



Australian Alpaca Fibre

Improving Productivity and Marketing

A report for the Rural Industries Research
and Development Corporation

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FOREWORD

Although the alpaca industry has only been established in Australia since 1982 alpacas have successfully been farmed in South America for hundreds and possibly thousands of years. While information from South America was initially invaluable in the management and care of alpacas in Australia it became essential to determine base-line data for alpacas farmed in Southern Australia for the industry to develop and progress.

The key areas that were investigated in order to determine the base-line data were:-

- Fleece production, fibre quality and fibre assessment
- Phenotypic and genetic parameters for production traits in Australian alpacas
- Blood minerals, trace elements and vitamin levels of alpacas
- Internal parasites and their control

This report was developed from the research carried out on five alpaca farms across Southern Australia over a period of four years using both Huacaya and Suri breeds.

The bringing together of researchers from different facilities and states has allowed for better use of facilities and a greater range of industry issues to be addressed. It has also resulted in a larger range of researchers having an increased depth of knowledge of alpacas and the alpaca industry.

This report, a new addition to RIRDC's diverse range of almost 400 research publications, forms part of our Rare Natural Animal Fibres R&D program, which aims to facilitate the development of new and established industries based on rare natural fibres.

Most of our publications are available for viewing, downloading or purchasing online through our website:

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ABBREVIATIONS AND GLOSSARY

ANOVA	One way analysis of variance
CFW	Clean fleece weight
Crias	Alpacas less than 6 months
CWY	Clean washing yield
CV(D)	Coefficient of variation of diameter measures the spread of fibre diameter variation relative to the average. Calculated by dividing the S.D. by the mean diameter and then multiplying by 100.
DSE	Dry sheep equivalent
FD	Fibre diameter
GFWt	Total fleece greasy weight
GFW	Grease fleece weight
Hauteur	The mean fibre length in the top before spinning
Hembras	Adult female alpacas
IAA	International Alpaca Association
Lks	Fleece form the front legs, back legs, head, apron, belly and floor sweepings
LW	Live weight
Machos	Adult male alpacas
Midside position	Centred over the last rib. Midway between the backline and The belly line
MS	Midside fibre sample
MFD	Mean fibre diameter
MFD CV(D)	Relative distribution of fibre diameter as the coefficient of variation of the MFD
NKS	Neck
OFDA	Optical Fibre Diameter Analyser
PCS	Pieces
PF	Prickle Factor (PF) is associated with wool's that have 5% of their fibres greater than 30 microns. The wool prickle is apparel garments can cause skin irritation.
RC	Resistance to compression
SD	Standard deviation. The amount of variation in the data
SE	Standard error
SGS	Saddle grid sample
SDFD	Standard deviation of fibre diameter
SL	Staple length
SpnF	Spinning Fineness Provides an estimate of the ultimate performance of sample if it is spun into yarn. This is calculated by combining the measured mean diameter and the measured CV. SpnF performance can be improved by either decreasing mean fibre diameter or decreasing the level of fibre diameter variability.
SS	Staple strength
TF	Total fleece
Tuis	Weanlings alpacas less then two years of age
YLD	Fibre yield

EXECUTIVE SUMMARY

Five alpaca properties and one research herd in southern Australia were used in this study each containing between 30 and 150 alpacas. These properties had both Huacaya and Suri breeds with all ages up to twelve years old. The properties were visited five times per year, over four years and data were collected on fibre, pedigree, chemical constituents of blood and feed supplements and parasitology. The collaboration between four leading research groups in the collection, storage and analyses of data allowed for a greater utilisation of resources and synergy of ideas and effort.

Fibre

At present most alpaca fibre is processed on equipment designed for and operated by manufacturers in the wool industry. There is limited published research on the specifics of alpaca processing. This research project was designed to provide information on most of the raw fibre characteristics of direct relevance to manufacturers and processors of alpaca fibre.

Since the design of the project in 1993 new technology has become available enabling the easier measurement of a range of characteristics including curvature (crimp) and medullation of fibres. This has enabled the gathering of further information on alpaca fibre characteristics.

The fibre section of the project was designed to provide baseline data on:

- Variation in alpaca fibre production and quality in Australia
- Expected supplies of differing qualities of alpaca fibre for marketing and processing
- Influence of production variables on alpaca fibre production and quality.

The composition and development of the alpaca fleece and changes over time are described. The Huacaya alpacas available for this study had an annual fleece production of 2.5 kg/animal/year. On average the proportion of the raw greasy alpaca fleece components were: saddle 55.9 %, neck 16.3 %, pieces 27.8 %. With the current Australian alpaca population estimated at 20,000 the current estimated annual production of alpaca fibre in Australia is $20,000 * 2.5 \text{ kg/head} = 50 \text{ tonnes}$. This production would consist of approximately 28 tonnes saddle, 8 tonnes neck and 14 tonnes pieces.

