illustrations according to his preference order. In total, 10 functions were suggested, covering the categories transport, sale or use of products, integration of animals in cultural events and herd size as capital asset. Ranking frequencies of stated preferences were calculated. A rank-based *t*-test was applied for multiple pair-wise comparisons within ranking groups gender and community provenance, respectively. Between-group comparison was performed by non-parametric Wilcoxon rank-sum test. The capital function was most important (14.6% of total ranking frequency) followed by the transport function to cultivated areas (13.7%) and the transport function for other purposes in third place (10.8%). All pair-wise comparison analysis indicated a significant difference for the two highest ranked functions. Functions ranked from 3rd to 9th position showed poor separation due to similar means with high variance. Bottom ranked function with significant separation for all ranking groups was the 'Integration of animals in cultural events or rituals'. Women appreciated the dung of the animals more than men ($p = 0.0376$), whereas men put higher value on the sale of live animals for cash generation in case of emergency ($p = 0.0006$) and for cash availability ($p = 0.0371$). It is concluded that traditionally important functions of llamas like wealth accumulation and the close integration of the animals in mixed farming systems prevail. Breeding policies and breeding decisions will be more suitable when taking into account farmers' preferences and gender-specific perceptions.

Keywords: Llamas; Animal functions; Smallholders; Stated preferences; Multiple pair-wise comparisons; Bolivian highlands

2.2 Introduction

Many of the world's poorest and marginalised people depend directly on livestock as a key component of their livelihood and social security strategy. Livestock in complex, diverse and risk-prone livelihood systems, with often low and unsteady resource availability, need to fulfil multiple functions to meet the requirements within the farming systems (Anderson, 2003; van't Hooft and Wanyama, 2005).

Since the domestication of the llama (*Lama glama* L.) in pre-Hispanic times, camelid husbandry in Bolivia remains an essential survival strategy for local indigenous people in the Andean highlands. Although the population of llamas had been steadily decimated with the Spanish invasion, which resulted in their disappearance from the greatest part of their reign, they survived within the framework of a traditional, socioeconomic organization[1] and continue to play the most reliable nutritional and economic resource available to the peasants who inhabit zones at, or above, the upper limit of crop cultivation (Sumar, 1988). Bolivia holds 60% of the llama population worldwide. All of the estimated 2.4 million llamas are kept by approximately 54,000 smallholder families in marginal areas (UNEPCA et al., 1999).

In these smallholder Andean communities, the animals contribute to the economic and social life of their herders by a variety of functions and products. They do not only provide food and fibre, but also dung for fuel, a means of transport and fulfil cultural, social and capital functions (Sumar, 1988; Flores Ochoa and MacQuarrie, 1995; Camino and Sumar, 2000; Nürnberg, 2005).

Despite recurring statements of the various functions and products provided by llamas in the relevant literature, little is known about the order of magnitude of the specific functions. However, to identify starting points and strategies for the improvement of peasant livestock systems, measures are required that allow to describe the relative importance of the multiple livelihood functions of the animals. This holds especially true when aiming at breeding activities and breeding plans. Animal breeding in the Andean region has been considered secondary in most development programmes.

[1] The term 'socioeconomic organization' describes the interconnection of the animals (llamas) and their herders (Andean societies or communities); the importance the animals receive from native Andean communities, in social and economic terms, contributes to their survival.

Improvement in management, nutrition and animal health produces favourable short-term results and therefore prevail in development and improvement issues (Iñiguez, 1998). Short-term effects, however, often require additional inputs that resource-poor farmers cannot afford, whereas genetic change is permanent and does not require a continuous use of expensive input factors (Van der Werf, 2000; Nakimbugwe et al., 2002).

Knowledge about the importance of the multifunctional roles that llamas play in smallholder systems in mountainous regions, as well as farmers' preferences in this regard, is a useful input in designing breeding strategies and a prerequisite when formulating sustainable breeding goals (Jabbar et al., 1999; Olivier et al., 2002). Therefore this study assessed the relative importance of the functions llamas fulfil in smallholder Andean communities in Bolivia from the farmer's point of view.

2.3 Materials and methods

2.3.1 Study area

The study area is located in the eastern Andes cordillera (Cordillera de Cocapata), in the Province of Ayopaya, Department Cochabamba, Bolivia, approximately 120 km north-west of the city of Cochabamba. The large and remote province of Ayopaya is among the poorest areas in Bolivia with high infant mortality rates, prevalent malnutrition and low income (PAHO, 1998). The tropical highland climate (tierra helada) is characterised by an average annual precipitation of 600 mm and an average annual temperature of 3.3 °C. The rainy season is between December and March. Frosts can occur all year round with an average of 150 days per year. The central community of the present study in the north of Ayopaya province is accessible by one single road. Although infrastructure has considerably improved during the last years, the road frequently turns inaccessible during the rainy season. Transportation from the central community to the provincial capital of Quillacollo takes approximately 9 h by truck. The remote villages in contrast are either not accessible by heavy vehicles or transportation facilities are considerably less frequent, resulting in a different market access.

2.3.2 Data collection

Primary data was collected from August to November 2005 in 6 peasant communities located at altitudes between 3400 and 4300 m above sea level. The 6 communities are composed of one central community in terms of infrastructure and transportation possibilities from and to the provincial capital, and 5 remote villages. The criterion for the selection of communities was the service area of the farmers' organization ORPACA (Organización Regional de Productores Agropecuarios de Calientes) that has been cooperating in former research activities initiated by the University of Hohenheim. A total of 75 farmers were interviewed, of which 48 were men and 27 women. It was intended to survey an equal number of men and women, which was, however, not accomplishable due to language constraints. Participating farmers were selected according to their past or present experience in llama husbandry and their village provenance. Hence, all farmers were keeping llamas or kept llamas in the past.

2.3.3 Study material

Ten important functions of llama keeping have been selected based on survey and literature results presented by Nürnberg (2005), as well as preliminary interviews. The selection covered the categories transport, sale or use of products, integration of animals in cultural events and herd size as capital asset. To the sales function of live animals a purpose of use was added to account for emergency situations. Hence, the following ten functions were suggested: i) means of transportation to cultivated areas, ii) means of transportation for other purposes, iii) llama dung as energy source, iv) sale or consumption of fresh or dried meat, v) sale of live animals for cash availability, vi) sale of live animals in case of emergency, vii) sale of fibre, viii) domestic use of fibre, ix) integration of animals in cultural events or rituals, and x) herd size as capital asset. The functions of llama keeping were presented visually in the form of illustrations prepared by a local painter. The illustrations were explained to each respondent, who subsequently ranked his or her reasons (first to tenth) for keeping llamas.

2.3.4 Statistical analysis

Data analysis was performed using SAS 9.1 (SAS Institute Inc., Cary, NC, USA). Considered factors were gender (2 subgroups) and village provenance (2 subgroups).

Ranking frequencies were calculated for total respondents and the different subgroups to obtain a general ranking order. Rank-means and their standard deviations were calculated for within- and between-group comparisons. Importance of functions within groups was investigated by paired *t*-test statistics for dependent data based on ranks for all pair-wise comparisons following an approach described by Brunner and Langer (1999). This is a non-parametric test for equality of groups. Letter display of all pair-wise *p*-values resulting from the significance statements is done according to a method developed by Piepho (2004), which in contrast to the common true line display, can allow gaps in the lines connecting non-significantly different groups as is often necessary for data with heterogeneous variance of mean differences.

Differences of preference ranking between investigated subgroups were compared by the non-parametric Wilcoxon rank-sum test. The two-sample test was performed for the classified groups gender and village provenance, respectively. Tests were based on simple linear rank statistics using the ranks of the observations (Wilcoxon scores) as the response variable. For each score an asymptotic test of the null hypothesis of no difference between the two classification levels was computed. Results display the asymptotic two-sided *p*-values. Exact *p*-values were estimated to account for small sample size and/or tied values. However, exact *p*-values were only marginally different from asymptotic results and are therefore not reported here.

2.4 Results

2.4.1 Frequencies of llama keeping functions

Frequencies of stated preferences were calculated for total respondents and separately for men and women as well as for the central village and remote villages, respectively. The functions most frequently preferred over all groups (more than 10% of ranking frequency) were ‘Herd size as capital asset’, ‘Transportation to cultivated areas’, ‘Transportation for other purposes’ and ‘Sale or consumption of fresh or dried meat’ (Table 1). Rank order of functions shows that in all groups the first two positions are identical, i.e. ‘Herd size as capital asset’ in 1st and ‘Transportation to cultivated areas’ in 2nd position. The same applies to the ‘Integration of animals in cultural events or rituals’ that is ranked last in all groups.

Table 1: Frequencies of llama keeping functions for total respondents, by gender and community provenance

	Ranking groups				
	Total	Men*	Women*	Central village+	Remote villages+
Stated primary preference (%)					
Herd size as capital asset	14.6	13.8	15.9	15.7	13.6
Transportation to cultivated areas	13.7	13.7	13.7	14.0	13.4
Transportation for other purposes	10.8	10.1	12.2	10.8	10.9
Sale or consumption of fresh or dried meat	10.6	10.8	10.3	10.7	10.5
Domestic use of fibre	9.9	9.1	11.2	10.2	9.6
Dung as energy source	9.4	8.3	11.4	8.8	10.0
Sale of live animals for cash availability	8.8	9.5	7.1	8.2	9.1
Sale of live animals in case of emergency	8.7	10.2	6.2	8.3	9.2
Sale of fibre	8.5	8.9	7.8	8.1	8.9
Integration of animals in cultural events or rituals	5.0	5.6	4.2	5.3	4.9
Number of respondents	*75*	*48*	*27*	*35*	*40*

* Statistically significant relationship between ranking of functions and gender (chi-square with 9 degrees of freedom = 49.16, p<.0001); + No statistically significant relationship between ranking of functions and community provenance (chi-square with 9 degrees of freedom = 8.22, p=0.51)

Further important functions are the 'Transportation for other purposes' and the 'Sale or consumption of fresh or dried meat', equally in all groups passing the 10% mark, but taking different ranking positions. Male respondents additionally stated the 'Sale of live animals in case of emergency' as an important function (10.2% of ranking frequency), whereas women respondents considerably valued the 'Dung as an energy source' and the 'Domestic use of fibre', with 11.4% and 11.2% respectively. In the

remote villages the dung use as energy resource likewise reached 10% of ranking frequency.

2.4.2 Preference rankings within and between gender groups

Multiple comparisons for male respondents show a significant difference for the two highest ranked functions 'Herd size as capital asset' and 'Transportation to cultivated areas', as well as the bottom ranked function 'Integration of animals in cultural events' (Table 2).

Table 2: Analysis of preference rankings within and between gender groups

Importance of functions for male respondents[+]	Mean rank *(SD)*	Importance of functions for female respondents[+]	Mean rank *(SD)*
(A) Herd size as capital asset	7.56^{a} *(3.38)*	(A) Herd size as capital asset	8.96^{a} *(2.32)*
(B) Transportation to cultivated areas	7.48^{a} *(2.07)*	(B) Transportation to cultivated areas	7.73^{b} *(1.95)*
(C) Sale or consumption of fresh or dried meat	5.92^{b} *(2.35)*	(D) Transportation for other purposes	6.88^{bc} *(2.52)*
(D) Transportation for other purposes	5.64^{bc} *(2.99)*	(I) Dung as energy source*	6.19^{cd} *(2.77)*
(E) Sale of live animals in case of emergency**	5.58^{bc} *(2.59)*	(H) Domestic use of fibre	6.07^{cd} *(2.35)*
(F) Sale of live animals for cash availability*	5.34^{bc} *(2.60)*	(C) Sale or consumption of fresh or dried meat	5.56^{d} *(1.60)*
(G) Sale of fibre	5.00^{bc} *(2.22)*	(G) Sale of fibre	4.38^{e} *(1.81)*
(H) Domestic use of fibre	5.00^{c} *(1.99)*	(F) Sale of live animals for cash availability*	4.00^{e} *(1.94)*
(I) Dung as energy source*	4.66^{c} *(2.85)*	(E) Sale of live animals in case of emergency**	3.50^{e} *(1.70)*
(J) Integration of animals in cultural events or rituals	3.04^{d} *(2.72)*	(J) Integration of animals in cultural events or rituals	2.26^{f} *(2.38)*
Number of respondents	*48*		*27*

[+] Means followed by the same letter in columns are not statistically different at $p < .05$; Letter display according to Piepho (2004); Capital letter assignment in brackets for each function for Wilcoxon rank-sum test. Test results based on the rank sum associated with the smaller sample: A x A = 0.0718, B x B = 0.6864, C x C = 0.3399, D x D = 0.0928, E x E = 0.0006**, F x F = 0.0371*, G x G = 0.2282, H x H = 0.0607, I x I = 0.0376*, J x J = 0.0756; *significant at α=.05 level; **significant at α=.01 level.

No significant differences between the two top ranked functions could be found. Functions ranked from 3rd to 9th position are closely connected due to similar rank means with high variance. However, the functions 'Domestic use of fibre' and 'Dung as energy source' are well separated from the 'Sale or consumption of meat', ranked in 3rd position by male farmers. The functions 'Sale of fibre' and 'Domestic use of fibre' have the same means, yet the significance statements differ due to different standard errors.

Women's ranking (Table 2, column on the right) only reveals a clear cut-off for the function 'Herd size as capital asset' at the top of the ranking list and the previously seen separation of the function 'Integration of animals in cultural events' at the bottom. Ranking of the sales functions of the product fibre and live animals are significantly valued inferior than functions in the upper part of the ranking list (2nd to 6th position), composed of the two 'Transport functions', the 'Dung as energy source', the 'Domestic use of fibre' and the 'Sale or consumption of meat' functions.

Significant differences between men and women's ranking are based on Wilcoxon scores (Table 2). Men ranked the 'Sale of live animals in case of emergency' (p = 0.0006) and the 'Sale of live animals for cash availability' (p = 0.0371) higher than women. Women on the other hand perceived the 'Dung as energy source' more valuable (p = 0.0376) than men. Although not statistically significant at α = 0.05 level, the 'Domestic use of fibre' also received more attention by women (p = 0.0607).

2.4.3 Preference rankings within and between community provenance

Respondents from the central community significantly ranked 'Herd size as capital asset' in 1st and the 'Transportation to cultivated areas' in 2nd position (Table 3). There is poor differentiation among functions from 3rd to 9th position, giving very limited basis for specific interpretation. However, the 'Transportation for other purposes' (3rd position) is significantly different from the functions 'Sale of fibre' and 'Sale of live animals in case of emergency' (8th and 9th place, respectively). Remote communities' ranking shows a different picture, as no significant differences at all could be found amongst functions between 3rd and 9th positions (same superscripts, see Table 3, column on the right). A significantly higher valuation of the functions 'Herd size as capital asset' and 'Transportation to cultivated areas' –

without significant difference between the two – however persists, as well as the significantly lower valuation of the function 'Integration of animals in cultural events' (Table 3).

Table 3: Analysis of preference rankings within and between community provenance

Importance of functions for central community[+]	Mean rank *(SD)*	Importance of functions for remote communities[+]	Mean rank *(SD)*
(A) Herd size as capital asset	8.74[a] *(2.72)*	(A) Herd size as capital asset	7.48[a] *(3.33)*
(B) Transportation to cultivated areas	7.79[b] *(1.98)*	(B) Transportation to cultivated areas	7.38[a] *(2.06)*
(C) Transportation for other purposes	6.21[c] *(2.99)*	(C) Transportation for other purposes	5.98[b] *(2.81)*
(D) Sale or consumption of fresh or dried meat	5.77[cd] *(1.99)*	(D) Sale or consumption of fresh or dried meat	5.80[b] *(2.23)*
(E) Domestic use of fibre	5.51[cd] *(2.20)*	(F) Dung as energy source	5.50[b] *(3.04)*
(F) Dung as energy source	4.88[cd] *(2.73)*	(E) Domestic use of fibre	5.28[b] *(2.17)*
(G) Sale of live animals for cash availability	4.70[cd] *(2.28)*	(I) Sale of live animals in case of emergency	5.05[b] *(2.71)*
(H) Sale of fibre	4.67[d] *(1.98)*	(G) Sale of live animals for cash availability	5.00[b] *(2.61)*
(I) Sale of live animals in case of emergency	4.62[d] *(2.28)*	(H) Sale of fibre	4.88[b] *(2.20)*
(J) Integration of animals in cultural events or rituals	2.86[e] *(2.73)*	(J) Integration of animals in cultural events or rituals	2.68[c] *(2.54)*
Number of respondents	*35*		*40*

[+] Means followed by the same letter in columns are not statistically different at $p < .05$; Letter display according to Piepho (2004); Capital letter assignment in brackets for each function for Wilcoxon rank-sum test. Test results based on the rank sum associated with the smaller sample: A x A = 0.1131, B x B = 0.3227, C x C = 0.6146, D x D = 0.9914, E x E = 0.6213, F x F = 0.3479, G x G = 0.6630, H x H = 0.8053, I x I = 0.5914, J x J = 0.9444.

Nonparametric tests on basis of each function show no significant differences in preference ranking by community provenance, which is also reflected by similar mean rank values (Table 3). The largest distance between mean values can be found for the 'Herd size as capital asset'-function, that received even more value by respondents

from the central community as opposed to farmers from remote communities (μ = 8.74 and 7.48, respectively; $p = 0.1131$).

2.5 Discussion

According to farmers' rankings, the major functions of llama keeping in Ayopaya region were herd size as capital asset as well as transportation. These traditional functions of the animals were already considered as most important at the time of the Incan empire, where llamas represented wealth and the most important means for transportation (Franklin, 1982). The herd size as capital asset was acknowledged as most important by all farmers and all subgroups in terms of gender and community provenance (Table 1). This animal function is of common importance in smallholder systems (Udo and Cornelissen, 1998; Bebe et al., 2003; Ouma et al., 2003; Siegmund-Schultze et al., 2007). However, average herd sizes of 46–52 llamas in Ayopaya region are rather small (for details see UNEPCA et al., 1999; Delgado, 2003; Nürnberg, 2005) and the animals do not only compete with other species for feed resources, but also for land use through extended potato cultivation. Therefore accumulation of wealth by means of increasing herd size is more restricted the higher the cropping activities on the communally owned land.

The transportation function of llamas to cultivated areas was perceived by farmers as equally important as the capital function (Table 2 and Table 3). This highlights the value and role of llama keeping in a mixed system within a poorly accessible region with a strong integration of the animals into cropping activities and thereby securing livelihoods. Although several authors assumed a decreasing importance of llamas as pack animals through the extension of the road and path network even in remote areas of the Andes and the decline of barter trade (Caro, 1992; Iñiguez and Alem, 1996), Nürnberg (2005) already stated that this could be specific to the Altiplano–Puna plateau, whereas in the eastern cordillera of the Andes the transportation function of llamas cannot be completely substituted. This study confirms the high actual importance of the transport function, even if the transportation function to cultivated areas is neglected. The means of transportation for other purposes – including every kind of transport not undertaken from or to cultivated fields – is consistently ranked in 3rd position for all subgroups, except for male respondents (Table 1).

The llama dung, which is the main source of energy for cooking, constitutes an essential resource within the Andean agro-ecosystem. Alternative energy sources are either still not available or more cost-intensive, as Winterhalder et al. (1974) already stated. However, the actual value of the dung is often not perceived by the farmers (Nürnberg, 2005). The ranking approach can partly support these statements, in particular in the case of men, who ranked the importance of the llama dung in second last position, affecting considerably the total ranking order with the llama dung being displaced to the 6th position. However, as rank ordering of women shows, llama dung is much more appreciated by the gender group who directly uses this resource (1 and Table 2).

Functions indicating the sale of live animals or the product fibre (in 7th, 8th and 9th positions of total ranking order) were actually not perceived as highly important by the farmers. Nevertheless, significant gender differences could be found. Men attached much more importance to the generation of cash in case of emergency or for cash availability through the sale of live animals than women (p = 0.0006 and p = 0.0371, respectively). This could be due to the fact that men are more conversant with finance and market action, whereas women are in charge of household matters and husbandry activities in the communities. A study of Kabutha (1999) has documented the low access of women to capital and financial assets. While in general the poor have little access to finance, data from several African countries suggests that women face specific gender barriers, including lack of collateral, low levels of numeracy and formal education as well as less time to undertake a journey to a credit institution. A gender-specific labour organization is furthermore distinctive in smallholder communities in Ayopaya region (Nürnberg, 2005).

A slight discrepancy in the ranking results from the statements above can be observed concerning the sale or consumption of fresh or dried meat, which was ranked considerably higher (see Table 1) from other sales functions. Whilst formerly llama meat was depreciated in the urban sector and only consumed traditionally by peasant communities of the Andes (Foronda, 2006), the consumption of llama meat, especially in the form of dried meat (charque) in towns and cities has increased considerably since 1997 (Zambrana, 2002), with an average annual 10.3% increase in the production of charque between 1990 and 2000 (UNEPCA et al., 2002 cited in

DESEC, 2003). The suggested change in consumer behaviour, also in the middle and upper class, is mainly attributed to a national promotion and information campaign of public projects for the nutritional quality of the product (high protein, low fat and cholesterol content) (Zambrana, 2002; DESEC, 2003). In spite of still existing resistance to the consumption of llama meat by parts of the society, current changes are encouraging and are well perceived by the producers originating almost exclusively from Aymará and Quechua families.

Previous studies revealed an outstanding fibre quality of the llama population of the Ayopaya region when compared to other Bolivian populations and hence a promising potential for fine fleece production (Delgado, 2003). However, as present ranking of farmers for the function 'Sale of fibre' suggests, attention for market production of llama fibre is still of minor importance. The potential of an income and welfare-generating product is not yet seen by the livestock keepers. The reasons for and consequences of this are manifold: low shearing frequency, low proportion of animals shorn, varying fibre quality due to not sorting and classifying llama fleeces, low and seasonally varying prices and absence of easily accessible market infrastructure amongst others. These circumstances result in low income from llama fibre and hinder its access to the international market (Valle Zárate et al., 2000; Delgado, 2003). These findings, however, have to be interpreted with caution, as they do not negate the fibre marketing potential. To this day, the vertically integrated Peruvian industry that controls the textile sector of camelid fibre in Bolivia is non-competitive, which is a result of the disposability of raw material in industrial quantities, among other reasons. The producer's part on the other hand is characterised by a strong influence of intermediaries, reducing the negotiating possibilities of local farmers (Claros, 2006). However, promising perspectives for high quality fibre production from llamas in Ayopaya remain, most notably because of the competitive capacity of the local animal population regarding its quality fibre attributes. By a strong support towards initiatives of associated commercialization, informal markets could be overcome and resulting better prices could also change perception of the importance ranking in the future.

Local breeds and species have often played a central role in the social life of rural populations (Gandini and Villa, 2003). The results of this study regarding the bottom

ranking of the function 'Integration of animals in cultural events or rituals' must not hide the fact, that the llama keeps playing an important role in the social and cultural life of the Aymará and Quechua people in the Andes (Nürnberg, 2005). In this context the method applied in this study has to be considered. A ranking approach always forces the respondents to rank one function over the other. Automatically one function results to be the bottom ranked on average. This does not imply, however, that the specific function is of no importance or even meaningless. The results of the present study allow only for the general statement that in relation to the other proposed functions, the 'Integration of animals in cultural events or rituals' is of lower perceived importance. After all, 9% of total respondents ranked the cultural value of the animals among the first three positions. In this regard it is worthwhile to note the high variance associated with the mean rank of the function (Table 2 and Table 3). The vision of a camelid holder from the region of Turco, department Oruro, Bolivia, on the natural and ancestral llama husbandry gives the general impression, that the cultural value and importance of the animals cannot be completely detached from the other beneficial functions. The specific products utilized as well as the transport function might already constitute important cultural aspects in their own right (Canqui, 2006).

No significant differences regarding village provenance could be found in preference ranking. Ranking order of functions from the central community and the remote communities is very similar. Regarding the *p*-values obtained from the Wilcoxon rank-sum test, there seems to be a slightly higher appreciation of the 'Herd size as capital asset' and the 'Transportation to cultivated areas' functions in the central community and a marginal higher appreciation of the 'Dung as energy source' in the remote communities. Basically, preference ranking in the remote communities is rather homogenous. A possible explanation for this observation could be that an almost equal importance is attached to the different animal functions and products. The consent in preference perceptions between the central community and the remote communities could be due to the strong traditionalism in the utilization of the animals. Finally, the slightly more favourable market access from the central community apparently did not change as yet the utilization of llamas from a multi-purpose species to a more specialized one.

The presented farmers' preferences on llama functions could provide a useful basis when aiming at sustainable improvement of this valuable genetic resource and contribute to the decision-making process of resource allocation for llamas regarding husbandry, management and breeding issues. Recently, more attention has been directed towards the importance of local knowledge related to breeding (Adams et al., 2002; Jaitner et al., 2003; Mwacharo and Drucker, 2005). It can be derived from the presented results that the transport capability of the animals has to be maintained when formulating a sustainable breeding goal. A good physical condition, sturdiness, size and a good body conformation would be the relevant selection traits. This is confirmed by an upcoming study on the selection criteria for llama males (Markemann and Valle Zárate, submitted).

The high value of transport geldings in the mixed farming system in Ayopaya region could be an indication of a potential separation of breeding lines into transport males and breeding males. However, whether this selection is carried out simultaneously or one of the two groups is given preferential consideration by the farmers cannot be answered by this study.

The herd size as a capital asset or wealth accumulation in traditional livestock systems has been recognized by many researchers (Udo and Cornelissen, 1998; Bebe et al., 2003; Ouma et al., 2003; Siegmund-Schultze et al., 2007). This animal function accounts for an intangible role of llama keeping. The need to include intangible functions of animals in breeding goal definition has been discussed for different low-input farming systems (e.g. Bichard, 2000). Kosgey et al. (2004) accounted for financing and insurance benefits from sheep in pastoral systems and concluded that total profit per year is higher, when both – tangible and intangible returns – are included in the breeding objective. As long as alternative savings and insurance options are not available for farmers in Ayopaya, their perception of this animal function is expected to remain high, and hence should be considered when planning sustainable genetic and production improvement programmes under the prevailing traditional farming system.

Wurzinger et al. (2008) simulated different scenarios for the implementation of a village breeding programme in Ayopaya. The fastest genetic progress was achieved when all females are mated in an already existent central mating station with

exclusive use of males in the station. Fleece weight and fibre diameter were the only selection criteria considered. Economic weights were not available. As shortcomings the high labour demand, necessary commitment of farmers and unsolved questions regarding organisational aspects of the station's use were mentioned. Based on the findings of the present study the definition of the breeding goal should be reconsidered. A more complex breeding goal to account for the multi-functionality of the animals has to be contrasted with the feasibility of the aspired breeding objective. Intangible benefits need to be included in a breeding programme under the given conditions. The derivation of economic values for such traits and functions remains a challenge for future research.

2.6 Conclusions

This study emphasizes the traditionally important functions of llamas in terms of wealth accumulation and transportation as well as their continued close integration in a mixed farming system. Gender-specific analysis revealed partially gender-related results, e.g. the dung utilization and the domestic use of fibre, and should generally be taken into account when evaluating the functions of animals. Breeding policies and breeding decisions will be more effective when the multi-functionality of llamas for the livestock keepers is taken into account.

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3 Traditional llama husbandry and breeding management in the Ayopaya region, Bolivia

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3.1 Abstract

The llama claims the largest population of the domestic South American camelids, most of which are raised in Bolivia. More than 53,000 rural families are dedicated to llama husbandry as part of their livelihood strategy. Contemporary Andean societies deliberately select animals for specific traits and employ substantial livestock management to secure subsistence. This study presents traditional llama husbandry and breeding management activities in the Ayopaya region, Bolivia. Traditional selection traits for male and female llamas are documented and assessed by a ranking and a ratio-scaled evaluation. Husbandry and management parameters are in concordance with other studies conducted in the region, but show a high variation. Average llama herd sizes are rather small (μ=45.6). In some herds, breeding males are utilized for a long time and mix with other herds, causing concerns about inbreeding. Preferred trait groups for llama males according to farmers' responses were body conformation, fibre, testicle conformation, fleece colour and height at withers. Traditional selection criteria generally relate to the phenotype, but also include the commercially interesting fibre trait. The presented results should be considered in breeding and management programmes for the respective llama population to ensure sustainable use of this genetically and culturally valuable llama population.

Keywords: Bolivian highlands, Llamas, ratio-scale evaluation, selection criteria, smallholder farmers.

3.2 Introduction

With more than four million individuals worldwide, the llama (*Lama glama* L.) upholds the largest population of the domestic South American camelids. After domestication in the Peruvian puna about 6,000 years ago (Wheeler, 1991), the llama distribution reached its farthest expansion as pack trains for the royal armies during the Incan period (1479-1532). At this time, llama breeding and management were rigidly organized and controlled by the Incan government. A nucleus state herd was formed, detailed herd records were kept, animals were divided according to colour, sex and age, and redistribution was largely state-controlled (Murra, 1965). The Spanish conquest had a disastrous effect on the llama population, leading to a dramatic reduction of approximately 90% within little more than a century as well as

their displacement from inter-Andean valleys and coastlines to marginal high-elevation pastures (Wheeler, 1994; Wheeler, 2003). In recent years, the llama population has remained relatively stable. More than 60% of the 3.7 million animals worldwide are found in Bolivia (FIDA et al., 1999; INE, 2008) and more than 53,000 rural poor families in Bolivia are dedicated to llama husbandry as part of their livelihood strategy (DESEC, 2003).

Though the decline of sophisticated camelid husbandry applied by the Incan government after the Spanish conquest is a trend that has never been reversed (Novoa and Wilson, 1992), contemporary Andean societies still deliberately select animals for specific traits and undoubtedly employ substantial livestock management to secure their subsistence (Browman, 1990; Flores et al., 2007). In the Bolivian highlands, farming systems are characterized by a high degree of heterogeneity with respect to animal species raised and the manifold roles and functions the animals play within household economies (Alzérreca and Genin, 1992; Caro, 1992; Markemann et al., in press; Moll, 2005). These risk-prone systems are very complex and therefore not easily understood. Modern animal breeding methods - developed for the conditions of intensive livestock production in developed countries - often neglect the various roles livestock play in agrarian households in developing countries (Valle Zárate, 1996). Livestock development policies still tend to focus on physical products and emphasize market production (Behnke, 1985; Moll, 2005).

Breeding activities are considered to play an important role in the promotion of small ruminant production in the Andean region (Iñiguez, 1998). For the establishment of sound breeding programs, it is crucial to understand how livestock-keeping and selection procedures are presently being conducted under specific local conditions. In the development context, constraints can only be overcome if research is oriented towards sustainability based on local animal species and technology, which allows animals to fulfil their various functions within the farming systems (Tichit and Genin, 1997; Iñiguez, 1998).

In this respect, the current research presents traditional llama husbandry and breeding management activities in the Ayopaya region, department Cochabamba, Bolivia. The findings are combined and compared with information from other studies relating to past camelid research in the same region as well as areas in Bolivia.

3.3 Material and Methods

Information on llama husbandry was gathered between August 2005 and April 2006 from semi-structured interviews conducted on 47 randomly selected households in three communities in the Ayopaya region, department Cochabamba, Bolivia. The three communities Cajas-Calientes, Milluni and Putucuni are located at an altitude between 3,800 and 4,300m a.s.l. All of the communities are interconnected by a road that is accessible by off-road vehicles. In contrast to Milluni and Putucuni that are located more remote, Calientes is frequently approached by trucks en route to and from the provincial capital and can therefore be denominated as the central community of the region. Furthermore it serves as the central meeting place for the farmers' organisation ORPACA (Organización Regional de Productores Agropecuarios de Calientes) and a mating centre for llamas. A detailed description of the study site is presented in an earlier part of this study (Markemann et al., in press). Questionnaires were comprised of topics related to herd structure and management, animal selection and selection criteria and the utilisation of products. Additional information on herd sizes and herd structure, also for cross-checking statements from interviews, was derived from 21 llama registers, which were put up in August 2007 within a collaboration project between the farmer's organisation ORPACA, the local NGO ASAR (Asociación de Servicios Artesanales y Rurales) the UHOH (University of Hohenheim, Stuttgart, Germany), and the UMSS (Universidad Mayor de San Simón, Cochabamba, Bolivia). Dependent on previous animal identification carried out, the actual registers were implemented in the very remote communities Huayllas, Lagunas and Pulchentas, which were not included in the past years' activities, but had a considerable amount of llamas.

Selection criteria traditionally applied by farmers were enquired by open-ended questions. Stated criteria for male and female llamas were noted verbatim and then assigned to trait groups. The evaluation was performed in two different approaches. First, the selection criteria were ranked according to the number of times mentioned (sum of frequencies). The second step included the order in which criteria were mentioned by individual farmers. It was assumed that criteria mentioned first are of relatively higher importance to the farmer than subsequent criteria. The relative weighting was done on a ratio-scale from zero to one, giving one point to the first, and

fractions of one to the consecutive criteria, based on the total number mentioned by each respondent. Evaluated criteria on the ratio-scale were ranked correspondingly.

3.4 Results

3.4.1 Herd size and herd management

From the 47 interviewed llama-keeping households in Ayopaya, 91% additionally kept sheep, 74% alpacas, 55% cattle, 34% horses and 11% donkeys. Considering the total number of animals, the predominant livestock kept in the investigated households is sheep (3017 head), followed by llamas (2144 head) and alpacas (1269 head). Considering the metabolic weights of the animal species in ovine units (OU, calculated according to Tichit, 1991, p.83), however, the predominant is the llama (4288 OU), followed by sheep (3017 OU) and Alpacas (1903.5 OU). Average herd size of llamas per household was 45.6 animals, showing a wide range from 5 to 153 animals. Herd registers from 21 farmers show an almost equal number with 43.7 llamas per household (Table 4).

Table 4: Average herd size of llamas in Ayopaya region, Bolivia

	From questionnaires[a]	From registers[a]	Delgado, 2003	Nürnberg, 2005	FIDA et al., 1999
Mean	45.6	43.7	52.0	50.0	46.0
SD	34.2	25.3	37.9	38.4	-
Range	5 – 153	13 – 95	6 – 254	9 – 218	-
*Number of respondents/ herds**	*47*	*21**	*65*	*43*	*51,997***

[a]Source: Authors' own survey; *derived from 21 registered herds in August 2007, with a total of 918 animals from 3 communities; **derived from the national census of 2,398,572 llamas and 51,997 families

Multiple use of community land in the region leads to different grazing patterns. In contrast to sheep, llamas are seldom herded. They wander freely during the day and instinctively return to the homestead at night. However, herds are often split up into groups of castrates (transport animals) and a herd of females with the 'macho' (breeding male). The majority of respondents (72%) is practising this kind of management. The other interviewed farmers do not separate their llamas, at least not

as frequently or consistently enough to constitute as a management measure. Usually, different families and households share the community pastures. In this context it is relevant to note that only 23% of farmers stated that there are no 'machos' from other herds entering their own herd, whereas 77% of respondents concede a substantial mixing of their own herds with other herds and other male llamas.

3.4.2 Selection and productive life

Selection of breeding male llamas is mainly realised by castration of males that are not considered for reproduction. Males are castrated after reaching an age of more than 2 years. The procedure is carried out with an ordinary kitchen knife and without anaesthesia. The number of breeding males needed in the herd depends on the number of females. Usually one 'macho' can serve 10 to 20 females. Due to rather small individual herds, the majority of farmers are making use of only one breeding male (85% of interviewed farmers).

Replacement of breeding males is usually done within the herd (76% of households). A small percentage of respondents (14%) stated that they have bought their current 'macho' from another region (additionally 9% declared that they had bought a 'macho' in past years) and 11% are using the 'macho' from a family member (mother-in law or own father) or neighbouring herds. The age of sexual or reproductive maturity in llamas is considered to be 2 to 3 years. Average selection age of male llamas in the investigated households is 2.2 years. The rather low average, however, is composed of a wide range of specific selection times. Some male llamas are already considered as 'machos' when they are still foals. The primary selection age of male llamas is 2 years, as indicated by the median value (Table 5).

Replacement of 'machos' is done on average every 3.7 years. However, 20% of farmers stated to keep their 'machos' in the herd five or more years. Two farmers even stated to keep their 'machos' for 8 and 10 years in the herd, respectively. Replacement data was crosschecked with present age of breeding males in the herd at the time of the survey. Average age of male llamas in the herds was 2.8 years, ranging from one month to 8 years. It has to be noticed, however, that a considerable proportion of male llamas had only recently been selected. In 27% of the households, 'machos' are below the age of 2 years and in 40% of the households even below 2.5

years. The latter is considered to be the first mating age for male llamas. Removing non-productive males from the data, the average age of male llamas in the herds rises to 4 years (Table 5).

Table 5: Selection data for breeding male llamas in Ayopaya[a]

	Average age of 'machos' at selection for breeding	Average productive life of 'machos'	Actual age of 'machos' in the herd at the time of the survey	Actual age of reproductive 'machos' (>2.5 years) in the herd
Mean (SD), years	2.2 (0.7)	3.7 (1.7)	2.8 (1.9)	4.0 (1.6)
Median, years	2	3	3	3
Range, years	0.5 – 4	1 – 10	0.1 – 8	2.5 – 8
Number of respondents	*46*	*45*	*45*	*26*

[a]Source: Authors' questionnaire survey

On the female side, there is only minor selection. Females usually stay in the herd until they die or they are culled because of disease. In seldom cases, they are intentionally culled due to other reasons. Hence, the average productive life for a female or average age at culling is 8.9 years (Table 6).

Table 6: Selection data for female llamas in Ayopaya[a]

	Stated age of females at the time of culling*	Actual age of females in the herd[+]	Actual age of reproductive females (>2.5 years) in the herd[+]
Mean (SD), years	8.9 (2.7)	4.2 (2.6)	5.5 (2.0)
Median, years	9	4	5
Range, years	4.5 - ∞	0.1 – 12	3 – 12
Number of respondents/ herds	*36*	*20*	*20*
Number of animals	-	*591*	*402*

[a]Source: Authors' questionnaires survey, except [+]from herd registers; *for more information on the term "culling" refer to Paragraph *3.4.2*

Stated answers from questionnaires were compared to the actual age of female llamas in 20 registered herds in August 2007. The average age was 4.1 years with a range from one month to 12 years. If only the reproductive females over 2.5 years of age are considered, average age of females in the herds rises to 5.5 years (Table 6).

The reasons mentioned by the farmers for culling females were age, sterility and meat demand for home consumption, in this order. Reasons for no selection on the female side were the retention of the herd size and lack of knowledge regarding appropriate female selection criteria (Table 7).

Table 7: Reasons for culling / no culling of females[a]

Main reasons for culling/ disposal of females	*Percentage of total respondents (%)*	Reasons for not selecting on the female side	*Percentage of total respondents (%)*
age	63	securing herd size / only few mares available	47
sterility	31		
meat consumption	25	no knowledge on selection criteria for females	35
Number of respondents	*32*		*17*

[a]Source: Authors' questionnaires survey

3.4.3 Selection criteria of male and female llamas

From 47 questionnaire respondents, a total of 48 and 33 selection criteria were noted verbatim for male and female llamas, respectively. A considerable number of expressions were consistent among farmers and hence recurrent.

Most important traits mentioned for male llamas were testicle conformation (18.5%), fibre (18.5%), body conformation (17.5%), fleece colour (17.1%), healthiness (13.3%) and height at withers (10.0%) (Table 8).