Within the existing alpaca population and under current management systems significant quantities of saddle fibre meet the following quality standards:

- 70% of fibre of suitable length for worsted processing (20 tonne)
- 98% of tested fleeces had sound staple strength ($> 35 \text{ N/ktex}$) with a mean value of 76 N/ktex
- 10% of fibre had a mean fibre diameter $< 24 \mu\text{m}$ (approximately 3 tonne)
- nearly 40% of Huacaya fibre had a $\text{CV(D)} < 24\%$
- 30% of Huacaya and Suri fibre had $< 20\%$ of their fibre population medullated
- the softness of Australian alpaca, when measured as resistance to compression, was superior to that reported for Merino wool.

Recommendations are made regarding the marketing of Australian alpaca and the application of the research findings to the structure of fibre selling operations.

Between 1 and 8 months of age the mean fibre diameter of Huacaya cria ranged about 23 to 24 μm and then rose rapidly to 29 μm at ages greater than 10 months. Over all fleece types and ages in both Huacayas and Suris about 50% of fleeces had a mean fibre diameter $> 29.9 \mu\text{m}$.

The Australian alpaca clip has a lower than expected incidence of medullated fibres based on a comparison with Peruvian alpaca textiles and fibre in Peruvian classing warehouses. Medullated fibres are more noticeable in fine alpaca as the fibre diameter of medullated fibre is up to 40% greater than the MFD for the fleece whereas in coarser fleeces the differential between the fibre types declines to about 10%.

Present management practices are such that they result in fleece weights of alpacas being the greatest at 2 to 3 years of age with most of the alpaca fibre harvested from these animals being classed as overgrown.

This is mainly because age at first shearing has been delayed. The present shearing method for alpacas has a high labour unit requirement and a low productivity rate, resulting in significantly higher costs for alpaca production compared to the wool, mohair and cashmere industries.

Fibre quality traits showed a steady decline after alpacas reached 3 years of age with:

- mean fibre diameter increasing
- staple length declining
- incidence of medullated fibres increasing.

In the third and fourth years of the project a comparative study was undertaken to investigate the effect of seasonal conditions on the productivity and fibre quality of Huacaya alpacas and Peppin Merino's grazing on annual pastures. This study incorporated species differences with regard to internal parasite, mineral, vitamin and trace elements.

This study showed that in general when nutritional conditions resulted in adult alpacas losing live weight they also grew less fibre. When fibre growth declined it was associated with a decline in fibre diameter and clean fibre content of greasy fleeces. Whereas the annual fleece growth of adult Huacaya alpacas was affected to a greater extent than the annual fleece growth of Peppin Merino sheep. In terms of fibre quality measurements the alpaca fleece was little affected by a significant reduction in nutritional conditions whereas the fibre quality measures of wool were all significantly affected.

A key finding associated with feed availability for Alpaca was that to optimise fibre growth feed availability should exceed 0.5 t DM/ha and should not exceed 1.2 to 1.6 t DM/ha.

While the Alpaca industry major priority is breeding it is recommended that identification of superior genetic material be used to increase fibre production.

To improve the comfort and handling of alpaca the spinning fineness must be decreased. Spinning fineness should be used in the trading of fibre and animals associated with imports and judging competitions.

To reduce the degree of medullation there should be comprehensive training and an education program developed. This along with harvesting guidelines and the support of research to

identify the causes of high sampling variance of medullated fibre measurements and their influences.

There is need to continue to develop and define the quality standards for fibre grown by alpaca in Australia and processed into textiles that can use an appropriate Alpaca mark. This development must be in-conjunction with discussions with the International Alpaca Association. Testing procedures to determine the main determinants of processing performance of pooled alpaca lots must be developed.

The study identified a range of required improvements in alpaca fibre harvesting. The alpaca industry must maximise the production of fine alpaca fibre by improving the shearing management of alpacas up to two years of age. Generally the industry must harvest fibre before staple length exceeds 15cm. Shearing intervals must aim to maximise the harvesting of high quality fine fibre of an acceptable fibre length for processors. There is also a need to develop alternative methods of shearing to lower costs.

The report recommends that

- mid side sampling be used in selection for mean fibre diameter and fleece weight
- saddle grid sampling be used for mean fibre diameter coefficient of variation, and incidence of medullated fibre.
- caution is used when selecting animals on small differences in test results

Until such time as the alpaca producers implement animal culling practices which remove poorer quality fibre from the market, the alpaca industry should initially expect the actual quantity of poorer quality fibre offered for sale to increase.

Phenotypic and genetic parameters

Phenotypic and genetic parameters for young Australian Alpacas are compared with Alpaca reports in the literature, as well as with estimates for South Australian Merino sheep. Most mean values fell within those found in the literature, except for fibre yield, which was greater in our study. The heritability was high (0.37 or greater) for all traits.