Table 8: Stated selection criteria for llama breeding males

		Preferred trait groups*					
Rank	Trait	No. times mentioned[#]	%	Rank	Trait	Ratio-scaled evaluation[##]	%
1.	Testicle conformation	39	18.5	1.	Body conformation	29.66	23.0
	Fibre	39	18.5	2.	Fibre	24.05	18.6
2.	Body conformation	37	17.5	3.	Testicle conformation	23.36	18.1
3.	Fleece colour	36	17.1	4.	Fleece colour	18.68	14.5
4.	Healthiness	28	13.3	5.	Height at withers	14.70	11.4
5.	Height at withers	21	10.0	6.	Healthiness	12.13	9.4
6.	Ears	6	2.8	7.	Ears	3.30	2.6
7.	Weight	2	0.9	8.	Character	1.67	1.3
	Character	2	0.9	9.	Fertility	1.00	0.8
8.	Fertility	1	0.5	10.	Weight	0.45	0.3
	Total	*211*	*100.0*		*Total*	*129.00*	*100.0*

*verbatim noted selection criteria from questionnaires were assigned to trait groups, i.e. big testicles and testicles of equal size were assigned to trait group 'testicle conformation', fibre quantity and fibre quality to trait group 'fibre', straight back, straight neck and straight legs to trait group 'body conformation', for details see Paragraph *3.3*; [#]multiple answers were possible; [##]relative weighting on a ratio-scale from 0 to 1, for details see Paragraph *2*

The main criteria contributing to the trait group 'testicle conformation' mentioned verbatim were big testicles and testicles of equal size. The trait group 'fibre' is made up of fibre quantity and quality in almost equal shares. The trait group 'body conformation' refers to different physical parts of the animal, but was principally stated as "buena parada", which targets a "square appearance" of the animal with a

straight back, straight legs and a straight neck. For the trait group 'fleece colour' in a few cases specific colours were preferred. The majority of farmers, however, prioritise a single coloured animal. The trait 'healthiness' exclusively relates to animals without congenital defects. The trait 'ears' could on the one hand be added to 'healthiness', as short, 'gopher' ears are often seen as a defect. On the other hand, the ears are a mere appearance trait. Although ears do not affect the function of the animal, farmers appreciate long and upright ears rather than 'gopher' (very small) ears. The criteria 'weight', 'character' and 'fertility' were only mentioned by five farmers and are hence not of high importance.

The ratio-scaled evaluation slightly changed the ranking order of traits, showing a higher importance of the 'body conformation' in contrast to the 'fibre' and 'testicle conformation', as well as a higher importance of the 'height at withers' in contrast to the 'healthiness' of the animals (Table 8, right hand side). Furthermore, there is a clearer differentiation of ranking positions, as two traits no longer take the same values.

Selection criteria mentioned for females were generally not different from male selection criteria (Table 9). However, 28% of interviewed farmers did not mention selection criteria for females due to the following reasons: a) there is no selection; all females are utilized irrespective of good or bad characteristics (6 respondents), b) selection criteria for females are the same as for males (5 respondents) and c) good or bad characteristics for females or adequate selection criteria are unknown (2 respondents).

Table 9 reveals that, in contrast to male selection criteria, 'strength' and 'type' were additionally mentioned as characteristics for females. The trait groups 'weight' and 'fertility' are of higher importance for females than for males (Table 8 and 9). The ranking order was changed to a lesser extent by the ratio-scaled evaluation. The trait group 'body conformation' is considered to be most important in females, as could already be seen for male selection traits.

Table 9: Stated selection criteria for llama females

		Preferred trait groups*					
Rank	Trait	No. times mentioned[#]	%	Rank	Trait	Ratio-scaled evaluation[##]	%
1.	Fibre	27	23.9	1.	Body conformation	18.27	24.4
2.	Body conformation	25	22.1	2.	Fibre	16.42	21.9
3.	Fleece colour	18	15.9	3.	Fleece colour	13.58	18.1
4.	Height at withers	15	13.3	4.	Height at withers	11.72	15.6
5.	Healthiness	12	10.6	5.	Healthiness	5.44	7.3
6.	Weight	5	4.4	6.	Weight	3.42	4.6
	Fertility	5	4.4	7.	Fertility	2.92	3.9
7.	Character	2	1.8	8.	Character	1.33	1.8
	Ears	2	1.8	9.	Ears	1.15	1.5
8.	Strength	1	0.9	10.	Strength	0.50	0.7
	Type	1	0.9	11.	Type	0.25	0.3
	Total	*113*	*100.0*		*Total*	*75.00*	*100.0*

*verbatim noted selection criteria from questionnaires were assigned to trait groups, i.e. fibre quantity and fibre quality were assigned to trait group 'fibre', straight back, straight neck and straight legs to trait group 'body conformation', for details see Paragraph *3.3*; [#]multiple answers were possible; [##]relative weighting on a ratio-scale from 0 to 1, for details see Paragraph *2*

3.5 Discussion

The farming system in Ayopaya region comprises three dominant species that contribute to rural economies and farmers' strategy to cope with uncertainty. Mixed herds of camelids and sheep in the Bolivian highlands are common and have been

reported in many cases (Caro, 1992; Iñiguez et al., 1997; Tichit and Genin, 1997; Camino and Sumar, 2000; Nürnberg, 2005).

Considering the number of animals as a reference base, sheep is the predominant species in the investigated Ayopayan households (Paragraph *3.4.1*). These findings are also reported by Nürnberg (2005) for 6 communities in the Ayopaya region. Sheep – though also among the species introduced to the region only about 500 years ago – have obviously become an increasingly important part of Andean livestock systems (Caro, 1992) and are prevalently seen to play complementary roles in mixed herds with camelids in the use of available resources and in the products they supply. Tichit and Genin (1997) found a strong correlation between the sheep-camelid ratio and the dominant plant community as well as the size of the landholdings. Mixed herd structures were dominated by llamas only in either extensive areas of low quality forage (*pajonales*) or very high altitudes above 4000m, characterized by steep slopes. Other landscape categories were dominated by sheep or represented a balanced herd structure. Landholdings of communities in Ayopaya region are found at elevations between 3800m and 4300m a.s.l. with a dominant vegetation of coarse bunchgrasses (Nürnberg, 2005). Average llama herd size of Ayopayan families reported in this study are similar to average herd size of llamas presented by FIDA et al. (1999), Delgado (2003), and Nürnberg (2005), who investigated the same study area in former years, with 46, 52 and 50 llamas per producer, respectively (Table 4). The figures thus indicate no changes over these years.

Alpacas were introduced to Ayopaya region in the 1980s and further distributed as well as heavily promoted in the 1990s, principally by two organisations. Ever since, there is a high tendency in Ayopaya towards a mixed herd composition of three species, including alpacas. However, mixed herds of alpacas and llamas can give rise to the procreation of the undesired hybrid between them (*huarizo*), contributing to the deterioration of the genetic pool. Alpaca numbers apparently have increased since 1999, when FIDA et al. (1999) declared a population size of 741 head in the province of Ayopaya, as opposed to 1269 alpacas reported by only 47 farmers in this study, although some questioning about the accuracy of the census remains.

The dominant herd management mentioned by 72% of farmers in this study, separating the castrates from the remaining herd, was also observed and described by

Nürnberg (2005). The author also stated that castrates are not tolerated by 'machos' in the breeding herd, which might be one reason that 28% of farmers in the present study not actively separating males from castrates. Farmers in the remote Wallat'ani community in the Choro district, region Ayopaya, stated that llama males from different family herds do not mix (Nürnberg, 2005) and hence interbreed. This cannot be confirmed by the present study, where the majority of respondents (77%) concede a substantial mixing of breeding males from different herds. A possible explanation for this different conception could be the fact that only 5 families live in Wallat'ani community and therefore land resources are not so much under pressure. Random interchange of llama males counteracts inbreeding, but hinders breeding organisation, selection and the collection of pedigree information.

The wide range of selection times of breeding males indicates that farmers do not adhere rigidly to selection measures, but flexibly respond to particular situations. As described by Nürnberg (2005), a male's mating capacity is observed during the mating season. In case of a poor mating behaviour or other inadequacies, the breeding male is replaced. This could be one explanation for the late selection time (4 year old animals) stated by two farmers in this survey. In some cases old and young breeding males are kept in simultaneously in the herd, which accounts for the early selection age of 0.5 to 1 year of age, stated by 5 farmers. The prevalent selection time, however, remains at around 2 years (Table 5).

Average productive life of breeding males is 3.7 years, also showing a wide range of one to 10 years. Nürnberg (2005) assessed a higher productive life span for breeding males with an average of 5.5 years and a maximum of 15 years in the same region. The maximum value, however, is at least questionable. Novoa (1986) gives a female productive life span of 10 to 12 years. Nuevo-Freire (1994; cited in Graziotti et al., 2001) reports a productive life of 8 to 10 years. However, it is not specified whether this figure relates to male or female llamas. Maximum age of breeding males stated by farmers in this study was 8 years, which already gives cause for concern about inbreeding. As selection or culling of females is not a common practice in Ayopayan farming systems, females are kept longer for reproduction as males. However, a longer utilization of females does not generally predicate a longer productive capacity.

Selection criteria for llama males were precisely defined amongst farmers. Most frequently mentioned criteria are related to the fibre quantity and quality, the fleece colour, the animals' conformation, well developed testicles, the height at withers and health aspects in terms of genetic abnormalities. These findings are affirmed by Nürnberg (2005), who identified fibre characteristics, conformation and mating capacity with 97.6%, 81.3% and 72.1%, respectively, to be the most important selection criteria. Health aspects associated with selection criteria primarily refer to congenital defects and are of average importance to farmers in the present study (Tables 8 and 9). Besides congenital defects the often fatal disease symptom diarrhoea in young and even adult llamas, and frequent ecto- and endoparasites are of relevance (Alandia, 2003; Nürnberg, 2005).

A variety of other studies has focussed on methodologies to identify selection criteria and preference traits for livestock kept by smallholders. A number of established rural appraisal methods exist to generate and provide results. Ranking and rating techniques are applied to produce quantifiable data of preferences for different animal species and breeds and their traits (Bebe et al., 2003; Drucker and Anderson, 2004; Ouma et al., 2004; Ndumu et al., 2006; Wurzinger et al., 2006). However, the techniques have shortcomings. Ranking scales are able to measure many characteristics of one item, but ranking positions have to be interpreted in relation to each other and do not indicate the magnitude of preference (Russell and Gray, 1994). Rating systems are susceptible to the problems faced by rating scale constructs and non-differentiators, leading to a low variance between rated items and a lower validity of rating data (Krosnick and Alwin, 1988). Further results to assess the relative importance of items and the trade-off between them rely on more advanced stated preference approaches, like conjoint analysis or choice experiments (Nielsen and Amer, 2007; Ouma et al., 2007; Roessler et al., 2008).

In the present study, the open question format to collect selection criteria was chosen in order not to influence the respondents by providing ready-made answers. Verbatim noted selection criteria were categorized to trait groups and ranked according to the number of times mentioned. An additional ratio-scaled evaluation was applied to integrate the order, in which the criteria were mentioned. The assumption that criteria mentioned first are of relatively higher importance than subsequently mentioned

criteria is often used as an indicating tool in social sciences. Easier to verify, however, is a lower response time for familiar stimuli (Buchner and Jansen-Osmann, 2006). A similar phenomenon is also known to influence consumer behaviour that is believed to be related to the cognitive effort the consumer makes in eliciting the attribute. Fazio (1986) states that the smaller the cognitive effort, the greater the influence on consumer behaviour, i.e. 'top of mind' attributes are the most important as regards consumer choice.

The ratio-scaled evaluation slightly changed the ranking order of selection traits for llamas and resulted in a better differentiation of trait groups (Tables 8 and 9). Even though a further analysis by a linear model is not feasible, because of missing values in the data set (not all respondents mentioned the same number of selection criteria), the methodology applied gives a reasonable alternative to a common rating survey.

3.6 Conclusions

This study describes traditional llama husbandry and breeding management in the Ayopaya region and documents precisely defined selection criteria for male and female animals by local livestock keepers. The traditional selection criteria generally related to the phenotype of the animals, but also included the commercially interesting fibre trait. The presented method for a relative evaluation of selection criteria is a reasonable alternative to a follow-up rating exercise and still includes more information than pure ranking results. The presented results should be considered and applied in participatory planning of community-based breeding and management programmes for a sustainable use of this genetically and socio-economically valuable llama population.

3.7 Acknowledgements

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4 Estimation of farmers' preferences for llama traits: A stated choice experiment

4.1 Abstract

Highland farming in Bolivia is characterized by subsistence-oriented systems. Livestock often form a crucial part of these systems, but its importance is generally underestimated because of the numerous non-market values of animal functions and attributes. This paper presents the first WTP estimates for llama breeding males based on preferences amongst Andean highland farmers in Bolivia, employing a mixed logit (MXL) model. The results indicate high preference heterogeneity amongst respondents. Highly-valued llamas are of rather high stature, with fine fibre and a single-coloured fleece, and are free of deficiencies or abnormalities in body and testicle conformation. Important fibre quality traits for the processing industry are already considered in the selection decision of smallholder farmers in the region alongside with functional traits. The significant heterogeneity within the respondent population should be further investigated and taken into account in the decision-making process of breeding goal definition. Despite the theoretical solid base for a more efficient utilization of the valuable fibre resource, the potential for high-quality fibre production remains unexploited due to several factors described in the paper.

Keywords: Bolivia; Choice experiment; Llamas; Mixed logit model; Selection traits; Smallholders

4.2 Introduction

Low-input livestock production systems in developing countries are characterized by a series of factors that have to be considered in the formalization of breeding objectives for animals, such as deficiencies in formal markets, poor farm production and economic data, various intangible values of animal traits, socio-cultural features of livestock keepers and heterogeneous preferences, just to mention a few (Anderson, 2003; Nielsen and Amer, 2007). The majority of the farming systems in the high Andes are mixed crop-livestock systems. Livestock production plays an important role in the sustainability of these systems and is less susceptible to environmental risks than crops. Animals convert feed resources that are not suitable for human consumption into protein, energy, wool and hides for the family household. They also provide draught power for cropping and transport, manure as fertilizer and fuel, and represent a capital asset of small farmers (León-Verlarde, 2000; Nürnberg, 2005). The

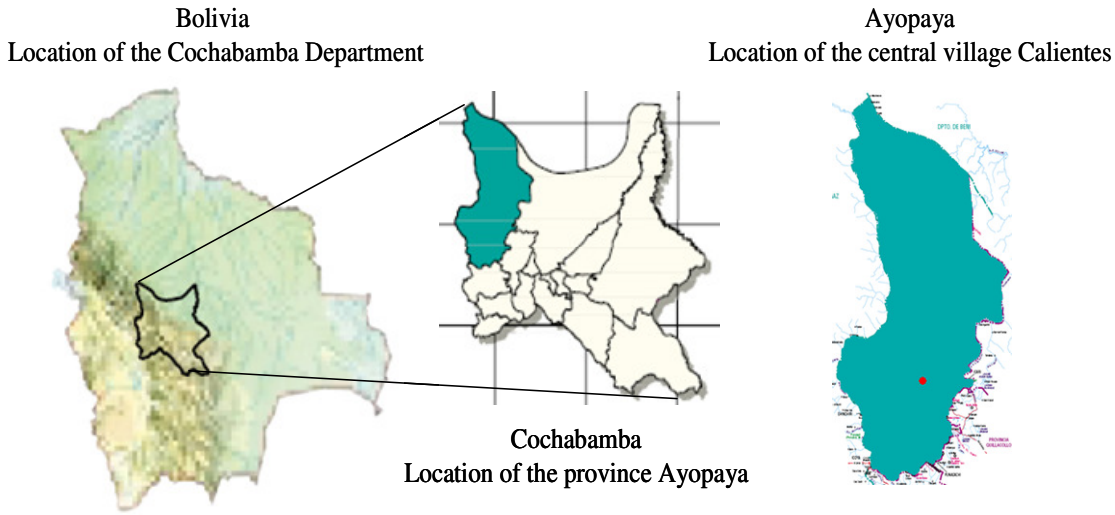
largest proportion of products derived from llamas is for self-consumption and only surpluses are sold in local markets (Nürnberg, 2005). Thus, keeping livestock for rural people is mainly for non-income purposes and the fulfilment of household needs precedes profit maximization. Therefore, consumer-based preference methods were suggested to assess the numerous non-market values of animal functions that are not captured in the market place. The range of available analytical techniques to capture market, non-market and potential breed attributes has been reviewed by Drucker et al. (2001). Most of them have been adopted from other areas of economics, such as marketing, health and transportation economics. The most frequently used method to reveal estimates for the values of environmental goods is the contingent valuation method (CVM). However, more recently, choice experiments (CE) have been used as an advantageous alternative and complement to CVM in the valuation of environmental goods (Boxall et al., 1996; Adamowicz et al., 1998; Carlsson and Martinsson, 2001). In the context of conservation and evaluation of animal genetic resources, CE were recently applied to value tangible and intangible selection criteria of various livestock breeds: e.g. the Ankole cattle in Uganda (Ouma et al., 2007), pigs in North-West Vietnam (Roessler et al., 2008), and cattle breeds in East Africa (Zander and Drucker, 2008). The early development of the selection index approach by Hazel (1943), later modified by Henderson (1963), simultaneously improved multiple-trait components of performance by combining estimated breeding values and the economic importance of the component traits. The derivation of economic weights generally relied on profit equations or bio-economic models that were based on long-term price observations and the current market economy. In contrast, the derivation of economic weights from results of CE or other stated preference techniques are also valuable in the planning and design of breeding programs that incorporate non-market or intangible values, which are not or only partly transferred via the market (Nielsen et al., 2006; Nielsen and Amer, 2007). Von Rohr et al. (1999) applied a CVM to derive economic weights for meat quality traits in pigs. Olesen et al. (2006) used CE to derive economic weights for traits related to animal welfare and Nielsen and Amer (2007) derived economic weights for parameters obtained by a simulated partial profile CE.

This study builds on comprehensive results on functions and selection criteria of a llama population in the northern Ayopaya region of Bolivia (Markemann and Valle

Zárate, 2009; Markemann et al., 2009). The objective was to evaluate traits of llama breeding males by a choice experiment, as a prerequisite for defining breeding objectives in community-based breeding programs.

4.3 The study site and significance of llamas

The study was conducted in the Ayopaya region, the north-western province in the Cochabamba department, Bolivia (Figure 1).



Source: Machaca Benito, G.C., 2005.

Figure 1: Map of the study area

The highland communities are located at altitudes between 3400 and 4300 m above sea level. For further details, see Markemann et al. (2009). Farmers in this remote highland province live on communal lands and are of mixed Quechua-Aymará background. They rely on mixed farming systems for subsistence purposes with a strong livestock component of two, sometimes three species (llamas, sheep and alpacas). Since pasture land is the only fodder resource, ruminant species dominate. Llamas do not only constitute an important financial backbone for the peasant families due to the variety of products they deliver, but they also serve as pack animals and fulfil social, cultural and capital functions and hence contribute substantially to production diversity and receive high appreciation within the farming system (Camino and Sumar, 2000; Nürnberg, 2005). All animal products are mainly utilized within the households. Fresh meat, 'charque' (dried salted meat), live animals, sheep wool and fibre from llamas are either commercially marketed or still traditionally traded, however, in low and varying quantities and qualities. The

marketing quantity and frequency of products depends on the current economic household situation and is adjusted to urgent needs of cash flow and income from the potato harvest, the latter constituting the main source of revenue in the study region (Nürnberg, 2005). The livelihood strategies adopted by smallholder farmers in Ayopaya are diversification of production activities, mobility in terms of temporary migration, action flexibility, social networking and preservation technologies. However, internal and external changes affecting the high Andes mountain system require permanent adaptation strategies. The most serious change observed in recent years, and still on-going, is an extension of crop land towards an intensified seed potato production at the expense of grazing land. In interaction with a strong reduction of transhumance, the introduction of alpacas and an increasing human population density, forage shortages in the dry season are seen to be the major constraint in the development of camelid husbandry (Rojas, 1995; Nürnberg, 2005). The greater the competition between animals and plants for resources becomes, the greater possible threats will be emerging to llama husbandry. Livestock research and development projects often focus on short-term financial and technical support that is seldom sustainable. Animal breeding is a vital component of livestock production that demands long-term commitment and planning, but accumulates genetic gains over generations. Further, systematic breeding schemes for indigenous breeds also contribute to conserve animal genetic resources and breed diversity (Jaitner et al., 2001) by utilization. A secured utilization and maintenance of llamas in the High Andes of Bolivia therewith contributes to the preservation of the fragile local ecosystem, supports the economy and traditional habits of Andean communities and constitutes an appropriate path to the national economic development.

4.4 Methodology

4.4.1 Econometric specifications

Choice modelling practice conventionally applies random utility models derived from consumer theory developed by Lancaster (1966); preferences for goods are obtained by the different characteristics and attributes, not by the goods themselves. This implies that the overall utility of a good can be decomposed into separate utilities for its constituent attributes. For the specific case of llamas, preferences are analyzed in terms of the utility famers perceive from different llama traits by choosing an

alternative *A* with the highest utility *U* from a finite set of *j* alternatives in choice set *k*. This can be specified as

$$U_{nA} = V_{nA} + \varepsilon_{nA} \quad \text{(Eq. 1)}$$

where utility *U* for individual *n* is represented by a deterministic component V_{nA} of the attributes of alternatives and a stochastic component ε_{nA} of a set of unknown parameters.

The probability of an individual *n* choosing alternative *A* from a choice set *k* can be formally expressed as

$$P(A) = Prob\ \{V_{nA} + \varepsilon_{nA} \geq V_{nj} + \varepsilon_{nj}\}$$

$$\forall \quad A, j \in k, A \neq j, \quad \text{(Eq. 2)}$$

The traditional method analyzing choices uses the multinomial logit (MNL) model (McFadden, 1974) and assumes the error terms ε to be independent and identically distributed following a standard extreme value type I distribution across individuals. In this case, the closed-form expression for the probability *P* of an individual *n* choosing alternative *A* is

$$P_{nA} = \frac{exp\ \beta' x_{nA}}{\sum_j exp\ \beta' x_{nj}} \quad \text{(Eq. 3)}$$

where utility is specified to be linear in parameters with $V_{nj} = \beta' x_{nj}$, x_{nj} is a vector of observed variables relating to alternative *j* and the scale parameter of the error term is normalized to 1 and hence omitted.

The model relies on the restrictive assumption of independently and identically distributed (IID) error terms across alternatives and observations and hence, presumes homogeneity of preferences, which might not be well suited to the realistic taste preferences of individuals.

McFadden and Train (2000) and Train (2003) describe mixed logit (MXL) models as more flexible random utility models to represent heterogeneity, as they allow taste parameters to vary randomly across respondents according to the parametric

distribution. Mixed logit probabilities are the integrals of the standard logit probabilities over all possible values of β, which can be expressed in the form

$$P_{nA} = \int \left(\frac{exp\ \beta' x_{nA}}{\sum_j exp\ \beta' x_{nj}} \right) f(\beta) d\beta. \qquad \text{(Eq. 4)}$$

where $f(\beta)$ is the distribution of parameter estimates specified to be normal, lognormal or triangular in most applications.

4.4.2 Survey design

4.4.2.1 Traits for the CE

The relevant attributes to be included in the CE were derived on the basis of results of an earlier part of this study on important functions and selection traits of llamas (Markemann and Valle Zárate, 2009; Markemann et al., 2009), as well as the results of a PhD study conducted in the same study area on the identification of specific fibre quality traits (Delgado, 2003). The chosen attributes were therefore: (1) fibre diameter; (2) fleece colour; (3) body conformation; (4) height at withers; and (5) testicles. The payment vehicle was specified as the price of an adult llama at local markets. The attributes fleece colour, body conformation, height at withers and testicles were stated among the most important selection criteria by farmers in Ayopaya (Markemann and Valle Zárate, 2009).

The fibre diameter is the most important quality attribute for both, the processing industry and the end consumer. A low diameter constitutes a solid base for a quality-oriented llama fibre production and an industrial transformation into exclusive products (Delgado, 2003). The levels chosen for fibre diameter and height at withers are based on average values derived from llama registers that have been set up within a cooperative research project between the farmers' organization ORPACA (Organización Regional de Productores Agropecuarios de Calientes), researchers from UHOH (University of Hohenheim, Stuttgart, Germany) and UMSS (Universidad Mayor de San Simón, Cochabamba, Bolivia), and the local NGO ASAR (Asociación de Servicios Artesanales y Rurales, Cochabamba, Bolivia).

Table 10: Lama attributes and levels used in the choice experiment

Attribute	Attribute levels			
	Level 1 (High; good)	**Level 2** (Medium; average)	**Level 3** (Low; poor)	**Level 4** (Very low; poor)
Fibre diameter	17 microns	21 microns	25 microns	29 microns ('base')
Fleece colour	Single-coloured			Spotted ('base')
Body conformation	"Squared"; Straight back, neck and legs ('base')	Straight neck and legs, hollow back	Straight neck and back, crooked legs	Straight back and legs, aquiline neck
Height at withers	120 cm	100 cm ('base')	80 cm	
Testicles	Big and even ('base')	Big and unequal	Small and even	
Price	400 Bs	350 Bs	300 Bs	250 Bs

Notes: 'base' represents the omitted level for the respective attribute in the model; Bs = Bolivian Boliviano (1 US Dollar = 8.32 Bs.; exchange rate on April 15, 2006; 1 US Dollar = 7.91 Bs.; exchange rate on August 31, 2007) (OANDA, 2009).

Though a large variability of natural fleece colours of llamas exist, the price relevant quality criteria for an improved production and marketing is uniformity in colour. Therefore, only the two relevant levels, i.e. single-coloured and spotted, were considered. The 'base' levels for body conformation and testicles represent the desired specification of the animal. The other three and two levels for body conformation and testicles, respectively, present in each case a non-desired defect or shortcoming of the trait in contrast to the 'base' level. The attributes and their levels are summarized in Table 10.

4.4.2.2 CE design

The design combines different levels of the given llama attributes into so-called alternatives. Every alternative is different and in this study represents a hypothetical type of llama (they are therefore often referred to as animal profiles). The

combination of two or more alternatives is called a choice set, which is presented to each respondent. Selecting the most preferred alternative from the choice set is how respondents make trade-offs between the presented attributes and their levels. Given the number of attributes and attribute levels used in the CE, the large number of possible different profiles from the full factorial design ($4^3*3^2*2^1$) is practically not feasible. Therefore, a fractional factorial design (based on a D-efficiency criterion – see e.g. Scarpa and Rose [2008] for detailed statistics) was created using the SAS macro described in Kuhfeld (2003), which aimed at investigating only the main effects, but still guaranteed the identification of all taste parameters during estimation (Kuhfeld, 2003). The procedure yielded 32 profiles of llamas (alternatives), which were blocked into pairs of two, resulting in 8 different choice sets with two alternatives. An opt-out alternative was added in order to prevent respondents from being forced to make a choice, thereby biasing the results (Banzhaf et al., 2001). Furthermore, combinations of body conformation and price attributes levels were restricted, thereby reducing the design's efficiency but increasing its realistic meaning. Restriction was imposed on the combinations of body conformation levels other than the 'base' level (see Table 10) with the two higher price levels (350 and 400 Bs).

Eight choice sets were presented to each of the respondents, who then were required to choose a llama profile that they would prefer to buy from the two profiles presented in each set. If neither of the two were found satisfactory, the respondents were allowed to choose the opt-out (or "zero") option, thereby stating that they preferred neither of the two.

Following Scarpa et al. (2003a, b), Omondi (2008a, b) Roessler et al. (2008) and Zander and Drucker (2008), drawings were made to visually describe the different levels of the attributes (Figure 2). Pictorial presentations help the respondents, particularly those with low literacy levels, to process the information, thereby facilitating the interpretation and choice of the profile (Green and Srinivasan 1978). Moreover, the use of the indigenous language Quechua on the cards, apart from Spanish, further facilitated the selection process and increased the level of understanding for the experimental task, especially for women, who do not fluently speak Spanish (Figure 2).

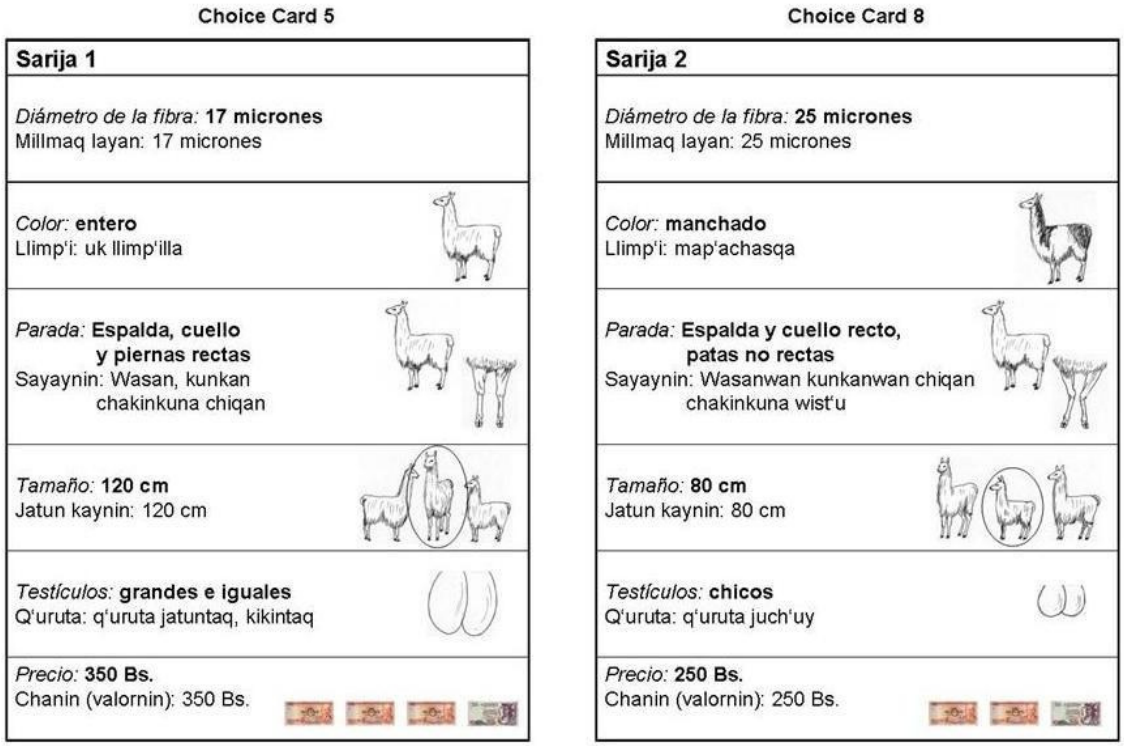


Figure 2: Example cards of the choice set

4.4.2.3 Sampling frame

The choice tasks were conducted in seven communities of the Ayopaya region in two fieldwork phases: March to May 2006 and July to October 2007, respectively. One of the communities (Calientes) is situated in a central area, while six communities are remote, three of which were assigned to the categories remote and very remote, respectively. The remote communities are inaccessible to different extents, i.e. the very remote communities are located farther from the central community and are not accessible by off-road vehicles. In total, 159 randomly selected farmers were interviewed. A few of the respondents (31) were met twice during the two fieldwork phases and thereby completed the full choice set consisting of 32 cards instead of the half set (16 cards). The majority of farmers opted-out for at least one of the presented eight choice pairs, i.e. preferred not to choose a profile. The 159 respondents with their various amount of choices resulted in 1520 observations.

4.4.3 Analysis

The MXL was analyzed with LIMDEP 8.0 NLOGIT 3.0 (Greene 2002) using 500 Halton draws. All attributes are specified to be random in order to capture unobserved preference variation in the population. The random coefficients are assumed to follow a normal distribution, except for the price, which is assumed to be log-normally distributed. The lognormal distribution constrains the price coefficient to be negative and hence, guarantees a normally behaved utility function.

Since the MXL model accounts for unobserved preference heterogeneity, it was intended to improve the model by using demographic information to partly capture the source of the heterogeneity. Therefore, the variables "community provenance", "gender", "age of the farmer", "ORPACA membership" and "herd size" were included as interaction terms in the initial MXL model. The number of years of formal education of the interviewed farmers was not consistently surveyed. As its inclusion led to non-convergence of the model, this interaction variable was skipped from the model.

Table 11: Descriptive Statistics of the Sample

Variable	Definition	No. of respondents*/ households	Sample mean (St.Dev.)	
Continuous variables				
Age	Years of age of farmer	159	37.7	(12.3)
Education	No. of years of formal education	87	3.5	(2.7)
Herd size	No. of llamas owned by farm household	159	34.3	(26.3)
Dummy variables				
ORPACA	ORPACA member=1, otherwise=0	91	0.62	(0.49)
Central	Farmer from central community=1, otherwise=0	29	0.19	(0.39)
Remote	Farmer from remote community=1, otherwise=0	89	0.57	(0.50)
Very remote	Farmer from very remote community=1, otherwise=0	41	0.24	(0.43)
Male	Male=1, female=0	104	0.69	(0.46)

*Total number of respondents = 159; number of respondents for dummy variables refers to dummy=1.

All other variables were dummy (0/1) coded and interacted with the llama attributes, except for "age" and "herd size" that entered the model as continuous variables (Table 11).

Extensive testing of the various interactions, revealed the best model fit for a model with a total of 26 interactions.

Welfare measures were calculated for statistically significant attributes based on the coefficients of the MXL model without interactions. As the price coefficient has a log-normal distribution, the mean, median and variance of the coefficient are given by *exp(m+s/2)*, *exp(m)* and *exp(2m+s [exp(s)-1]*, respectively, where *m* and *s* represent the mean and variance of the log of the coefficient. For the randomly distributed coefficients of the MXL model, the willingness to pay (WTP) values have to be approximated by simulated draws from the log-normally distributed price coefficient and the normally distributed random attribute parameters. The WTP values are obtained following the approach outlined in Thiene and Scarpa (2009), i.e. from both of the estimated distributions 10^4 replications are drawn and combined in pairs so that for each replicate r the values of $WTP_r = \alpha_r / \beta_r$ are computed, where α is the coefficient of the attribute and β the negative of the price coefficient, by using the statistical software package R.[2]

4.5 Results

4.5.1 Results of mixed logit (MXL) model

Maximum likelihood estimates of the MXL model are shown in Table 12. The coefficients of all attributes show the expected signs and all random coefficients are statistically significant, except for the attribute '80 cm height at withers'. The estimated standard deviations of the random parameters indicate significant taste heterogeneity for the attributes 'fleece colour', '120 cm height at withers', 'big and unequal testicles', 'small and even testicles', 'price' (all significant at the 1% level), 'straight neck and back, crooked legs' (significant at the 5% level) and '21 µm fibre diameter' (significant at the 10% level). Insignificant estimates for derived standard deviations suggest that all information in the distribution is captured within the mean

[2] http://www.r-project.org

(Hensher et al., 2005), as is for example the case for the highly significant mean coefficients of '17 µm fibre diameter' or '25 µm fibre diameter'. The model results reveal a preference for llamas of rather high stature, with fine fibre and a single-coloured fleece that are free of deficiencies in body and testicle conformation.

Table 12: Estimation Results from Mixed Logit (MXL) Model[a]

Variable	Mean Coefficient (s.e.)		St.Dev. Random Coefficient (s.e.)	
17 µm fibre diameter	0.539***	(0.093)	0.182	(0.119)
21 µm fibre diameter	0.190*	(0.104)	0.242*	(0.134)
25 µm fibre diameter	0.405***	(0.090)	0.186	(0.130)
Single-coloured fleece	0.377***	(0.090)	0.439***	(0.088)
Straight neck and legs, hollow back	-0.287***	(0.072)	0.160	(0.133)
Straight neck and back, crooked legs	-0.668***	(0.094)	0.342**	(0.115)
Straight legs and back, aquiline neck	-0.314***	(0.095)	0.112	(0.226)
80 cm height at withers	-0.125	(0.084)	0.165	(0.184)
120 cm height at withers	0.183**	(0.072)	0.270***	(0.094)
Big and unequal testicles	-0.908***	(0.099)	0.495***	(0.099)
Small and even testicles	-0.690***	(0.086)	0.389***	(0.089)
N_Price[b]	-6.381***	(0.381)	1.013***	(0.329)
Log-likelihood function	-1408.545			
Pseudo-R^2	0.156			
Adjusted Pseudo-R^2	0.149			
No. of observations	1520			

Notes: s.e. = standard error; st.dev. = standard deviation; ***1% significance level, **5% significance level, *10% significance level; [a]Simulation based on 500 Halton draws; [b]Variable name 'N_Price' reflects the opposite of the original price variable.

The magnitude of the parameter estimates shows that small and particularly unequal testicles are strongly disliked. Crooked legs also have a high negative coefficient and are much less acceptable than the other deficiencies of the body conformation, i.e. a hollow back or an aquiline neck, respectively. Relative to an animal with 29 µm fibre diameter ('base' level), llamas with 17 µm and 25 µm fibre diameter are preferred, in that order. The coefficient for the attribute '21 µm fibre diameter', however, is rather small and only significant at the 10% level. Further, it is the only fibre attribute that suggests the existence of heterogeneity over the sampled population and thus, does not fit into the sequence of gradually increasing preference with increasing fibre

quality. A llama with a single-coloured fleece is preferred over a spotted one, expressed by a positive coefficient. The positive coefficient for the attribute '120 cm height at withers' – expressing the preference for bigger animals – is rather small in comparison to the other coefficient estimates, but statistically significant at the 5% level.

4.5.2 Results of the MXL model with interactions

Compared to the MXL without interactions, an increase of the log-likelihood function by 58.98 units is obtained, leading to an improvement in model fit with a pseudo R^2 of 0.193. Results of the MXL with interactions are shown in Table 13, reporting only significant interactions. The coefficients for the attributes '21 µm fibre diameter' and '120 cm height at withers' are no longer significant. Significant interactions were found for the attributes 'fleece colour', 'testicles' and the price. Herd size has a positive effect on 'fleece colour', 'big and unequal testicles' and the price attribute. This suggests that farmers with higher number of llamas rather disregard the testicle conformation in contrast to their preference for a single-coloured fleece. Further, they seem to be less sensitive to the price. The age of the farmers has likewise a positive effect on selecting animals with 'big and unequal testicles', but not on the price. Older individuals seem to pay less attention to the testicle conformation, but have sensitivity for the price value of the animal. The latter can also be observed for farmers from both, the central and the very remote communities. Insensitivity towards unequal or small testicles can be further observed for male farmers and farmers from the central community. The latter observation, however, cannot be generalized, as the respondents group from the central community was rather small. The positive effect of male respondents on 'big and unequal testicles' remains peculiar.

The estimated standard deviations of coefficients are still highly significant for the attributes 'fleece colour', '120 cm height at withers', 'big and unequal testicles', 'small and even testicles' and the 'price', indicating that farmers' preferences vary considerably more than can be explained by the observed and included characteristics.

Table 13: Results from Mixed (MXL) Logit Model with interactions[a]

Variable	Mean Coefficient (s.e.)		St.Dev. Random Coefficient (s.e.)	
Attributes in utility function				
17 µm fibre diameter	0.694***	(0.199)	0.140	(0.205)
21 µm fibre diameter	0.188	(0.131)	0.110	(0.312)
25 µm fibre diameter	0.477***	(0.100)	0.049	(0.403)
Single-coloured fleece	0.455**	(0.220)	0.464***	(0.131)
Straight neck and legs, hollow back	-0.213**	(0.099)	0.194	(0.220)
Straight neck and back, crooked legs	-1.100***	(0.403)	0.289	(0.192)
Straight legs and back, aquiline neck	-0.262*	(0.140)	0.048	(0.485)
80 cm height at withers	-0.151	(0.114)	0.090	(0.303)
120 cm height at withers	0.160	(0.241)	0.310***	(0.119)
Big and unequal testicles	-2.263***	(0.380)	0.466***	(0.133)
Small and even testicles	-0.914***	(0.183)	0.408***	(0.115)
N_Price[b]	-5.112***	(0.259)	0.569***	(0.152)
Interaction terms[c]				
Single-coloured fleece *X* herd size	0.006*	(0.004)		
Big and unequal testicles *X* central	0.796***	(0.260)		
Big and unequal testicles *X* herd size	0.007*	(0.004)		
Big and unequal testicles *X* male	0.497**	(0.215)		
Big and unequal testicles *X* age	0.018**	(0.008)		
Small and even testicles *X* central	0.426**	(0.205)		
Price *X* very remote	-0.28E-02*	(0.15-E02)		
Price *X* central	-0.14E-02*	(0.80E-03)		
Price *X* herd size	0.17E-04*	(0.10E-04)		
Price *X* age	-0.12E-03***	(0.32E-04)		
Log-likelihood function	-1349.570			
Pseudo-R^2	0.193			
Adjusted Pseudo-R^2	0.178			
No. of observations	1520			

Notes: s.e. = standard error; st.dev. = standard deviation; ***1% significance level, **5% significance level, *10% significance level; [a]Simulation based on 500 Halton draws; [b]Variable name 'N_Price' reflects the opposite of the original price variable, [c]only significant interactions reported.