The traits studied were greasy and clean fleece weight, fibre yield, mean fibre diameter, standard deviation and coefficient of variation of fibre diameter, staple length and live weight. Fibre yield, fibre diameter, standard deviation of fibre diameter, staple length and live weight were greater than for Merino sheep, whereas the opposite was true for greasy and clean fleece weight. The estimate for live weight fell within the range in the literature, whereas for greasy fleece weight and staple length our values were greater. Relative to those for Merino sheep our estimates were greater for greasy and clean fleece weight, coefficient of variation of fibre diameter and live weight, whereas they were lower for the remaining traits, except for staple length, which had the same value. Phenotypic correlations from the literature were in broad agreement with ours. Those from South Australian Merino hoggets, except for some correlations involving fibre yield and staple length, were in remarkable agreement with ours.

The results presented and briefly discussed in this paper provide the first phenotypic and genetic parameters for Australian Alpacas.

Average production levels: greasy and clean fleece weight, and fibre diameter require attention if Australian Alpacas are to become competitive as fibre producing livestock. Fleece weight was well below that of South Australian Merino, whereas the opposite was true for fibre diameter.

By contrast, fibre yield and staple length were at such high levels that further emphasis in those traits would not be justified. In refining the emphasis placed in the various fibre traits in Alpacas, it would be necessary to ascertain whether their relative importance in processing and in final product attributes is the same as for wool.

Even after allowing for possible sources of (positive) bias in some of the estimates, one may conclude that there is abundant genetic variation and hence scope for genetic improvement in fibre production and quality among Australian Alpacas.

With a few exceptions as earlier discussed, the phenotypic correlations in Alpacas showed a remarkable agreement with those in Merino sheep. As is the case with the latter, the antagonism between fleece weight and fibre diameter was present, but it was not strong enough that it would prevent the simultaneous improvement of both traits by selecting for an appropriate index.

It is concluded that our study provides sufficient pointers to confidently proceed with the development and implementation of scientifically based genetic improvement programs for Australian Alpacas. The information gathered in such a program would not only constitute an invaluable tool for breeders in their selection and mating decisions, but it would also have great research value, contributing to refinements in our phenotypic and genetic parameter estimates for Australian Alpacas.

Huacaya by Suri crosses

Data on 145 Huacaya sire by Huacaya dam, 24 Suri sire by Huacaya dam and 35 Suri sire by Suri dam mating records (and their corresponding progeny) were used to determine the mode of inheritance of the Huacaya and Suri feature in Alpacas. The results indicated control by a single gene (or by an haplotype), and dominance of the allele responsible for the Suri type (AlF^S) over that responsible for the Huacaya type (AlF^h). The practical implications for Huacaya and Suri breeders are further discussed in chapter 3.

Biochemistry of alpacas

The first part of this research was a survey of mineral, trace element and vitamin concentrations in blood of alpacas. The work involved testing large numbers of alpacas on five properties in South Australia and Victoria. This work identified a number of key areas worthy of further investigation.

One of the most important findings was that alpacas in southern Australia were at risk of Vitamin D deficiency in late winter – early spring. A research project was undertaken to determine the dosage of vitamin D required to prevent the deficiency in crias and dams.

The survey also showed that apparently healthy alpacas have lower blood copper and zinc concentrations than found in healthy ruminants. Species differences in blood minerals, trace elements and vitamins were examined in some detail in sheep and alpacas grazing the same pasture.

The results have been presented in three sections, the first addressing the survey results, the second vitamin D supplements for alpacas and the third a comparison of blood constituents in sheep and alpacas grazing together.

Survey of blood mineral, trace element and vitamin concentrations of alpacas in southern Australia:

This study was undertaken to establish benchmark values for a number of minerals, trace elements and vitamins in blood of apparently healthy alpacas at pasture in southern Australia.

Blood samples for chemical analysis were collected on each five farms on five occasions in 1994-5 and on four farms in 1995-6. At the time of blood sampling, pasture and any feed supplements were collected for chemical assay.

The study showed that factors such as time of blood sampling, location and age affect the mineral, trace element and vitamin concentrations in alpacas. These findings were of importance in establishing typical blood values for healthy alpacas in southern Australia. This information has not been available to veterinarians in the treatment of alpacas in Australia. This baseline information has been critical in the further development of the alpaca industry.

Vitamin D doses for alpacas:

It was clear from the survey results that alpacas in southern Australia were at risk of vitamin D deficiency during the winter – early spring.

Vitamin D plays an important role in controlling calcium and phosphorus utilisation in the body, and in early stages of vitamin D deficiency blood phosphorus concentrations will readily fall whereas blood calcium concentrations, which are tightly controlled, will only fall in severe deficiencies. Vitamin D synthesis in the skin as a result of solar radiation is likely to be reduced in winter months, particularly in animals with thick fleeces. A syndrome of lameness, limb deformity and poor growth rates (rickets) associated with low blood phosphorus concentrations had been observed in alpacas and llamas in the USA and in alpacas in New Zealand. Alpaca owners in southern Australia are concerned about the risk of vitamin D deficiency in their animals during the winter months.

Because of the widespread use of vitamin D supplementation in alpacas we investigated the effect of two dosages of the vitamin in crias and adult female alpacas at pasture in South East of South Australia. The farm (SA1) selected for the experiment is near Penola.