4.5.3 Welfare measures

In Table 14, simulated WTP values for the .25, .5 and .75 quantiles are reported. Here, it is preferred to display the median so as to avoid to present extreme and potentially unreasonable mean values, often resulting from the distribution of ratios of random variables.

Table 14: Median WTP/WTA for llama attributes

Attribute[a]	WTP/WTA[b]	
	Median	**(percentile 25,75)**
17 µm fibre diameter***	303.33	(142.11, 628.76)
21 µm fibre diameter*	84.38	(9.28, 248.44)
25 µm fibre diameter***	219.07	(96.37, 475.20)
Single-coloured fleece***	170.16	(26.56, 480.84)
Straight neck and legs; hollow back***	-144.55	(-60.40, -327.05)
Straight neck and back, crooked legs***	-342.02	(-148.18, -758.82)
Straight back and legs, aquiline neck***	-171.66	(-81.14, -356.07)
80 cm height at withers		n.s.
120 cm height at withers**	79.97	(0.28, 247.19)
Big and unequal testicles***	-458.27	(-193.77, -1034.39)
Small and even testicles***	-346.13	(-144.18, -786.08)

[a]significance levels from MXL model, ***1% significance level, **5% significance level, *10% significance level; [b]simulations based on 10^4 replications, WTP/WTA values in Bs = Bolivian Boliviano (1 US Dollar = 8.32 Bs.; exchange rate on April 15, 2006; 1 US Dollar = 7.91 Bs.; exchange rate on August 31, 2007) (OANDA, 2009).

Highest estimate of WTP are observed for very fine fibre animals, followed by an improvement of the fibre fineness from 29 µm to 25 µm, with 300 Bs and 220 Bs, respectively. A llama with a single-coloured fleece is valued at 170 Bs more than a spotted one, and an animal reaching 120 cm height at withers averages 80 Bs more than a moderate height at withers of 100 cm. The 25^{th} and 75^{th} percentiles reflect considerable taste variation in the population, which is especially noticeable for the trait 'fleece colour', suggesting that a considerable amount of people do not prefer single-coloured llamas. The body and testicle conformation traits receive a negative value indicating the negative preference for traits showing some kind of deficiency,

typically denominated willingness to accept (WTA). The estimates show that farmers have a considerable welfare loss for llamas that show abnormalities or deviations from well developed testicles and a well-conformed llama with a "square appearance" (straight back, neck and legs). Highest aversion is expressed towards unequal testicles with a WTA value of 460 Bs, followed by small testicles and crooked legs that almost take the same values with 346 Bs and 342 Bs, respectively. Even though an aquiline neck and a hollow back are still disliked amongst llama keepers in Ayopaya, the welfare loss appears to be considerably lower in comparison to crooked legs, with only the 75th percentile reaching the median WTA value of crooked legs.

4.6 Discussion

The special importance of non-market benefits of livestock in developing countries due to smallholders' multiple objectives has been widely recognized (Drucker et al., 2001; Anderson, 2003; Bebe et al., 2003; Jaitner et al., 2003; Moll, 2005). Numerous authors have used CE in recent years to quantify economic values of animal traits and attributes and many of the studies report a high importance of adaptive traits along with performance traits, e.g. disease resistance and feed requirements together with live weight and litter size (Roessler et al., 2008) (local pigs in Vietnam), fertility, disease resistance and calf vigour together with milk yield (Kassie et al., 2009) (indigenous cattle in Ethiopia), tick tolerance, fertility and watering frequency together with daily milk yield (Zander and Drucker 2008) (local cattle breeds in Kenya). The results of the present study on male llama selection criteria show similar findings with respect to the functional traits included in the choice design. Whether farmers attach high importance to adaptive traits or disease resistance in llamas, as frequently mentioned in other studies, cannot be answered from the present findings and remains open to consideration.

The attributes included in this CE represent a mixture of productive traits (e.g. fibre diameter), reproductive traits (testicles) and a combination of functional and appearance traits (e.g. body conformation and fleece colour). The results show that the selection of male llamas in the Ayopaya region is done on the basis of well-determined and clear-cut phenotypic traits that most likely assure to fulfil the functions and roles that farmers expect from their animals. Most important selection criteria are well-developed testicles, a good body conformation and a fine fibre fleece.

This is indicated by high estimates for both, the WTP for those traits and the WTA compensation to deal with the disliked traits. In comparison to the desired big and even testicles (included as 'base' level in the MXL), uneven testicles receive the highest rejection by farmers as demonstrates the high WTA value. Small and even testicles are also disliked, but to a lesser extent. The testicular conformation relates to the reproductive soundness of the breeding male. Well-developed testicles that are properly balanced indicate adequate reproductive ability, as they are directly correlated to sperm production (Tibary and Vaughan, 2006), as also seen in other species (Brown, 1994). The considerably higher depreciation of big and uneven testicles compared to small and even testicles could be due to the fact that farmers associate uneven testicles with cryptorchidism, a congenital defect that causes retention of one or both testes, or testicular hypoplasia, an underdevelopment of one or both testes. Both reproductive disorders have been reported in South American camelids and are considered to be inherited traits leading to reduction or absence of spermatogenesis (Sumar, 1983; Sumar, 1996; Tibary, 2004).

A good body conformation is most likely associated with a good transport capability of the animals, which has been reported to be of high importance in the region (Markemann et al., 2009). Zander and Drucker (2008) reported high coefficients for traction suitability of bulls, especially in Ethiopia, where livestock keepers are very dependent on animal traction. The results for the different body conformation levels in contrast to the well conformed ("squared") llama underpin the coherency to transport. The conformation deficiencies are perceived worst for crooked legs, followed by an aquiline neck and a hollow back. Straight legs obviously support the transport function far more than a straight neck or a straight back.

A good fibre quality and a uniform colour have been identified as quality requirements of both, the processing industry and the end consumer (Delgado, 2003). Both traits are highly-valued by farmers in Ayopaya. These findings are surprising, as in an earlier part of this study that focused on the roles and functions of llamas, the sale of fibre was considered to be of relatively minor importance (Markemann et al., 2009). However, regarding important selection criteria, the fibre quantity and quality was stated to be of high importance (Markemann and Valle Zárate, 2009), which is also confirmed by another study conducted in the same study region (Nürnberg, 2005).

This apparent contradiction could be explained by three arguments: First, farmers in Ayopaya prefer the Th'ampulli type llamas ("wool-llamas") in contrast to the Kh'ara type (meat-llama), the latter being found in higher numbers in other regions of Bolivia. This is demonstrated by a proportion of 89% of the Th'ampulli type found in llama herds in Ayopaya (Delgado, 2003). Second, a "project influence" could be assumed through the permanent propagation of the fibre marketing potential due to its outstanding quality standard by the local NGO ASAR and researchers of UHOH and UMSS. Third, a cultural heritage and tradition of the ancient Incan civilization have survived and become manifest in the holistic perspective that connects culture and practice, economic and symbolic aspects, which are often not understandable for western researchers. All arguments might be closely interwoven and cannot be separated analytically. The valuation of single-coloured animals over spotted ones can neither be proved nor disproved by other studies. A previous evaluation of selection criteria showed a relatively high importance of the selection trait 'fleece colour'. Delgado (2003) found approximately 78% of llamas with a uniform colour, leaving a relatively high proportion of 22% of spotted llamas. The present study indicates an overall preference for single-coloured animals, but assumes a preference for spotted llamas of some individuals or individual groups.

The fibre quality categories of 25 µm, 21 µm and 17 µm fibre diameter showed an increasing appreciation for better fibre, except for the '21 µm fibre diameter' trait. The estimation results give evidence to suggest that the latter category was either not clearly identified or recognized by respondents, or too narrow categories were selected in the development of the CE design. However, the trait in the MXL model without interactions is only significant at the 10% level and this significance disappears with the introduction of interactions to the model (Tables 12 and 13).

The findings suggest that important fibre traits for the processing industry are already considered and relatively high-valued by smallholder llama-keepers in the Ayopaya region, providing a promising basis for fibre marketing. The necessity of farmers' participation in the planning and development procedures for a sustainable breeding program has been stressed in the relevant literature (e.g. Valle Zárate, 1996; Sölkner et al., 1998; Jaitner et al., 2001). The present study points to significant taste heterogeneity across respondents that could not be sufficiently captured by the

observed characteristics, but should be further identified and incorporated in the decision-making process of breeding goal definition. In addition to productive traits regarding fibre and meat, functional traits supporting the transport capability of the animals cannot be ignored.

4.7 Concluding remarks

This paper employed a MXL to examine preferences for llama breeding males amongst Andean highland farmers in Bolivia. The results of the present study showed that price relevant quality criteria for the textile industry are incorporated alongside traditional criteria in the selection decisions of smallholder farmers in Ayopaya. The outstanding fibre quality of the llama population in the region had been identified and evaluated in a previous study. Furthermore, an analysis of the national Bolivian llama fibre processing sector revealed that the domestic production cannot accommodate the demand for llama fibre by the processing industry and the presently installed capacity for textile production is not efficiently used (Delgado, 2003). The given theoretical solid base for a more efficient utilization of the valuable fibre resource, however, cannot hide the fact that other constraints and shortcomings exist elsewhere than solely on the producer's side. The latter refer to low shearing frequency, low proportion of animals shorn and varying fibre quality due to not sorting and classifying llama fleeces (Valle Zárate et al., 2000; Delgado, 2003), resulting in only 5 tons per year of llama fibre produced in Ayopaya. Moreover, only 33% of the total fibre produced in Bolivia gets to the market, the majority is for household use (Delgado et al., 2000). Thus, despite of the high general importance of llamas in Bolivia and the outstanding fibre quality found in some small populations, fibre production with llamas remains a secondary activity and yields only little income for smallholders in the highlands. Determining the demand for a product and the quality requirements of the market and knowing the potential of a specific genetic resource is a contribution to the improvement of animal production, but the potential remains unexploited, if many factors hinder the marketing possibilities and fail to establish a direct connection between producers' organizations, processors and salespersons. The Bolivian fine fibre marketing system appears to have developed more as an adjunct to the Peruvian one than independently and self-supporting (Westreicher et al., 2007). Although a considerable number of organizations, associations and institutions have

dedicated their efforts towards a commercialization of llama fibre on national and international level (for an overview see Delgado, 2003) the Bolivian textile industry remains non-competitive with Peru, where 80% of the collected camelid fibre from Bolivia, Chile and Argentina is processed (Claros, 2001). It appears that Bolivia still encounters several difficulties, some of which Peru has experienced before, i.e. unwillingness of herders to collaborate, because of the strength and personal character of their ties to local buyers (intermediaries), internal management problems, small and disperse family units that keep the natural genetic resources, antique machinery with low utilization ratio, poor quality management of the raw material and lack of technological knowledge, just to mention a few. However, the worst fact to be mentioned is that none of the benefits since the rediscovery of camelid fibre for the European market have ever reached the producers and livestock keepers in the marginal, but primary productive zones. Hence, the implications and recommendations to be made are evident, but by no means simple. Any development aid or assistance should focus on the establishment and consolidation of marketing chains that directly link producers' organizations with manufacturing companies by contracts that undoubtedly stipulate the quantity and quality to be delivered for an ascertained and guaranteed price. If the mentioned requirements and prerequisites for the marketing of llama fibre are met, an organized community-based breeding program for llamas in the Ayopaya region presents a potential tool to promote both: controlled high-quality production of fibre according to market standards and the conservation and improvement of the valuable genetic resource while considering socio-economic aspects of the underlying production system.

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5 General discussion

The general discussion starts with the discussion on the major findings of the three publications in the general study context (Chapter 5.1 to 5.4). Subsequently the applied methodological approaches are discussed (Chapter 5.5) and general conclusions are drawn and recommendations are given (Chapter 6).

5.1 Overview on South American camelids research

In the middle of the 20th century camelid husbandry and the production of fibre, meat and hides experienced a dynamic impulse, leading to an extension of investigations from the biology of the animals to more production and commercialisation related issues. In this particular time the prime and most detailed study on South American camelids was put on the market, entitled "Auchénidos" (Cardozo, 1954). For more than half a decade – until its recent revised and expanded re-release (Cardozo, 2007) – this book was always read and constituted a special and valuable reference work for students, professors and researchers interested in South American camelids. Numerous other bibliographies have been published on general and specific aspects of the camelid species, especially since the end of the 1970s when a number of actions started in Bolivia and Peru in terms of technical assistance and infrastructure financing by economic co-operation and development programmes. Nevertheless, it cannot be dismissed that other species have been better researched than camelids and many articles are published in local journals or non-conventional sources that are difficult to access. Moreover, greatest interest in camelids does not seem to be in countries with the largest number of animals, where the camelid species provide services to man and nature. These are some of the reasons for the recurring statements in scientific papers on South American camelids that "little is known" and "few scientific papers have been published". In contrast to the bulk of research topics dealing with domestic livestock in general, the issues related to South American camelids have a narrower spectrum and are not so widely spread. Hence, the above mentioned statements are true in some respects. However, the specific research topics, as well as the dissemination process of the various livestock topics, have to be considered before too generalised statements are released.

Regarding the emphasis put on different South American camelids research topics, health and veterinary matters take a prominent place from the 1960s to date. Reproduction and anatomy are also popular, the former often related to health issues, as infertility, early embryonic death and abortion, therewith referring to the reproductive peculiarities of South American camelids compared to other domestic livestock, which is offering challenging research topics (for an overview see Vaughan and Tibary, 2006), the latter because anatomical research can be carried out logistically more easily, on a few animals only and in a laboratory. Nutritional research has apparently been confined to physiological aspects and often appears to have little practical application in the South American camelids' original environment and on their real diet (for a review on nutrition of llamas and alpacas see San Martin and Bryant, 1989).

Research on the improvement of productivity and management has regrettably continued to receive lesser attention. Management issues in high-altitude agro-pastoral systems are obviously interlinked with a number of other factors, i.e. herd structure, grazing area, farm or rangeland size, socio-cultural aspects, and are hence much more complex to investigate than management in the context of modern specialised livestock systems with their often narrow production objective utilising specialised breeds in a standardised environment In the Bolivian and Peruvian highlands mixed herds of camelids and sheep are common. This herd diversification has been a matter of controversial discussion (e.g. see Flores Ochoa, 1988), but can hardly be disentangled from the management applied. Tichit and Genin (1997) tried to identify factors that influence the proportion of different species kept within the herd in the arid Andean highlands (see also Chapter 3.5). The authors conclude that herd composition and the managing activity in agro-pastoral systems in the highlands is primarily related to typology constraints and hence, the availability and access to pastures. Tichit et al. (2004) assessed the effectiveness of controlled and uncontrolled breeding practices in llama herds and high-care and low-care practices in sheep flocks under unpredictable environmental conditions in the Bolivian highlands. With the term „controlled breeding", the authors refer to a certain selection within the female population (for details see Tichit et al., 2004, p.409), whereas the term "uncontrolled breeding" describes the procedure of breeding all adult females each year, which has also been characterised for the predominant llama management in the Ayopaya region

(see Chapter 3.4.2). The study found that numerical productivity at weaning was not significantly higher for controlled breeding herds of llamas and high-care sheep flocks compared to the uncontrolled and low-care ones, respectively. It appeared that the effectiveness of management in securing long-term herd viability as an overall objective under uncertainty is related to family wealth and only richer farmers are in the position to control the breeding rate of their animals. Management likewise affects productivity. However, low off-take and production rates that are frequently stated for camelid production in the Andes are in turn a partial result of the interdependence of the production systems level with the different forms of social organisation, which have permitted the survival of populations in such adverse environments. Tichit (1991) gives a profound reflection of the camelid sector in Bolivia, encompassing the contemporary camelid husbandry in Bolivia, its production limits and potential under the given influence of the multiple exogenous factors.

Other studies on the productivity of camelids exist from various countries and regions. Fibre production is the principal economic trait in alpacas and thus, the majority of studies are dealing with quality characteristics and production yield of alpaca fibre in different countries (for an overview see Delgado, 2003, p. 31). More recent studies included the investigation of variation sources in fibre diameter attributes and sampling techniques in Australian alpacas (Aylan-Parker and McGregor, 2002; McGregor and Butler, 2004), and a description of fibre characteristics of Huacaya alpacas in the US and Peru (Lupton et al., 2006; Montes et al., 2008). Frank et al. (2006) performed both, a phenotypic and genetic description of fibre traits in alpacas and llamas, respectively. Other studies on llama fibre characteristics exist from Martínez et al. (1997) and Iñiguez et al. (1998) for Bolivian llamas and from Coates and Ayerza (2004) and Frank et al. (2006) for Argentinean llamas, respectively. Data on fleece weight for llamas in Bolivia was only determined by very few authors (Rodríguez, 1981; Martínez et al., 1997; Cochi, 1999; Quispe et al., 2001). The much less research conducted on fibre production from llamas might be to the most part due to the fact that fibre is not the main production objective, but llama husbandry is a multi-objective venture for smallholders in the Andes. In addition, this calls for more holistic research investigations of the livestock system, which are again more time and finance-consuming than systems research focussing on the optimisation or maximisation of one or few product outputs. Production of llama meat, yet another

important product derived from the animals, has in contrast gained more attention than fibre production - especially in the course of the EU-funded project SUPREME - and a number of studies evaluated body and carcass characteristics, as well as other important meat production parameters of llamas reared in the Andean highlands (e.g. Cristofanelli et al., 2004; Cristofanelli et al., 2005; Polidori et al., 2007a, b). The SUPREME-project additionally assisted in developing a meat production chain from camelids, apart from its breeding efforts that will be referred to below.

The achievements that have been made in data collection and research results for the specific llama population in the Ayopaya region, as well as the deficits in terms of still lacking information are described in the following Chapter.

5.2 Breeding of South American camelids

The role of animal breeding in the development and improvement of South American camelid production has been dismissed by most development programmes assuming that health and nutritional issues are more critical in achieving production changes (Iñiguez, 1998). In addition, funding and development agencies tend to favour subject areas that are demanding little effort to generate more rapid short-term results. Animal breeding programmes in contrast are long-term in nature and effective results become evident only after a long time. Hence, investments for non-genetic improvements in management easily rival with long-term investments to increase the efficiency of animal production. Nevertheless genetic improvement programmes are justified by cumulative and sustainable effects and in the long run, genetic gains may provide the most secure option for sustainable livestock improvement (Ponzoni, 1992; Nakimbugwe et al., 2002), if such programmes are well planned, executed and sustained.

Breeding programmes have also been proposed as a viable option to promote small ruminant production in the Andean region (Iñiguez, 1998). However, only very few organised breeding schemes have been established in the region. Llamas in particular have not been subject to a genetic improvement programme up to now (Stemmer and Valle Zárate, 2006). Key problems and difficulties are likely to be the same or similar to smallholder production systems in the tropics in general: small animal populations, lack of systematic animal identification, inadequate animal performance and pedigree

recording, low levels of literacy, and organisational shortcomings (Iñiguez, 1998; Jaitner et al., 2001; Wollny et al., 2002). Although a number of programmes utilizing or incorporating indigenous breeds have failed in the past, Kosgey et al. (2006) document an existing and encouraging rate of success of such programmes for small ruminants in the tropics.

For camelids in the Andean region, Iñiguez (1998) reported breeding plans being in the process of consolidation in the region. Most past efforts were apparently achieved in Peru focussing on Alpaca breeding for fibre marketing. Structured breeding plans in Peru selected on fleece yields and the elimination of coloured animals; the latter would later appear to be one reason for a decline in fibre diameter, which was recognised as a drawback by the textile industry (Rainsford, 2005a, b; Montes et al., 2008). Peru designed its programme in 1994 under the auspices of the NGO DESCO (Centro de Estudios y Promoción del Desarrollo), which was planned to evolve into an open-nucleus incorporating 2,500 alpaca producers from different regions of the country. The programme was expanded with the establishment of multipliers in 1996 and the development of a breeding plan in 1998. In addition, the programme received considerable support from the European Union research programmes SUPREME (1997-2000) and DECAMA (2002-2006). In 2005, the Peruvian open nucleus selection plan started its full operation with an estimated population of 200.000 animals of the Caylloma province, Arequipa region. In 2007, DESCO became a member of the International Committee of Animal Recording (ICAR) (Antonini, 2008; Pacheco et al., 2008). Another example is PACOMARCA S.A., an experimental ranch founded in 1992 in the department of Puno, SE Peru, by the INCA group to act as a selection nucleus from which basic genetic improvement of alpaca fibre can spread throughout the rural communities in the Peruvian altiplano. The ranch has developed a specific performance recording software and gathered an impressive number of 3,328 pedigree records since its foundation. Recently published work that was partly funded by PACOMARCA (Gutiérrez et al., 2009; Cervantes et al., 2010) jointly analysed fibre traits and subjectively scored type traits in two breeds of the Peruvian altiplano alpacas. The results recommend carrying out mass selection based on a scoring trait, in areas where no performance recording can be implemented. Further, the current empirical indices constructed by the experimental ranch to increase the textile value of alpacas appear to be inferior to the fibre diameter as the

main selection criterion. Although such long lasting co-operations and their achievements are highly valuable research results for the breeding value evaluation process of camelids in the Andes and the project seeks to extend its advances to the small rural communities (Morante et al., 2009), Peru's alpaca herders remain amongst the poorest members of Peruvian society in some regions until today. Few processing plants dominate the industry and intermediaries capture much of the value in the production chain, which is causing serious problems for the herders in profitably commercialising the fibre from their animals (Montes et al., 2008).

In Bolivia with its dominant native small ruminant - the llama - the efforts fall far short of the Peruvian situation, though the potential for improving llama fibre traits is well recognised. All of the estimated 2,500,000 llamas in Bolivia are kept in marginal highland regions under a traditional production system of small family herders, which exacerbates the difficulties in data recording, management, organisation and coordination of a breeding programme.

Within the long-term collaborative research project between the UHOH (University of Hohenheim, Stuttgart, Germany), the UMSS (Universidad Mayor de San Simón, Cochabamba, Bolivia), the local NGO ASAR (Asociación de Servicios Artesanales y Rurales, Cochabamba, Bolivia) and the farmers' organisation ORPACA (Organisación Regional de Productores Agropecuarios de Calientes) initiated in 1998, it was intended to meet the fundamental prerequisites for genetic improvement strategies and breeding goal definition for lower input production environments, well documented by Hammond and Galal (2000) and Groen (2000).

Nürnberg (2005) presented a detailed description of the predominant production system in the remote, north-western Ayopaya region, department Cochabamba, which is amongst the poorest areas in Bolivia. Contrary to the common popular opinion that llama fibre is coarse and highly medullated, the local llama sub-population in Ayopaya was found to have an outstanding fibre quality, with the lowest fine fibre diameter in Bolivia, a high proportion of fine fibres and a low proportion of kemp in the fleece (Delgado, 2003). In comparison with literature values for llama populations in the Northern and Central Andes (for example see Martinez et al., 1997), the animals from the Ayopaya region feature a great potential for fibre production. In subsequent research periods from November 1998 to August 2007 more than 4,000

animals were registered. Body measurements and live weights were taken from 2,821 and 1,536 llamas, respectively. In addition, more than 2,800 analyses of fleece characteristics were conducted in the wool laboratory at Hohenheim University. Heritabilites and genetic correlations were estimated for body weight, height at withers, chest circumference, body length, abdomen circumference, mean fibre diameter, diameter of fine fibres, proportion of fine fibres and proportion of kemps (Wurzinger et al., 2005; Wurzinger et al., 2006a). The heritability estimates provide a good supplement to heritability estimates from other countries (for an overview see Delgado, 2003) and form a solid basis towards the design of a breeding programme. Data on fleece weight is still scarce. Fernández (2005; also see Fernández et al., 2005) calculated phenotypic correlations between fibre quality and fibre quantity traits that did not indicate an antagonism between the two. However, these results should be confirmed by estimating genetic correlations.

Wurzinger et al. (2008) simulated a simple breeding programme for the llama population in Ayopaya with the computer programme *ZPLAN* (Willam et al., 2008). The fastest genetic progress in terms of genetic gain was achieved with the utilization of a central mating station, where all females are mated. However, fleece weight and fibre diameter were the only selection criteria considered and economic weights were not available. Considering the findings in Chapter 2 the preliminary breeding goal should be reconsidered. This issue will be addressed more in detail in the following chapter.

5.3 Multiple functions of llamas and trait selection

Apart from the factors constraining the success of breeding strategies in smallholder production systems mentioned in the previous chapter (5.2), the livestock resources required by poor farmers in harsh environments and highly diverse and complex traditional systems have widely been denominated as multi-purpose (Rege, 1999; Anderson, 2003; van't Hooft and Wanyama, 2005; Hoffmann, 2008). In contrast to farmers in the "developed" world that often operate commercial enterprises under the premise of profit maximisation, smallholders tend to keep animals primarily for family needs on a subsistence basis. Hence, products directly derived from livestock in these systems are unlikely to be important on their own (Kosgey et al., 2004), but additional intangible roles (e.g., savings, insurance, cultural, ceremonial, and prestige)

need to be fulfilled by the animals. The broad perspectives smallholder farmers in developing countries take to sustain their livelihoods foreshadow the importance of livestock keepers' preferences concerning the traits that are assumingly embedded in the functions the animals are expected to perform (Peters, 1988; Ayalew et al., 2003a, b). The importance of traditional or local knowledge of indigenous livestock breeding communities has been widely recognised (Valle Zárate, 1996; Jabbar et al., 1999; Jarvis et al., 2000). Traditional livestock keepers have acted as custodians of pure breeds and have developed farm animals over many generations with unique traits that are most suitable for livestock production under unfavourable conditions (Köhler-Rollefson and Wanyama, 2003). Nevertheless, research on the preferences of livestock keepers for certain breeds or breed traits often do not document the selection criteria *per se*, but carry out a comparative analysis of local and exotic breeds (e.g. Bebe et al., 2003; Mwacharo and Drucker, 2005; Lemke et al., 2006). However, few studies exist that focus on the documentation and/or evaluation of selection criteria within one breed (Perezgrovas et al., 1992; Jaitner et al., 2003; Wurzinger et al., 2006b, c; Ndumu et al., 2008). Apart from the strategic constraints mentioned in the previous Chapter, livestock studies in harsh environments encounter by the additional complications in adequately measuring and valuing the several outputs of economic value derived from the animals or their relative importance to the farmer (Roeleveld, 1996). To exemplify the difficulty, the socio-economic capital function of livestock is referred to as a non-market or 'intangible' function that has been described, assessed and analysed by numerous studies in different countries and different species, mostly however, for cattle in Africa. The capital function is related to the absence or ill-functioning of markets for finance and insurance in developing countries, especially in rural and marginal areas (von Pischke et al., 1983) and is thus highly significant in communities, where no other means for banking and finance exist. However, the term "capital" may differ substantially, depending on country, region, socio-cultural background, access to financial institutions and other factors. It has been related to financing, insurance and risk aversion (Upton, 1985; Bosman et al., 1997; Jaitner et al., 2001), use as a gift or 'bride price' (Grandin et al., 1991; Stroebel et al., 2008), sign or symbol of wealth or status (Moll, 2005; Mwacharo and Drucker, 2005), savings or a form of 'currency' (Ouma et al., 2003; Siegmund-Schultze et al., 2007), stock value as 'banking function', among others.

The multi-facetted roles of the animals as a basic component of livelihood strategy have also severe implications for the formulation of a breeding goal under such conditions. The decisive step in the design of breeding programmes is seen in the definition of a comprehensive breeding objective incorporating the specific, immediate, and long-term social and economic circumstances of the target group as well as the ecological conditions (Sölkner et al., 1998; Kosgey et al., 2006). Too narrow and simplistic breeding objectives have been a major cause for the failure of most projects (Sölkner et al., 1998; Kosgey et al., 2006; Roessler et al., 2008).

Studies taking into account the multiple functions and roles llamas fulfil in Andean highland farming systems are rare. Even if the contribution of llamas to the economic and social life of their herders has been acknowledged and described by a number of authors (Sumar, 1988; Flores Ochoa and McQuarrie, 1995; Camino and Sumar, 2000; Nürnberg, 2005), little is known on the relative importance of the functions to the farmer. The results in Chapter 2.4 have shown that the primary purpose of keeping llamas is not product-oriented, but capital and transport are the most important functions of llamas for farmers in Ayopaya. Though it is beyond the scope of the present work to specify or more precisely quantify the benefits in financing or wealth storage derived from llama herd sizes, the capital function is most likely entangled with the transport function: the latter demands a high number of llamas to better fulfil the transport requirements within the production system, which automatically provides a higher status within the community. Although the transport function of llamas that was already adjudicated with a decreasing importance (Caro, 1992; Iñiguez and Alem, 1996), the llama as a "beast of burden" continues to receive high appreciation of farmers in Ayopaya. As mentioned before, also in this case the importance appears to be dependent on the region and hence, the evaluation of functions *per se* can be considered as purposeful as a complement to the likewise evaluation of specific animal traits.

Information on important selection criteria for llamas from the livestock keepers' perspective was documented by Nürnberg (2005). The criteria fibre characteristics, body conformation, mating capacity and health were found to be the most decisive selection criteria of llama breeding males. As the results in Chapter 3.4 show, these study findings can be largely confirmed. The precise definition and description for specific selection criteria amongst farmers in the present study helped to document a

detailed picture of the local selection practice and farmers perceptions. In total 48 and 33 selection criteria were verbatim noted for male and female llamas, respectively. Returning to the assumption that preferences for traits are embedded in the functions the animals need to perform (p. 82), the results of the section criteria evaluation (Chapter 3.4) partly match the results of the relative importance of functions (Chapter 2.4). The high importance of the transport capability of llamas is well reflected in the ranking order of selection criteria by the trait group 'body conformation'. The actual body size in terms of the trait 'height at withers' seems to be secondary in this respect, although still ranked as relatively important, which may be related to the fact that this trait is not regarded a "factor in minimum". The maintenance of a sufficient herd size is on the one hand pursued by little or no selection on the female side and hence maximising offspring per herd in the long run. On the other hand, the high-rated criteria 'testicle conformation' of llama breeding males promotes the potential reproductive capacity in the herd. Surprisingly 'fibre' and 'fleece colour' are amongst the top-five selection criteria, which wasn't expected on basis of the results of the preference ranking of llama functions. However, 97% of interviewed farmers in the study of Nürnberg (2005) also stated fibre characteristics as important selection criteria, with 20% hereunder specifically defining a single-coloured animal. As the sale of fibre is currently of minor importance for Ayopayan farmers and the domestic use of fibre does not seem to give sufficient reason for such a high valuation of the selection criteria in question, other reasons seem to be responsible for these findings, which cannot be identified by this study. Some assumptive explanations, however, were given in Chapter 4.6.

5.4 Economic valuation of animal genetic resources

The ranking and rating approaches shed some light on the relative importance farmers attach to selection traits or roles and functions of the animals. However, they can neither provide insight in the trade-offs farmers are willing to make between desirable characteristics, nor give information on the economic value of a certain breed (or species) and their specific characteristics. Moreover, a wealth of benefits, services and goods worldwide underlie the market failure problem and their values are not captured within the narrow economic focus on production and consumption issues and hence standard economic analysis. This leads to the successional problem in

making reasonable resource allocation decisions, as resources are usually scarce and not available in excess. This issue applies to environmental resources, plant and animal genetic resources and specifically also to the discipline of animal breeding.

Many benefits derived from the existence of well adapted local or indigenous breeds are not transacted in any market, simply because they are "intangible" or because of the absence or ill-functioning of markets for specific goods and services. This has led to reviews on valuation methods (for example see Drucker et al., 2001; Roosen et al., 2005) from different disciplines that are possibly able to provide estimates of the values that can be placed on non-marketable attributes.

After the pioneering work of Sy et al. (1997), many researchers have analysed economic values of animal traits by conjoint ranking and ordered probit models. A growing range of tools, models and methodologies available has contributed since then to a considerable growing pool of animal genetic resources valuation. An overview of different methods applied to varying species in different countries is given in Table 15.

A choice experiment study for llama attributes has not been performed hitherto. The present results on the functions and main traditional selection criteria of llamas in the Bolivian highlands have shown that llamas perform multiple functions in the livelihood system and the majority of these functions are not attributable to direct production output of one or few physical products. Quite to the contrary, a number of functions are of importance, which are not directly related to a specific product delivery and a number of traditional selection criteria refer to non-income traits (Chapter 2.4 and 3.4, respectively). Traditional economic analyses on livestock and genetic improvement programmes that are often focusing on production traits, with little emphasis on the non-income traits would disregard the real situation and most probably result in a low adoption rate of such programmes or even in their failure. The findings presented in Chapter 4 recommend the inclusion of non-income functional traits in addition to productive traits regarding fibre and meat in the development and implementation stages of a breeding programme for llamas. Though Scarpa et al. (2003a) give evidence that stated preference (SP) based estimates can be of the same magnitude as revealed preference (RP) information, the disadvantages of SP data has been pointed out and the combination and joint estimation of SP and RP

data is an important and promising methodological option, whenever market information is partly available (Whitehead et al., 2008).

As can be seen in Table 15, more recent studies employed MXL or latent class (LCM) models to derive economic values of animal traits. The MXL is able to identify preference heterogeneity, but it is not so well suited to explain the sources of heterogeneity (Boxall and Adamowicz, 2002). From a theoretical point of view, LCM is a special category of MXL, where the population consists of a finite number of groups of individuals (segments), whereas the mixing distribution of the MXL is continuous. Although Greene and Hensher (2003) generally conclude that no specific recommendation can be given regarding the superiority of either approach, they find stronger statistical support for the LCM. Boxall and Adamowicz (2002) support the latent segment approach, as the results allow a much richer interpretation of the data than the single segment (MXL) model, which is confirmed by Scarpa (2003a), who compared a two-segment LCM with distinct household preferences for pig breeds and a standard MNL with interactions. The studies listed in Table 15 employ either MXL or LCM, except for Ouma et al. (2007), who estimated both, a MXL revealing the existence of preference heterogeneity for cow and bull traits around the sample population, and a LCM with three segments identifying the differences being predominantly associated with the underlying production system of the livestock farmers.

The results in Chapter 4.5 have shown that the inclusion of interactions could not sufficiently explain the existing heterogeneity of the population for llama trait preferences. However, the authors calculated LCM with two, three and four segments as well, but no clear explanatory variables for class membership could be found. In addition, model fit of the LCM was reduced and thus, results from the MXL were reported.

When deriving WTP estimates from mixed logit models, one has to consider the fact that the distribution of WTP in the form of the ratio WTP = α/β does not have a closed form and must be approximated by simulation, though a number of studies seem to ignore this fact.

Table 15: Overview AnGR evaluation publications

Method/ valuation methodology	Type of AnGR	Country	Most important functions and/ or traits identified	Reference*
No. times mentioned/ frequency counting				
	pigs	SE Mexico	Evaluation of non-income functions including *convertible asset to make payments/ purchases, savings and consumption*	S. Anderson / Ecological Economics 45 (2003) 331-339
	cattle	The Gambia, West Africa	Frequencies of important traits for a good breeding bull for *growth, pedigree, milk yield of dam, health and reproduction*	J. Jaitner et al. / Tropical Animal Health and Production 35 (2003) 179-187
Rating/ Ranking				
	cattle	Uganda, Africa	Phenotypic ranking of bulls and cows considering size and beauty traits like *rump length, body weight and colour pattern* and production and fitness traits like *milk yield, fertility and disease resistance*	D.B. Ndumu et al. / Livestock Science 113 (2008) 234-242
	cattle	Burundi, Rwanda, Tanzania and Uganda, Africa	Ranking of reasons for keeping cattle including *milk, meat, hardiness, disease resistance, walkability, beauty, ghee production, tradition, insurance and wealth* and average ranks for importance of selection criteria considering *coat colour, horn, size, muscularity, milk yield, fertility, longevity, disease resistance, temperament and pedigree*	M. Wurzinger et al. / Tropical Animal Health and Production 38 (2006b) 571-581

Table 15: (Cont.)

Method/ valuation methodology	Type of AnGR	Country	Most important functions and/ or traits identified	Reference*
Rating/ Ranking				
	cattle	SE Kenya, Africa	Weighted average of rankings for *cattle diseases, veterinary services, reasons for keeping indigenous cattle and principal selection traits*	J.M. Mwacharo and A.G. Drucker / Tropical Animal Health and Production 37 (2005) 635-652
	pigs	SE Mexico	Matrix ranking of purposes of backyard pig keeping including *savings, insurance and buffering, sales, breeding and consumption*	A.G. Drucker and S. Anderson / International Journal of Agricultural Economics 2 (2004) 77-97
	cattle	Kenya, Africa	Preference rankings and follow-up ratings of reasons for cattle keeping such as *production of milk for family consumption, attractive looks, prestige, traction use and collateral for loans* and attributes of breeds including *milk yield, hardiness, traction ability, feeding behaviour, disease resistance, fertility and butterfat yield*	B.O. Bebe et al. / Livestock Production Science 82 (2003) 117-127
	cattle	The Gambia, West Africa	Matrix rating of relevant breeding traits including *size, milk yield, calving frequency, adaptation to dry season stress, utility for traction and disease resistance*	M. Steglich and K.J. Peters / 7th WCGALP (2002) Montpellier, France, Communication N° 25-04

Table 15: (Cont.)

Method/ valuation methodology	Type of AnGR	Country	Most important functions and/ or traits identified	Reference*
Rating/ Ranking				
	cattle	SW Nigeria, Africa	Matrix rating of cattle breeds based on *milk yield, disease resistance, size, ease of handling, marketability, market value, grazing behaviour and need for mobility for grazing*	M.A. Jabbar et al. / Journal of Sustainable Agriculture 12 (1998) 21-47
Contingent valuation method (CVM)				
	cattle	East Africa (Ethiopia and Kenya)	Willingness to accept (WTA) compensation for conserving traditional Borana cattle based on a safe minimum herd size	K.K. Zander et al. / Journal of Arid Environments 73 (2009) 550-556
	cattle	Kenya, East Africa	Willingness to pay (WTP) of cattle keeping hh for non-market benefits influenced by factors *cattle type, feeding system, animal breed, hh dependency ratio, sex of hh head and distance to milk collection centre*	Ouma et al. / 25th International Conference of Agricultural Economists (2003) Durban, South Africa, 328-334
Conjoint analysis				
	cattle	Manitoba, Canada	Preferences of cattle producers for the attributes *calving ease, fertility, milking ability, weaning weight, feed efficiency, carcass yield, muscling, slaughter weight and temperament*	H.A. Sy et al. / American Journal of Agricultural Economics 79 (1997) 463-476

Table 15: (Cont.)

Method/ valuation methodology	Type of AnGR	Country	Most important functions and/ or traits identified	Reference*
Conjoint analysis	cattle	Burkina Faso, West Africa	Farmer's breed preferences for bulls and cows based on *feeding ease, weight gain, disease resistance, reproductive performance, size, milk yield, temperament, fitness to traction and fertility*	K. Tano et al. / Ecological Economics 45 (2003) 393-407
Basic multinomial logit model (MNL)	cattle	East Africa (Ethiopia and Kenya)	Preferences of local livestock keepers for *body size, tick tolerance, watering frequency, horn shape/ size, traction suitability, milk quantity and fertility*	K.K. Zander and A.G. Drucker / Ecological Economics 68 (2008) 34-45
	pigs	NW Vietnam	Adaptive and productive traits for female weaner piglets including *liveweight, frequency of illness, feed, body conformation and litter size*	R. Roessler et al. / Ecological Economics 66 (2008) 184-192

Table 15: (Cont.)