Crias born during the late summer-autumn in southern Australia appear to be particularly vulnerable to vitamin D deficiency during their first winter. The study demonstrated that this disorder was associated with reduced growth rates in crias. There were no signs of rickets in adult females not given the vitamin, although two black females in this group were at risk of vitamin D deficiency. It was found that a single injection of 1000 or 2000 IU vitamin D/kg body weight maintained an adequate vitamin D status of crias for about 7 weeks and between 7 and 11 weeks respectively.

It was shown that adult alpacas were less susceptible than crias to vitamin D deficiency. Older animals have a greater opportunity to build up their vitamin D reserves during the summer – autumn than crias born before winter. A single injection of vitamin D at a dosage of 1000 IU/kg bodyweight in mid winter should prevent the vitamin deficiency in older animals. Although

there appeared to be a relationship between coat colour and plasma vitamin D concentrations, the importance of coat colour in affecting the susceptibility of alpacas to vitamin D deficiency is not fully understood.

The vitamin D supplement used in present study is an oil-based emulsion that also contains vitamins E and A. The need to provide A and E vitamins to alpacas on green pasture is questionable. For the prevention of vitamin D deficiency in alpacas it would be preferable to have a product containing only the vitamin D.

For alpacas in southern Australia, a single injection of 1000 IU vitamin D/kg body weight to crias in late autumn and again in mid winter and to adult females in mid winter should ensure vitamin D adequacy. While increasing the dosage to 2000 IU vitamin D/kg body weight will increase the period of adequacy it will not eliminate the need for a second injection in crias.

This information has provided alpaca owners with a simple treatment regime to reduce the risk of vitamin D deficiency in alpacas in southern Australia. Further studies are required to determine the significance of dietary intakes of calcium and phosphorus in preventing the disorder.

Blood minerals, trace elements and vitamins of alpacas and sheep grazing the same pasture:

The survey of alpacas at pasture in southern Australia showed that the concentration of a number of blood constituents differed from those concentrations normally encountered in healthy ruminants. In particular, plasma zinc and copper concentrations in all ages groups were lower than those observed in ruminants whereas plasma phosphorus concentrations in young alpacas were usually greater than that observed in ruminants.

A study was undertaken to compare a number of blood constituents in alpacas and sheep grazing the same pasture. The animals were held at Attwood in a paddock supporting improved pasture. Five alpaca wethers and five alpaca males were introduced initially followed by ten Merino wethers. Blood and pasture samples for chemical analysis were collected on 12 occasions over a period of about 21 months.

Compared to sheep, alpacas had significantly greater concentrations of blood selenium and plasma calcium, copper, zinc and vitamin B₁₂. Further, plasma phosphorus and vitamin D concentrations were more responsive to changing seasonal conditions in alpacas than in sheep. Small but significant differences were also noted between alpaca males and alpaca wethers for plasma concentrations of albumin, magnesium, vitamin B₁₂ and blood selenium concentrations.

This study has confirmed marked species differences for a number of blood constituents. It is evident from this work that for many blood constituents, reference ranges indicating adequacy in ruminants may not be appropriate for alpacas.

Parasitology

The overall aim of the parasitology component of the research project was to determine whether internal parasitism posed an immediate or potential threat to alpaca health and productivity in the southern Australian environment and if so how this should be addressed.

The initial work reviewed internal parasitism in alpacas in South America, identified the important worm species and management issues involved there, compared these where appropriate to local conditions, and broadly evaluated current and potential risks for the Australian industry. The second phase involved a study of the seasonality, abundance and impact of internal parasites and measures adopted to control them in the 5 southern Australian herds. A third study examined the parasite levels in alpacas and sheep communally grazing the same pasture over 2 years.

The naturally occurring worm parasites of the alpaca in South America fall broadly into 3 categories, namely lamoid-specific parasites, those normally associated with sheep or goats and those normally associated with cattle. The lamoid-specific worms are serious pathogens of the alpaca in its natural environment but none of them has yet been recovered from alpacas in Australia. Most of the ruminant parasites recorded from alpacas in South America are common in ruminants here and many have already been recovered locally from alpacas.

The Scourworms [*Trichostrongylus* spp. (Black Scourworm), *Ostertagia* spp. (Brown Stomachworm), *Cooperia oncophora* (Cattle Scourworm)] and *Nematodirus* spp. could all be important locally but probably only with concurrent disease, severe stress or heavy environmental contamination as contributory factors. Some worms of marginal importance in South America and not yet incriminated in problems here could become important, including *Fasciola hepatica* (Liver fluke), *Dictyocaulus* spp. (Lungworm) and *Haemonchus contortus* (Barber's Pole Worm).

Between November 1994 and January 1997 1192 faecal samples were collected from a total of 382 alpacas on the five study sites. A cross sectional sample from at least 20 alpacas representative of the whole herd was attempted on each visit (9-11 visits per farm) and, where possible, the same animals sampled each time. Worm egg counts in faeces were done at the laboratory and eggs were differentiated into various types based on size and morphology. Data from animals which had been treated for worms within 6 weeks before collection of faeces were discarded. The data were derived from clinically normal healthy alpacas and are assumed to be representative of the findings one would expect in a winter rainfall farming venture with reasonable management standards.