Method/ valuation methodology	Type of AnGR	Country	Most important functions and/ or traits identified	Reference*
Latent class models (LCM), Mixed logit model (MXL), Random parameter logit model (RPL)				
	cattle	Ethiopia, Africa	Estimation of preferred cow traits by a RPL model including *origin, body size, fertility, milk yield, calf vigour and illness*	G.T. Kassie et al. / Journal of Agricultural Economics 60 (2009) 386-401
	pigs	Sweden	Evaluation of attributes related to animal welfare using a RPL model with *transport, castration, housing system, feed, mixing of pigs, stock size and breeding straw*	C. Liljenstolpe / Agribusiness 24 (2008) 67-84
	goats	Kenya, Africa	Evaluation of non-market traits by MXL model including *disease resistance, drought tolerance, milk production, body size, body conformation and fertility*	I. Omondi et al. / Tropical Animal Health and Production 40 (2008b) 583-596
	sheep	Kenya, Africa	Evaluation of non-market traits by MXL model including *disease resistance, drought tolerance and fat deposition*	I. Omondi et al. / Tropical Animal Health and Production 40 (2008a) 615-626

Table 15: (Cont.)

Method/ valuation methodology	Type of AnGR	Country	Most important functions and/ or traits identified	Reference*
Latent class models (LCM), Mixed logit model (MXL), Random parameter logit model (RPL)				
	cattle	Kenya, Africa	Estimation of cattle traits by LCM models including *breed of animal, sex, body condition, weight and purpose of buying animal*	E. Ruto et al. / Agricultural Economics 38 (2008) 89-98
	cattle	East Africa (Kenya and Ethiopia)	Derivation of economic values for cattle traits with MXL and LCM models considering *trypanosomiasis, traction potential, fertility, milk yield, live weight, coat colour and watering frequency*	E. Ouma et al. / American Journal of Agricultural Economics 89 (2007) 1005-1019
	creole pigs	Yucatan, Mexico	Modelling of non-market traits by means of LCM models with *food conversion performance, heat tolerance, foraging capability and disease resistance*	R. Scarpa et al. / Ecological Economics 45 (2003a) 427-443

Table 15: (Cont.)

Method/ valuation methodology	Type of AnGR	Country	Most important functions and/ or traits identified	Reference*
Combined revealed (hedonic analysis) and stated-preference (MNL and MXL) approach				
	cattle	Kenya, East Africa	Information collected regarding purchased and/or negotiated cattle on *sex, age group, reason for purchasing, body condition, estimated weight and breed*	R. Scarpa et al. / Ecological Economics 45 (2003b) 409-426

*for detailed references refer to "Complete reference list".

The direct derivation of WTP from distributions of coefficients in the utility functions, often show an extreme and highly skewed WTP distribution, i.e. absolute values of the mean WTP being considerably larger than those of the median, as evidenced also in Chapter 4.5. This is particularly the case for WTP ratios, where the denominator is log-normally distributed and thus, close to zero. The attempts to deal with this issue have been numerous, involving the use of bounded distributions or assuming a non-random price coefficient. The latter currently prevails in the published literature, despite the low conceptual plausibility (this issue is discussed more in detail in Scarpa et al., 2008).

It has been frequently stated in the literature that measures of willingness to pay from stated preference techniques can be used to derive economic weights in breeding objectives. Though on the one hand surveys to elicit people's preferences or WTP for non-market goods have enormously increased, literature on the methodological approach to derive economic weights in breeding objectives remains scarce. The major difficulty appears to be in the difference between estimated coefficients that serve to derive monetary values in terms of WTP, and relative economic weights used in selection indices expressed per unit trait change or better, per standard deviation of the trait. Olesen et al. (2000) indeed discuss the implementation of non-market as well as market economic trait values in the aggregate genotype to allow for breeding programmes that contribute to sustainable production systems. The examples given for salmon, cattle and pigs, however, are based on simplified assumptions in order to show the major influences on selection responses from the inclusion of ethical priority values and do not refer to stated preference techniques. A further discussion is given in Olesen et al. (2006), suggesting that a non-market good, such as animal welfare, has to be paid for by consumers by e.g. taxes, a monetary value that corresponds more closely to the WTP estimate obtained from stated preference surveys than the relative economic value in selection index procedure. Nielsen and Amer (2007) aimed at showing how choice experiments can be used to derive economic weights in breeding objectives. However, the study rather examines an approximate optimal design for a corresponding choice experiment under the hypothesis that estimated economic weights should reflect the true preferences of respondents. Though the authors suggest that the vector of estimated regression coefficients from the logit model can be used to estimate the relative economic weights, these are set as true preferences of

respondents before simulating the profiles. In contrast to the approach suggested by Nielsen and Amer (2007), Roessler et al. (2009) defined the economic weight for the trait 'number of piglets born alive' by directly multiplying the WTP estimate with the additive genetic standard deviation of the trait.

Hence, there is scope for further research on the issue of deriving economic weights from choice experiments. Particular attention should be paid to examples that show how to integrate results from stated preference techniques in breeding objectives and selection indices. The WTP estimates for llamas in Chapter 4.5 are the first presented for this species. They may provide a basis for further research on the development of appropriate breeding goals for llamas in the high Andes of Bolivia.

5.5 Potentials and limitations of the methodological approach

The selection of the target area for the present study was based on prior comprehensive research work conducted in the same region and communities in the frame of a long-term collaborative project described in Chapter 1.2. All communities past or present are homestead to members of the farmers' organisation ORPACA and are connected to the central community of Calientes, where reunions are taking place and from where frequent travels to the city and market place are undertaken. Farmers for the different research parts were interviewed according to availability and willingness to participate in the study, also including non-ORPACA members, in order not to reduce the possible survey sample and because of membership fluctuations. Not all communities have been included in every investigation step. The choice experiments, however, were applied in all communities, as these requested the highest number of observations for analysis. For the ranking approach it was intended to survey an equal number of male and female farmers, which was not fully accomplished due to language constraints (see Chapter 2.3.2). The questionnaires containing the considered selection traits were conducted in the three communities Cajas-Calientes, Milluni and Putucuni with the lowest sample of 47 selected households.

The results of the surveys are site-specific and relate to the predominant production and management system in the Ayopaya region, which is different from other regions in Bolivia mainly due to the potato production activities intensively and successfully

promoted in the region. This distinctive feature might be reflected in the importance of the utilisation of llamas in the region in terms of transport to and from cultivated areas. However, the selection procedures applied by Ayopayan farmers and the relative importance of traits and functions can be relevant and valuable for other llama populations in other regions of Bolivia. Regarding the possible major production traits of llamas, i.e. meat and fibre, it appears that the type of llama predominantly kept in the herds is the more decisive factor than the particular region. Farmers in Ayopaya prefer the Th'ampulli type llamas ("wool-llamas") in contrast to the Kh'ara type ("meat-llamas"), the latter being found in higher numbers in other regions of Bolivia, which might have an influence on the predominant production output, at least in terms of fibre. Therefore, the herd composition has to be considered when defining production objectives. The WTP estimates provide a basis for breeding goal derivation and the inclusion of non-monetary traits or fibre traits, where adequate market prices are lacking. It has to be noted, however, that estimates might vary over the specific models applied. Hence, there is need to conduct extended research with specific segments of farmers that are accounting for the heterogeneity found in the respective study.

The step-wise, mixed methods approach presented in this study was able to partly describe the complexity and multi-functionality of llamas in marginal highland farming systems in Bolivia. The different approaches in Chapters 2, 3 and 4 allowed yielding more insights in the relative importance of the functions the animals fulfil for their herders and the predominant selection criteria considered for breeding animals. The presented results are in their combination not contradictory, but aid one another and provide for the main part a more comprehensive understanding of the analysed phenomena. The absence of profound contradictions also promotes the individual findings of the specific study components, as well as the explicit integration of llamas in the production system and their pattern of utilisation.

Results on farmers' rankings in Chapter 2.4 have shown that the sale of live animals or the product fibre was not perceived as highly important. A detailed discussion on the ranking results is given in Chapter 2.5; however, the evaluation of traditional selection criteria suggested a ratio-scaled evaluation to reveal more information than pure ranking results. The ratio-scaled evaluation is comparable to an 'external' rating

exercise, i.e. the rating is not directly performed by the individual respondents, but by the researcher as a follow-up to the ranking based on psychological stimuli described by Buchner and Jansen-Osmann (2006).

Rankings and ratings are frequently used in many research areas and there is no consensus as to the preferred method. Some shortcomings of the techniques are already discussed in Chapter 3.5. In general, the methodological advantage of the ranking technique is argued to be its higher reliability and validity, because respondents don't have to make statements on the strength or intensity of their preference. Further, the ranking method structurally resembles a purchase decision, in which one alternative is placed on top (i.e. chosen or bought) of the other options. In ratings – presenting the most important metric procedure to evaluate preferences – on the other hand respondents tend towards less discriminating decisions, as the structural forced-choice situation of rankings is lacking. The extreme case presents a person rating all available options identically (see e.g. Alwin and Krosnick, 1985; Krosnick and Alwin, 1988; Russel and Gray, 1994). Harzing et al. (2009) conducted a methodological comparison of the two commonly used response formats, ranking and rating, in terms of their ability to address response style differences and language bias in cross-national research. They used ranking in a *"more structured way"* and asked respondents to only rank their top 3 solutions out of a set of possible solutions, since they suggest that a high number of different options leads to unreliable results. Whether such findings from cross-cultural or cross-national research are generally valid across different research fields and thus also in the agricultural context, cannot be answered at this point. However, the results on the ranking of ten important llama functions revealed that functions ranked from 3rd to 9th position have similar rank means with high variance, which might be due to the fact that respondents had difficulties in handling a rather large number of options. Nevertheless, by multiple comparisons, differing significant statements have been found for functions having the same means, but different standard errors. Finally, the methodological comparison of Harzing et al. (2009) reports that ranking generally is a superior solution to traditional 5-point and 7-point Likert scale ratings. Van Herk and van de Helden (2007) recommend a combined rating-ranking approach to determine the preferences of all options in a set, including those assumed to be of minor importance.

For breeding goal definition, i.e. listing several traits of interest or importance and giving each trait a 'value' (economic values or economic weights) denoting the contribution of its improvement to the realisation of the development objective (Groen, 2000), the ratios among the economic weights are more important than their actual values. Hence, when defining a breeding goal, ranking and rating results might already provide the necessary information for a relative weighting of goal values. The breeding goal, however, is not the final criterion or tool used in selection. The decision on which males and females will become parents of the next generation is made upon the 'selection index'. The selection index approach to simultaneous improvement of multiple-trait components of performance relies on the calculation of the expected independent monetary return from a unit of change in each trait. Therefore the relative economic importance was defined as the net increase in profit unit of change in one trait (Hazel, 1943). The estimation of marginal profit is usually based on profit equations (see e.g. Brascamp et al., 1985) and implies unambiguously that 'economic weights' in selection index theory can hardly be separated from a tangible monetary unit. The latter cannot be obtained from ranking or rating approaches. Further, profit from non-monetary values as risk management, social capital, draught and transport usage, or aesthetic value cannot be calculated via market or price observation.

Economists have developed a wide range of tools for the valuation of goods and services that are not captured directly by market systems, including revealed preference methods (RP) and stated preference methods (SP). The contingent valuation method (CVM) is the most widely used SP method for non-market valuation (see Carson et al., 1995; Carson, 1998). However, there has been some criticism from environmentalists and economists on the method (e.g. Vatn and Bromley, 1994: Bromley, 1995) and other types of stated preference techniques evolved at the same time in both, marketing and transport economics (Louviere, 1994; Polak and Jones, 1997). Conjoint analysis and CEs have been widely applied in the animal genetic resources context, the latter being more recently dominated by MXL and LCM models (see Table 15).

MXL relax the limiting assumptions associated with standard logit models by allowing the parameters to vary randomly according to the specified distribution of

the coefficients. They are hence considered to be more flexible and powerful (McFadden and Train, 2000; Train, 2003). Strictly speaking, LCM are a special category of MXL, presenting a finite number of preference groups (segments) in contrast to the continuous distribution of parameter estimates in MXL. Though both models account for preference heterogeneity across individuals, they differently capture variations of taste parameters (Greene and Hensher, 2003). There is no consensus as to which model is to be preferred. While Shen (2009) found that LCM performs better than MXL using two datasets on transport mode choices in Osaka, Japan, Greene and Hensher (2003) state that none of the two approaches can be unambiguously preferred to the other, but each approach has its own merits.

In most MXL applications, the parametric distribution of the price parameter has been specified to be normal or lognormal. A lognormal distribution of the price, forces the mean coefficient to be negative, which is considered to be useful when the coefficient is known to have the same sign for every respondent (Train, 2003). Regarding the application of CEs remote regions of low-income or developing countries, this specification offers a considerable advantage that has been seldom discussed in the literature. Omondi et al. (2008b) found a positive and significant price coefficient for bucks, evaluating important goat criteria in the semi-arid Marsabit district of Kenya. The authors suggest that bucks are a special type of inferior good for which quantity demanded rises when price rises. Kassie et al. (2009) on the other hand report a negative, but insignificant price coefficient from a MXL estimating the relative importance of preferred traits of indigenous cows in Ethiopia. They point to the considerable drawback of the statistical insignificant price variable from which no implicit prices can be quantified. More examples of difficulties in obtaining a significant and negative price coefficient might be present in the literature or on the contrary not reported. The most reasonable explanation – underpinned by personal experience – is again mentioned by Omondi et al (2008b). They assume that producers in rural poor communities "*view expensive animals as better than cheaper ones*". The consequence of preferring higher priced animals is opposed to the neoclassical model of consumer choice, where the individual tries to maximise his or her utility with limited resources, i.e. budget, and leads to a positive price coefficient. Hence, the CE approach can be applied, but not brought to a favourable issue. Forcing the price variable to be negative by a lognormal distribution can hence overcome the

aforementioned difficulties, but does not abolish the fact that other communities and cultures than the more consumption-oriented society of major industrial countries might have different perception and attitude towards general means of payment, which is revealing the limitations of the CE method, at least in some cases.

6 General conclusions

The methodological approach of this study partly described the complexity and multi-functionality of llamas in marginal highland farming systems in Bolivia and yielded more insights in the relative importance of the animal functions the animals fulfil for their herders and the predominant selection criteria considered.

It is concluded that the llama population of the Ayopaya region is closely integrated into a mixed crop-livestock farming system, thereby fulfilling system-relevant and traditionally important functions in terms of transport and wealth accumulation. The evaluation of functions revealed a gender-related importance of the dung utilisation and the domestic use of fibre. Therefore a gender-specific analysis should be taken into account in livestock development policies, especially for cultures that show the presence of a gender-specific labour organisation.

The high importance of the transport capability of llamas in the region was shown to be well reflected by the relevant selection criteria considered in the selection decisions of farmers. The traditionally important criteria generally relate to the phenotype of the animal and that a suitable breeding animal is in good physical condition and has a good body conformation, apart from its size, sturdiness and a good fibre quality. The breeding management of farmers in Ayopaya showed a flexible response to particular situations rather than following a rigid regime. In contrast to the precisely defined selection criteria amongst farmers, the selection times of breeding males and their average productive life span showed a considerable variation, giving cause for concern about inbreeding. Inbreeding may also be further enhanced by the random interchange of different family herds.

The estimated marginal monetary values for the selection criteria confirmed the ranking and ratio-evaluation results. The highest values were attached to well-developed testicles, a good body conformation and a fine fibre fleece and at the same time highest aversion is expressed towards unequal testicles, followed by small testicles and crooked legs. The model results, however, indicated considerable taste heterogeneity across farmers that should be further investigated.

Though the evaluation of roles and functions of llamas in the Ayopaya region resulted in a relatively minor importance of selling fibre, the selection decisions appear to be highly influenced by fibre quality. The already existent incorporation of fibre traits in selection decisions provides a solid base for a more efficient use of the valuable fibre resource. Shortcomings and constraints on the producer level, the institutional level and the policy level hamper the marketing possibilities and fail to establish a sound marketing channel that allows an equal share of benefits to all participating actors. A structured and organised breeding programme for llamas in the Ayopaya region can only be considered as purposeful and sustainable, if producer's organisations and manufacturing companies consolidate their activities towards a stipulated quantity and quality product. Organised breeding taking into account the commercially interesting fibre trait and traditionally important functional traits, is able to promote high-quality fibre production according to market standards and the conservation of the valuable animal genetic resource.

7 Summary

Bolivia accounts for more than 60% of the llama population worldwide and more than 50,000 smallholder families in marginal areas are dedicated to llama husbandry as part of their livelihood strategy. To this day, llamas substantially contribute to the economic and social life of smallholder Andean communities, providing food and fibre, fuel and transport, and fulfil other cultural, social and capital functions. Although this multi-purpose contribution has been widely recognised, llamas have not yet been subject to systematic breeding activities in the Andean region. For the establishment of sound and sustainable breeding programmes, it is crucial to identify the contribution of the numerous non-market traits and functions of llamas to the breeding objective. A long term collaboration project aims at the detailed description and evaluation of the farming system in the remote north-western province of Ayopaya under the given prevailing environmental conditions. Perspectives for fibre production from llamas and its potential for development have been identified. A phenotypic and genetic characterisation of growth and fibre traits of the llama population was performed and alternative designs for a breeding programme were modelled and compared. The present study aimed at evaluating the important functions, roles and traditional selection criteria of llamas, intending to contribute to the aggregation of formerly missing information for the formalisation of an appropriate breeding objective.

Data collection was carried out in seven highland communities of the north-western Ayopaya province in the Cochabamba department, Bolivia. The study combines a step-wise, mixed methods approach. Semi-structured household interviews were conducted in 47 households in three communities. Questionnaires contained information on llama herd structure and management, animal selection and selection criteria. In addition, information from llama registers and previous research results were included for comparison and crosschecking. Average herd size of llamas and selection data is displayed by general descriptive statistics. Verbatim noted selection criteria were evaluated by a relative weighting on a ratio-scale. A ranking approach with ten functions of llama keeping presented by illustrations was performed with 75 farmers in six communities. A rank-based t-test was applied for multiple pair-wise comparisons within ranking groups according to gender and community provenance.

Between-group comparison was performed by non-parametric Wilcoxon rank-sum test. A choice experiment (CE) was designed on basis of the results of the ratio-scaled evaluation of stated selection criteria for llama breeding males. In total, five attributes and a payment vehicle were included in the CE. A fractional factorial design (based on D-efficiency) was created, resulting in a randomized selection of 32 llama profiles. The profiles were further blocked into pairs of two, resulting in eight different choice sets with two alternatives and an opt-out alternative. The choice tasks were conducted with 159 farmers in seven communities. Eight choice sets were presented to each respondent, who then was required to choose the preferred llama profile from the two profiles presented in each set or neither of them (opt-out). Data analysis was performed using LIMDEP 8.0 NLOGIT 3.0 econometric software applying a mixed logit model (MXL).

According to farmers' rankings, the major functions of llama keeping in the Ayopaya region are herd size as a capital asset and transportation, the latter highlighting the role and value of livestock in a mixed system and their integration into cropping activities, but also the persisting value of animal transport in marginal regions despite infrastructure development and decline of barter trade. The highest ranked functions are reflected in the relative evaluation of selection criteria, i.e. the animal traits that are considered to best promote and support the most important animal functions, play a superior role for farmers in Ayopaya. The high importance of the transport capability of llamas is reflected in the body conformation as a frequently stated selection criterion. Other precisely defined and highly valued criteria were well-developed testicles, fibre quantity and quality and fleece colour. The high-rated testicle conformation in combination with little or no selection on the female side is promoting the maintenance of a sufficient herd size, which is indirectly assuring a convenient capital investment. Maximum likelihood estimates of the MXL showed the expected signs for all attributes. The monetary value estimates – indicating the price the farmer is willing to pay (WTP) for a unit increase or a general improvement of a certain attribute, or the respondents' willingness to accept compensation (WTA) for a deterioration of a certain attribute - show that farmers have a considerable welfare loss for llamas that show abnormalities or deviations from well developed testicles and a well-conformed llama with a "square appearance" (straight back, neck and legs). Highest aversion is expressed towards unequal testicles, followed by small

testicles and crooked legs. Even though an aquiline neck and a hollow back are still disliked amongst llama keepers in Ayopaya, crooked legs are much less acceptable, as is shown by the high WTA value. Highest estimate of WTP is observed for very fine fibre animals. A llama with a single-coloured fleece is valued more than a spotted one and bigger animals are preferred over smaller ones. However, the 25th and 75th percentiles of the WTP estimates point to considerable preference variation within the respondent population that could not be sufficiently captured by the included demographic characteristics in the MXL model.