By reference to values conventionally applied to ruminants such as sheep or goats the faecal egg counts were low in all age classes. No animals showed ill effects from their worm burdens.

Scourworm egg counts greater than 100 epg comprised only 2.1% of the total. All counts greater than 200 epg were from crias or weaners. *Nematodirus* epg values were also generally low in all age classes; only 4 counts (1.5%) were greater than 100 epg. Crias and weaners had greater faecal egg counts than tuis and adults for all worm categories, confirming a very clear age resistance to internal parasites. Once age resistance has become established, usually in the second year, it should persist if general management and husbandry are adequate.

Egg counts in crias and weaners usually stabilise at low or moderate levels, and in most cases decline without treatment as the animals grow older. Egg counts in around 10% of them progress to elevated levels. Higher levels are generally found in those born in autumn and winter. Most *Nematodirus* infections in young animals also spontaneously resolve without treatment. Infections persist in some individuals, however, and they may be at risk.

All 4 species of coccidia present in South American alpacas (*Eimeria lamae*, *E. punoensis*, *E. alpaca* and *E. macusaniensis*) were found, although *E. macusaniensis* was only detected on one occasion in 2 crias from the same property. Moderate to high levels of oocysts in the faeces were found in low numbers of animals (2.7%) representing all ages. Older, clinically normal animals can heavily contaminate an environment for crias and weaners. To limit extreme exposure of crias to coccidia, clean, uncontaminated areas should be provided for hembras to give birth and, where possible, crias and weaners should be raised apart from older age classes.

Alpacas are routinely concentrated in small areas on Australian farms. This practice is dangerous, particularly for crias. Once a holding paddock becomes heavily contaminated with worms it can remain so for many months. A small change in climatic conditions can make it extremely dangerous overnight in terms of Scourworm, *Nematodirus* or coccidia infection.

Set-stocked alpacas tend to graze small areas to a very low pasture height. This can lead to abnormal exposure to internal parasites, especially where alpacas are set stocked on small paddocks or rotated regularly in limited areas. These practices can also negate the beneficial effects of the toilet habits of alpacas. The latrines substantially limit the exposure of alpacas to worms, but on overstocked paddocks they can provide massive concentrations of infective worm larvae which the animals may not be able to avoid.

Dangerous practices include overcrowding in small yards or paddocks, sharing or rotating grazing with other animal species, particularly calves and lambs, grazing crias and weaners with large numbers of older animals, and inadequate shelter or nutrition.

Removal and composting of faeces from pasture latrines is recommended. Faeces from pasture latrines should never be distributed on the pasture as fertiliser without first being composted. Rotational grazing of pastures every few weeks is unlikely to have an appreciable impact on parasite transmission.

Faecal egg counts of alpacas are inappropriate at the levels of sensitivity routinely used for sheep. Bulk faecal egg counts are unsuitable and counts from only one or two animals in a herd rarely provide useful information. Unless the egg types are accurately differentiated by an experienced person, the results may be meaningless.

Drenching of alpacas less than 1 year old is recommended only when the Scourworm egg count exceeds 350 epg, unless there is some unusual stress factor present or a concurrent burden of another parasite, such as *Nematodirus*, with an egg count of 50 - 100 epg or greater. *Nematodirus* infections in most young animals spontaneously resolve. Individuals with counts exceeding 100 epg should be drenched.

It is probably necessary to drench animals older than 1 year with a Scourworm egg count greater than 125 epg or *Nematodirus* count greater than 50 epg. In addition to their wellbeing, the justification for these treatments is related to the greater potential of mature animals to heavily contaminate the environment.

Faecal monitoring twice a year (July/August and December), will detect those animals which need to be drenched. The identified animals should be individually drenched. Regular monitoring of parasite levels can avoid a large amount of unnecessary drenching without

compromising the health of the animals. Routine drenching of the whole herd is not recommended because of the danger of the development of resistant worms.

Drenching based on the double summer drench concept commonly employed for worm control in sheep and sometimes recommended for cattle in southern Australia is not recommended. At most, animals should be treated once, in December, and a second drench only given to individual animals in February upon confirmation by faecal examination that it is required. Drenches given at other times of the year should be in response to a requirement identified by faecal sampling, and should therefore rarely include animals older than 1 year. The necessity to give a second drench in February is strong evidence that parasite control has failed under the management system operating on the farm and it should be urgently reviewed and amended.

The results of the study involving concurrent grazing of alpacas and sheep confirmed that: Adult alpacas maintain a natural resistance to infection with sheep nematodes under conditions of constant challenge.

The level of natural resistance that alpacas develop against internal parasites of sheep is probably much more robust than that developed by sheep, at least the Merino breed. Alpacas grazing with ruminants may acquire different levels and species of parasites to the ruminants.

Even in the absence of cattle, alpacas are able to maintain burdens of *Cooperia oncophora*, the calf Scourworm. Sheep are unlikely to acquire significant worm burdens through grazing with adult alpacas. They are much more likely to be the source of their own infections.

1. PRODUCTIVITY AND MARKETING IMPROVEMENT OF THE ALPACA FIBRE INDUSTRY IN AUSTRALIA

1.1. GENERAL INTRODUCTION

Four species constitute the group of South American Camelidae. They are the Lama (*Lama glama*); the Alpaca (*Lama pacos* or *Vicugna pacos*); the Vicuna (*Vicugna vivugna*) and the Guanaco, (*Lama guanicoe*). Following the Spanish invasion of South America, the populations of the llama and the alpaca were decimated.

Presently Camelids in South America are restricted to the region known as the 'Altiplano' which is the high Andean plain extending through the countries of Chile, Peru, Bolivia and Argentina. It is generally accepted that Peru has the largest number of alpacas and produces an average of about 3.5 million-kg of alpaca fibre annually, which represents 90% of the total world production.

Traditionally in South America the llama is a beast of burden whereas the alpaca is kept for fibre and meat production. The majority of alpaca in South America are farmed in marginal areas of the Altiplano. The small peasant farming groups in these areas own 80% of the total population of domestic camelids. Within these small groups, alpaca are often inbred and fibre production is low (1.8 kg per animal per year).

Alpaca fibre is regarded as a specialty fibre in the textile industry. It is sought for its softness, warmth without weight, range of natural colours and strength. It is typically blended with merino wool or other fibres for use in overcoats and high fashion knitwear (ACIL 1991).

1.1.1. Australian Alpaca industry

Australia first imported alpacas in 1858 but the project failed and none of the alpacas are known to have survived. More alpaca arrived in Australia in 1982 from Alaska and regular imports followed from Chile via New Zealand after 1986. It was estimated at the beginning of the project (1993) that there were about 6000 alpacas (3,000 breeding females) in Australia from 400 registered herds producing about 10,000 kg of fibre. At the end of the project (1998) the number of alpaca is estimated at about 20,000 with 9000 breeding females from 1500 registered herds.

The Australian alpaca industry is in the first stage of development. It is based on reproducing animals with a focus on selling breeders for industry expansion. This is a normal industry development phase, which has its own unique characteristics. While the number of alpacas have increased and prices have reduced for some classes, the prices paid are still higher than that which would be expected for a fibre producing industry. Also during this breeding up phase the improvement of both production and quality of fibre is not the highest priority.

1.1.2. The project

The development of the Alpaca industry in the eighties and early nineties was often based on anecdotal evidence. These assumptions were often to the detriment of the industry and its development. It was clear that a more factual understanding of the production characteristics was needed.

In 1994 the project was supported by the Alpaca industry, the Australian Alpaca Association and Rural Industry Research and Development Corporation. The project aim was to establish benchmark data for the alpaca industry. While information from South America was of some use the Australian environmental conditions and management were different. Issues of vitamin D deficiency, internal parasites, medullation of alpaca fibre and the dominance of the Huacaya gene needed to be investigated.

The first component of the study was involved in the collection of pedigree, reproductive and production records of alpacas on the properties. Fleece characters collected were the major determinants of fleece value, including fleece weights, fibre diameter, yield, strength, medullation and fleece colour.

The initial shearing was used to standardise fleece growth measurement from a known date. Shearing occurred for a further three years in late spring (Nov –Dec) with small variations due to weather and the onset of seed set.

The second component of the study was involved in regular blood sampling of animals for mineral and trace element assays to establish benchmark ranges for healthy animals in southern Australia. After the second year it was determined that sufficient data had been collected and to continue routine blood sampling would not provide significantly more information. At this stage a second and third sub-projects were established to evaluate dose rates of vitamin D and a comparison of blood constituents between sheep and alpacas grazing the same pasture.

The final component of the project was to examine the incidence of internal parasites and their control in alpacas farmed in southern Australia. While initially there was some difficulties due to precautionary drenching it was quickly determined that internal parasites were a minor health issue and that as the alpaca aged any internal parasite burdens were quickly overcome. The significance of this resistance to internal parasites by alpacas allows owners to not drench adults and to restrict the number of drenches given to only the crias that test positive to a worm egg test. This will not only be economic but will also reduce the risk of drench resistance.

The project was carried out jointly between Primary Industries & Resources South Australia (PIRSA) South Australian Research & Development Institute (SARDI), Victorian Institute of Animal Science, Agriculture Victoria, and with support of the Australian Alpaca Association (AAA) and Rural Industry Research and Development Corporation. (RIRDC).

This enabled four of Australia's leading researchers in the fields of fibre, biochemistry, parasitology and genetics to collaborate in the collection of samples and information in the one property visit.

The project aimed to involve the property owners in all major steps. This was facilitated by formal meetings with all owners and managers. These meetings were held to provide progress

reports of all facets of the project to alpaca owners and their staff. They also gave the owners the opportunity to have input into specific aspects or results relating to their property.