The presented mixed-methodological approach was able to partly describe the complexity and multi-functionality of llamas in marginal highland farming systems in Bolivia. The different approaches allowed yielding more insights in the relative importance of the functions the animals fulfil for their herders and the predominant selection criteria considered for breeding animals. The special importance of marketable and non-marketable benefits of llamas in Bolivia due to smallholder's multiple objectives has been quantified in monetary terms. It is worthwhile to note that in spite of the use of different methods, the results derived are not contradictory, but in fact aid one another and provide a more comprehensive understanding of the analyzed phenomena. However, it has to be taken into consideration that ranking positions of preferences allow for a relative interpretation, but do not indicate an absolute magnitude. Moreover, any preference measures are related to the specific focus group and are rather susceptible to changes from outside. In the absence of well-functioning markets, the evaluation of individuals' preferences might present a reasonable research method, but results can only capture a part of the underlying complex interdependency of multi-factorial systems.

With regard to the formalisation of a breeding objective for llamas in the Bolivian highlands, the findings of the present work suggest the incorporation of the traditionally important selection criteria of farmers parallel to commercially interesting traits at present and in the future. As long as no proper price information from functioning national fibre markets is available, an economic weighting of the fibre quality trait on basis of WTP estimates appears to constitute a reasonable alternative. There is need for additional work and research on the genetic correlations, apart from the existent phenotypic calculations, between fibre quality and quantity to

identify possible auxiliary traits to facilitate recording and implementation. The derivation of economic weights for traits from choice experiments to be incorporated in animal breeding selection indices remains a challenge. In parallel, the market development for llama products should be sequentially monitored, while shortcomings and constraints on the producer level, the institutional level and the policy level have to be considered.

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8 Zusammenfassung

Boliviens Lamabestand umfasst 60% der weltweiten Gesamtpopulation und mehr als 50,000 kleinbäuerliche Familien in marginalen Hochlandgebieten Boliviens halten Lamas zur Sicherung ihrer Existenzgrundlage. Bis heute liefern Lamas Fleisch, Wolle, Brennstoff, dienen als Packtiere für lokale Transporte, besitzen eine Funktion als Kapitalreserve und erfüllen weitere kulturelle sowie soziale Funktionen. Damit leisten Lamas einen beachtlichen Beitrag zum ökonomischen und sozialen Leben bäuerlicher Gemeinden in den Anden. Obgleich dieser vielseitige Beitrag allgemein anerkannt wird, sind Lamas in den Andenregionen bisher nicht Gegenstand systematischer Züchtungsaktivitäten gewesen. Für die Entwicklung nachhaltiger Zuchtprogramme ist die Ermittlung des Beitrags der zahlreichen nicht-geldwerten Merkmale und Leistungen von Lamas zum Gesamtzuchtziel ausschlaggebend. Im Rahmen eines langfristig angelegten Kooperationsprojektes wurden die Produktionssysteme unter den gegebenen extremen Umweltbedingungen in der entlegenen nord-westlichen Provinz Ayopaya des Department Cochabamba detailliert beschrieben und bewertet. Die Perspektiven der Faserproduktion mit Lamas und ihr Entwicklungspotential wurden aufgezeigt. Ferner erfolgte eine phänotypische und genetische Charakterisierung von Wachstums- und Fasermerkmalen der lokalen Lamapopulation Ayopaya's und alternative Konzepte für ein Zuchtprogramm wurden modelliert und miteinander verglichen. Die vorliegende Arbeit hat zum Ziel, die für die Tierhalter wichtigen Funktionen und Aufgaben von Lamas sowie die traditionell angewendeten Selektionskriterien zu bewerten, um bereits vorliegende Informationen zur Formalisierung eines geeigneten Zuchtziels zu ergänzen und damit zum Gesamtprojekt beizutragen.

Die Datenerhebung erfolgte in sieben Hochlandgemeinden in der nord-westlichen Provinz Ayopaya im Cochabamba-Department, Bolivien, wobei eine Kombination verschiedener methodischer Ansätze zum Einsatz kam. In drei Gemeinden wurden insgesamt 47 Bauern mittels semi-strukturierter Interviews befragt. Die Fragebögen beinhalteten Informationen zu Herdenstruktur und Herdenmanagement der Lamas, zur Tierauswahl sowie angewandten Selektionskriterien. Zusätzlich wurden Informationen aus Tierregistern und vorhergehenden Forschungsergebnissen zum Vergleich und zur Überprüfung der eigenen Ergebnisse herangezogen. Ergebnisse zur

durchschnittlichen Herdengröße und Selektion von Lamas sind deskriptiv dargestellt. Wortwörtlich aufgezeichnete Selektionskriterien wurden anhand einer Verhältnisskala relativ zueinander bewertet. Ein Ranking-Ansatz mit zehn, bildlich auf Karten dargestellten Funktionen zur Lamahaltung, wurde mit 75 Bauern aus sechs Gemeinden durchgeführt. Die Analyse erfolgte mittels eines rangsummenbasierten t-tests für multiple Paarvergleiche innerhalb der Ranking-Gruppen ‚Geschlecht' und ‚Gemeindeherkunft'. Der Vergleich zwischen den Gruppen wurde mit dem nicht-parametrischen Wilcoxon Rangsummentest durchgeführt. Ein Choice Experiment (CE) wurde auf Basis der erzielten Ergebnisse der relativen Gewichtung genannter Selektionskriterien für Zuchthengste konstruiert. Insgesamt sind fünf Lamaattribute und ein Zahlungsmittel für das CE berücksichtigt worden. Das experimentelle Design wurde basierend auf D-Optimalität/-Effizienz zu einem ‚fractional factorial design' mit 32 Lamaprofilen reduziert. Diese Profile wurden paarweise geblockt, so dass acht verschiedene Choice Sets mit zwei Alternativen und einer Ausweichalternative („opt-out") verfügbar waren. Das Choice Task wurde mit 159 Bauern aus sieben Gemeinden durchgeführt. Acht Choice Sets wurden jedem der Befragten vorgelegt, die dann aufgefordert wurden, jeweils das bevorzugte Lamaprofil aus den zwei vorgelegten Alternativen auszuwählen oder keine der beiden Optionen zu wählen. Die Datenanalyse erfolgte mit dem LIMDEP 8.0 NLOGIT 3.0 Software Paket unter Anwendung des Mixed Logit Modells (MXL).

Die Ergebnisse des Rankings der Bauern zeigen, dass die Herdengröße als Kapitalreserve und die Transportfähigkeit der Tiere die bedeutendsten Funktionen der Lamahaltung in Ayopaya darstellen. Letztere Funktion unterstreicht einerseits die Wertstellung und Integration des Tierbestandes in gemischten Ackerbau- und Viehzuchtsystemen, sowie andererseits den fortdauernden Wert der Tiere zur Transportmöglichkeit in entlegenen Gebieten, trotz des Infrastrukturausbaus und der Abnahme des Tauschhandels. Die am höchsten gerankten Funktionen spiegeln sich in der relativen Bewertung der Selektionskriterien wider, das heißt diejenigen Merkmale, welche am Besten die zu erfüllenden Funktionen der Tiere begünstigen, spielen für die Bauern in Ayopaya eine entsprechend übergeordnete Rolle. Die große Bedeutung der Transportfunktion von Lamas ist in den häufig als Selektionskriterium genannten Merkmalen des Körperbaus wiederzufinden. Andere genau definierte und hoch bewertete Kriterien waren gut ausgebildete Testikel, die Faserquantität und –qualität,

sowie die Vliesfarbe. Die hohe Bewertung gut ausgebildeter Testikel soll im Zusammenhang mit minimaler Selektion innerhalb der weiblichen Tiere die Aufrechterhaltung einer ausreichenden Herdengröße gewährleisten, was wiederum zu einer zweckdienlichen Kapitalanlage beiträgt. Maximum Likelihood Schätzwerte des MXL zeigten die erwarteten Vorzeichen für alle Attribute. Die monetären Schätzwerte, die die Zahlungsbereitschaft (WTP – willingness to pay) der Bauern für eine Verbesserung des jeweiligen Merkmals um eine Einheit, oder die Akzeptanzforderung (WTA – willingness to accept compensation) für die Verschlechterung eines bestimmten Merkmals darstellen, zeigten einen besonders hohen Wohlfahrtsverlust der Bauern für Lamas mit einer Abnormität oder Abweichung von einem Tier mit gut ausgebildeten Testikeln und einem guten Körperbau. Die Bauern zeigten die größte Abneigung gegenüber Lamas mit ungleichmäßigen Testikeln, gefolgt von kleinen Testikeln und krummen Vorderläufen. Wenngleich auch ein gebogener Hals und ein Senkrücken unerwünschte Merkmale bei Lamas darstellen, werden krumme Vorderläufe bei von den Bauern in Ayopaya als deutlich nachteiliger bewertet, worauf die deutlich höheren WTA-Werte hinweisen. Die höchsten Zahlungsbereitschaften der Bauern hingegen wurden für Tiere mit sehr feiner Faser ermittelt. Lamas mit einer einheitlichen Vliesfarbe wurden gegenüber gescheckten Tieren bevorzugt und größere Tiere gegenüber Kleineren präferiert. Die 25. und 75. Perzentile der WTP-Schätzwerte deuten jedoch auf eine beträchtliche Präferenzvariation innerhalb der Befragten hin, welche nicht ausreichend durch die in das MXL eingefügten demographischen Merkmale erklärt werden konnte.

Die verwendeten unterschiedlichen Methoden konnten die Komplexität und Multifunktionalität von Lamas im marginalen Hochland Boliviens teilweise erfassen. Die verschiedenen Ansätze ermöglichten eine Bewertung der relativen Wichtigkeit der Funktionen, die Lamas für ihre Besitzer erfüllen. Zudem konnten die vorherrschenden Selektionskriterien, die bei der Auswahl von Zuchttieren durch die Bauern zur Anwendung kommen, erfasst werden. Die besondere Bedeutung marktfähiger und nicht-marktfähiger Nutzenmerkmale von Lamas in Bolivien - zurückzuführen auf die multiplen Zielsetzungen der Kleinbauern - wurde in monetären Einheiten quantifiziert. Trotz der Anwendung verschiedener Methoden widersprechen sich die abgeleiteten Ergebnisse nicht, sondern konnten zur gegenseitigen Ergänzung für ein umfassenderes Verständnis des untersuchten

Phänomens herangezogen werden. Es muss jedoch berücksichtigt werden, dass Rankingpositionen von Präferenzen nur eine relative Interpretation zulassen, aber keinesfalls eine absolute Größe der Wichtigkeit einzelner Merkmale zum Ausdruck bringen. Zudem sind Präferenzmessungen eng an die jeweilige Zielgruppe gebunden und deren Ergebnisse somit wenig robust gegenüber äußeren Veränderungen. Bei vollständiger Abwesenheit regulärer Märkte oder Marktversagen kann die Präferenzmessung von Individuen eine angemessene Forschungsmethode darstellen, die jedoch die zugrundeliegenden komplexen Wechselwirkungen eines multifaktoriellen Systems immer nur zum Teil einfangen kann.

In Bezug auf die Formalisierung eines Zuchtzieles für Lamas im bolivianischen Hochland dokumentieren die Forschungsergebnisse der vorliegenden Arbeit die Bedeutung der Aufnahme von traditionell wichtigen Selektionskriterien der Bauern parallel zu gegenwärtig oder zukünftig marktfähigen Merkmalen. Solange keine maßgebenden Preisinformationen aus einem funktionierenden nationalen Fasermarkt verfügbar sind, scheint die ökonomische Gewichtung der Faserqualität auf Basis von Schätzwerten der Zahlungsbereitschaft eine sinnvolle Alternative zu bieten. Weitere Untersuchungen über genetische Korrelationen, abgesehen von den vorliegenden phänotypischen Kalkulationen, zwischen Faserqualität und -quantität sind notwendig, um mögliche Hilfsmerkmale zur Erleichterung der Datenerhebung und Implementierung zu identifizieren. Darüber hinaus bleibt die Aufnahme ökonomischer Teilgewichte für Merkmale aus Ergebnissen von Choice Experimenten in Selektionsindices eine Herausforderung. Gleichzeitig sollte die Marktentwicklung für Lamaprodukte fortlaufend überprüft werden, während Einschränkungen auf der Erzeugerebene sowie der institutionellen und politischen Ebene berücksichtigt werden müssen.

9 Resumen

Las llamas en Bolivia constituyen más que 60% de la población mundial y más de 50,000 pequeños productores se dedican a la cría de llamas como estrategia para su sustento en los Andes bolivianos. Hasta hoy en día, las llamas están contribuyendo considerablemente en la vida social y económica de los pequeños productores en las comunidades andinas. Estas proveen carne, fibra, estiércol, están utilisadas como animales de carga como también están cumpliendo varias otras funciones culturales, sociales y capitales. A pesar de que este uso polifuncional está reconocido generalmente, la llama todavía no ha sido sujeta a una mejora genética sistemática en las regiones andinas. Para la implementación de un programa de mejoramiento genético sostenible, la identificación de los atributos y beneficios monetarios como no-monetarios de las llamas es decisiva. Mediante un proyecto de colaboración a largo plazo, las condiciones del sistema de producción agropecuario en la región remota y marginal de la Provincia de Ayopaya fueron descritas en detalle, considerando las prevalecientes condiciones ambientales. Las perspectivas para la comercialización de fibra de llama, como también el potencial para su desarrollo fueron analizadas. Se han realizado descripciones fenotípicas y genotípicas de crecimiento de los animales y los parámetros de la fibra y además modelos alternativos para un programa de mejora genética fueron comparados. El presente estudio tiene como objetivo la evaluación de las funciones, roles y criterios de selección tradicionales de las llamas, intentando de contribuir a la agregación de informaciones pendientes para la formalización de un índice de selección apropiado para el mejoramiento genético.

El estudio se llevó a cabo en siete comunidades indígenas en la Cordillera Oriental del Departamento de Cochabamba, en la Provincia de Ayopaya. El estudio combina distintos métodos de investigación. Se realizó encuestas semi-estructuradas con 47 productores en tres comunidades. Las encuestas contenían preguntas sobre la estructura de los rebaños y su manejo, la selección de animales y los criterios aplicados. Adicionalmente, se recabó informaciones de registros de llamas para la comparación y comprobación de los resultados propios. Los tamaños medios de los rebaños de llamas y los datos de selección son representados de manera estadística descriptiva. Los criterios de selección, literalmente anotados, fueron valorados

relativamente mediante una escala comparativa. 75 productores provenientes de seis comunidades ejecutaban un ranking de diez funciones de la cría de llamas, que fueron presentados en dibujos diseñados para este fin. En el análisis del ranking dentro los grupos 'sexo' y 'comunidad' se aplicaron un t-test basado en la suma de rangos de comparaciones múltiples. Para la comparación entre los grupos se utilizó la prueba no paramétrica de Wilcoxon. Un experimento de elección (CE – choice experiment) fue diseñado basado en los resultados de la anterior valoración relativa mediante la escala comparativa. En total, cinco criterios más una alternativa de pago se incluyó en el diseño del experimento. Debido al elevado número de posibles combinaciones, la cantidad de combinaciones a presentar a las personas entrevistadas fue reducida utilizando un diseño factorial fraccionado (D-efficiency) del diseño factorial completo. Este factorial fraccionado contenía una selección arbitraria de 32 perfiles de animales. Los perfiles además fueron combinados en pares, lo que dio lugar a ocho opciones de elección con dos alternativas y una opción de indiferencia ("opt-out"). El experimento de elección se llevo a cabo con 159 productores de siete comunidades. Se le presentó a cada encuestado la secuencia de las ocho opciones de elección con dos alternativas, y se le pidió que eligiera entre una de las dos alternativas o ninguna de las dos. El análisis estadístico fue realizado con el paquete estadístico econométrico LIMDEP 8.0 NLOGIT 3.0, aplicando el modelo Mixed Logit (MXL).

Según el ranking de los productores, las funciones más importantes de la cría de llamas son el tamaño de los rebaños como recurso de capital y la función de transporte, la última revelando el valor de los animales en sistemas de producción agropecuaria combinadas y su integración en actividades agrícolas. El valor del transporte en regiones marginales sigue persistiendo a pesar del desarrollo de la infraestructura y la disminución del trueque. Las funciones más destacadas están representadas en la valoración relativa de los criterios de selección, de modo que se asume que las características que más soporten las funciones exigidas son de mayor importancia para los productores en Ayopaya. La alta importancia de las llamas como animales de carga se refleja en la valorización de la 'parada' del animal, que fue frecuentemente denominada como criterio de selección. Otros criterios precisamente definidos y altamente valorados fueron los testículos bien desarrollados, producción y calidad de la fibra y el color del vellón. La alta valoración de la conformación de los testículos en combinación con la escasa selección dentro de las hembras tiene el

objetivo de promover el mantenimiento de un tamaño suficiente de los rebaños, lo que indirectamente ayuda a asegurar una inversión conveniente de capital. Los coeficientes obtenidos mediante el modelo MXL mostraron los signos esperados para todos los atributos. Las estimaciones para las disposiciones a pagar (willingness to pay, WTP), que indican lo que una persona está dispuesta a pagar para el aumento del correspondiente atributo por cada unidad, o su disposición a aceptar (willingness to accept, WTA) de renunciar a un tal aumento, muestran que los productores tienen un considerable rechazo a llamas, que presentan anormalidades. La aversión más alta fue expresada por los productores contra testículos desiguales, seguido por pequeños testículos y piernas delanteras no rectas. Aunque también una espalda no recta como un cuello arqueado fueron desestimados por los productores de Ayopaya, piernas no rectas son mucho menos aceptables, como indica el alto valor WTA. El WTP más alto fue observado por animales con fibra muy fina. Llamas con color entero del vellón son preferidas a llamas manchadas y animales grandes preferidos a pequeños. Sin embargo, los percentiles 25 y 75 denotan una variación considerable de preferencias entre los productores, que no fue capturada suficientemente por la integración de características demográficas al modelo MXL.

Los diferentes métodos aplicados podían captar la complejidad y poli-funcionalidad de llamas en los sistemas de producción marginales de los Andes en Bolivia. Se logro un entendimiento más profundo de la importancia relativa de las distintas funciones, que los animales cumplen para los productores y se captaron los prevalecientes criterios aplicados en la selección de reproductores. Los atributos y beneficios monetarios como no-monetarios de las llamas, representando a los objetivos múltiples de los pequeños productores, se han podido cuantificar en valores monetarios. Cabe destacar que los resultados derivados de la aplicación de diferentes métodos no son contradictorios, pero se complementan, rindiendo una comprensión más profunda del fenómeno analizado. Sin embargo hay que considerar que posiciones en rankings de preferencias solamente permiten una interpretación relativa, pero no indican un valor absoluto. Además, cada declaración de preferencia esta vinculada al grupo focal específico y por lo tanto susceptible a cambios exteriores. En el caso de ausencia y/o la falta de información continua de los precios como de la oferta y demanda de los mercados, la evaluación de preferencias individuales puede

presentar un método de investigación apropiado, considerando que los la complejidad del subyacente sistema polifuncional no permite su captura completa.

Con respecto a la formalización de un índice de selección reflejando los objetivos de la mejora genética de llamas en los Andes de Bolivia, de los resultados de la investigación, se recomienda la incorporación de criterios tradicionales simultáneamente con atributos comerciales, relevantes en la actualidad o en el futuro. Mientras que no existan precios representativos para la fibra obtenidos de un mercado regular, la derivación del parámetro económico para la finura de la fibra mediante los valores estimados WTP constituyen una alternativa adecuada. Se requieren investigaciones adicionales en la estimación de las correlaciones genéticas, fuera de las calculaciones fenotípicas disponibles, entre la calidad y la cuantidad de la fibra para identificar criterios auxiliares que faciliten la registración e implementación. La derivación de los valores económicos a través de CE y su inclusión en un índice de selección sigue siendo un desafío. Simultáneamente se debe monitorear continuamente el desarrollo del mercado para los productos de la llama, tomando en consideración las restricciones y carencias al nivel productor, institucional y político.

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DECLARATION

I assure that this doctoral thesis is a result of my personal work and that no other than the indicated aids have been used for its completion. All quotations and statements that have been used are indicated. Furthermore I assure that the work has not been used, neither completely nor in parts, for achieving any other academic degree.

Stuttgart-Hohenheim, 15.01.2010