Due to the complexities of working on five properties and an ever changing industry the interaction between the owners and researchers was essential. This interaction allowed for the development of a number of new initiatives which targeted specific areas identified both by the researchers and property owners. These initiatives were able to be run in conjunction with the existing project and complemented the work which had already been conducted.

One of the property owners decided to sell most of his animals and after the second year the number of remaining animals was so small it did not warrant continuing to travel to that property and sampling the remaining animals. This allowed the project to increase the number of animals sampled on the other properties to compensate for the loss of this property from the project.

The project was initially carried out only on private properties due to the high price of stock and cost associated with developing a research herd. While generally this worked well problems did occur, as we did not have finite control of the management of the animals.

Some of the management issues that arose were:-

- many animals were agisted on the property and their use in the research was limited
- movement of stock off the property for sale or mating
- animals required to be in full fleece for sale
- animals supplemented with minerals and vitamins in prepared feed mixes
- precautionary drenching
- animals without identification tags
- reluctance to submit young animals to blood sampling

These issues while important did not overall affect the outcome of the project.

A small research herd of alpacas was established at the Victorian Institute of Animal Science, Attwood in 1995 and used for all three components of this project. This herd included Huacaya alpacas and Peppin Merino sheep managed under controlled conditions.

The study was conducted on five properties, two in South Australia SA1 and SA2 and three in Victoria V1,V2 and V3.

SA1

Soil	Terra Rossa
Rainfall	700mm
Stock	Predominantly Huacayas
Pasture	Rye grass, tall fescue, phalaris and clovers

SA2

Soil	Sandy loam
Rainfall	450mm
Stock	Predominantly Huacaya with some Suris
Pastures	Lucerne/Oats, clover and rye grass

V1

Soil Volcanic (black)
Rainfall 783mm
Stock Predominantly Huacaya and some Suris
Pasture Rye grass, phalaris, tall fescue and clovers

V2
Soil Volcanic (grey/red)
Rainfall 588mm
Stock Predominantly Huacaya and some Suris
Pasture Rye grass, fescue and clovers

V3
Soil Volcanic (grey/red)
Rainfall 753mm
Stock Predominantly Suris
Pasture Rye grass, fescue and clovers

Attwood
Soil Weathered granite.
Rainfall 560mm
Stock Huacaya
Pasture Subterranean clover (*Trifolium subterranean*), Annual rye grass (*Lolium rigidum*), Fog grass (*Holcus lanatus*), Brome grass (*Bromus mollis*), Silver grass (*Vulpia spp.*), Barley grass (*Hordeum leporinum*), Couch grass (*Cynodon dactylon*), Cape weed (*Cryptostemma calendula*).

LOCATION MAP OF PROPERTIES



1.2. OBJECTIVES

1.2.1 The objectives

1. To improve the fibre production, fibre quality and fibre characteristics of Alpacas in the southern Australian environment by establishing current performance levels and identifying areas where major gains could be made.
2. To improve the nutrition and health status of Alpacas in southern Australia by determining base blood mineral, trace element and vitamin profiles that will enable the identification of deficiency situations.
3. To reduce production losses due to internal parasitism by establishing the incidence of internal parasites in alpacas in southern Australia and formulating appropriate control programs.

1.2.2 Development / Extension Objectives

1. To provide information on alpaca fibre quality for the establishment of an objectively based alpaca fibre marketing system.
2. To assemble lots of alpaca fibre for processing and product development experiments using fibre of known and defined attributes.
3. To develop a genetic improvement program for alpacas in southern Australia based on estimated phenotype and genetic parameters determined by field research.
4. To develop a blood trace element and an internal parasite population profile for 'normal', healthy alpacas, to enable owners and veterinarians to accurately monitor health status.

2. FLEECE PRODUCTION, FIBRE QUALITY AND FIBRE ASSESSMENT

2.1. INTRODUCTION

2.1.1. Purpose and structure of fibre production and fibre quality research

The fibre research project was designed to provide baseline information about:-

- 1) variation in alpaca fibre production and alpaca fibre quality in Australia
- 2) expected supply of differing qualities of Australian alpaca for marketing and processing
- 3) the influence of production variables on alpaca fibre production and quality.

To achieve these outcomes three different subprojects were undertaken:-

- 1) a survey of the fibre quality and fibre production on 5 Australian alpaca farms
- 2) an assessment of sampling techniques for the measurement of alpaca fibre quality
- 3) a comparative study of the effect of seasonal conditions on the productivity and fibre quality of Huacaya alpacas and Merino sheep grazed together under commercial grazing conditions.

Preliminary activities and investigations were also undertaken into the assembly of fibre consignments for textile processing and for processing research. These activities were terminated midway through this project as they were no longer required by research groups active in the area, such as Jindalee Fibre Processors (J. Leeder pers. comm.) and the Alpaca Fibre Co-operative Ltd, which began its own fibre assembly and textile development program (P. White, pers. comm.).

This report provides comprehensive details of the first subproject (Productivity and marketing improvement of the Alpaca fibre industry in Australia) and the main findings of the second (Determining the optimum sampling technique for the objective assessment of fleece quality attributes in Alpacas) and third subprojects (Comparative studies of the effect of seasonal conditions on the productivity and fibre quality of Haucaya alpacas and Peppin Merino grazing on annual pastures). Full details of the second and third subprojects are being published elsewhere.

2.1.2. Importance of alpaca fibre quality

There are many attributes of raw alpaca fibre which are of commercial importance during textile processing (Table 1). Some of the raw fibre attributes are of great importance in early and latter (spinning) stage processing while others are only of importance in early stage processing. The difficulty for growers is that they have to produce a fibre which will please all stages of the industry from the early stage processor right to the consumer and make a profit at the same time. It is important to note that these fibre attributes are usually specified in orders and sometimes characteristics only become significant if upper limits are exceeded. The relative importance of different raw fibre attributes depends on the defined end use for which the fibre is destined. For example the presence of dark fibres is usually only a problem with white, pastel and fawn shades.

These raw fibre attributes are commercially significant as they directly affect: the speed of processing, processing yield, quantity of waste products, yarn quality, dyeing performance, visual attributes, handle attributes, fabric properties, cost of product and appeal to customer.

Table 1. The relative commercial importance of attributes of raw speciality animal fibres (McGregor 1997)

RAW FIBRE ATTRIBUTE	RELATIVE SIGNIFICANCE		PROCESSING	
	Scoured	Top/noil	Yarns	Cloth
Mean fibre diameter	****	****	****	****
Washing yield	****			
Vegetable matter contamination (amount and type)	***	***	**	**
Mean fibre length	**	***	*	
Staple strength/position of break	**	*		
Clean fibre colour	*	*	*	
Incidence of dark fibres	*	*	*	***
Incidence of medullated fibres	**	**	**	***
Mean fibre diameter variability			**	**
Proportion of fibres > 30 µm			*	**
Fibre length variability	**	**	*	*
Resistance to compression (crimp)	*	*	**	**
Incidence of cotts	**			
Degree of staple tipiness	*			
Style and handle			*	*

**** Highly significant, * Some significance.

Extensive trials in wool processing mills has shown that mean fibre diameter, staple length, staple strength, position of break, vegetable matter and yield account for approximately 80% of the variation in Hauteur (the mean fibre length in the top before spinning) and fibre wastage experienced during top making. The remaining 20% of the variation is explained by variation between processing mills, fibre diameter variation, crimp definition, style and other characteristics. Most alpaca fibre is processed on equipment designed for and operated by manufacturers in the wool industry. Specialist alpaca processors have adjusted their equipment to optimise their processing efficiency in similar ways to the adjustments made by fine wool processors compared to medium and coarse wool processors. There is very limited published research on the specifics of alpaca processing (Leeder et al 1998).

This research project was designed to provide information on most of these raw fibre characteristics. Some quality attributes were not measured, such as vegetable matter contamination as these impurities are easily removed during fibre preparation and the costs of testing individual fleeces are not justified. Since the design of the project in 1993 new technology became available enabling the easier measurement of a range of characteristics including fibre curvature (crimp) and medullation of fibres.

2.2. MATERIALS AND METHODS

2.2.1. Sampling and testing of alpaca

Five alpaca farms in southern Australia were visited at shearing in late spring in each of four years. Individually identified animals of the Huacaya and Suri breeds, male and female and of various ages from 1 month to 12 years were included in the study. The first year allowed all alpacas to be shorn at a common starting date, which was necessary as some animals had not been shorn for periods in excess of 12 months and up to 18 months. Prior to shearing all alpacas were weighed on live stock scales to the nearest 0.5 kg. Professional shearers carried out the shearing on four of the properties. On two of the properties an electric shearing hand piece was used, two properties used modified sheep hand pieces and the remaining property used a pneumatic mohair unit. The animal's legs were restrained and the animals held in a stretched position with a helper supporting the head of the animal as the other shore.

At shearing a midside fibre sample (MS) was collected from the midside position (centred over the last rib, midway between the backline and the belly line of each alpaca shorn) and weighing about 50 g. The fleece was weighed to the nearest g in the following components: midside sample, saddle, neck, pieces. Midside samples of about 20 g were also collected from some cria who were not shorn. Staple length of the midside sample was determined as the mean of three randomly drawn staples measured to the nearest 0.5 cm. Samples were then identified with a numbered card and placed into a plastic bag which was sealed. At the first shearing the components of the pieces were weighed separately viz: fibre shorn from the front legs, back legs, head, apron, belly and floor sweepings (locks).

Samples were tested at the Fibre Testing Service, Fibre Quality Department, Victorian Institute of Animal Science, Agriculture Victoria. From each midside sample a random subsample of 20 g was placed into a CSIRO mini corer which removes seven cores each of 2 mm diameter. Several coring operations were completed to remove at least 150 mg of fibre "snippets". The snippets were then washed, gently dried and placed into a conditioned room for 24 hours (65 ± 2 % RH and 20 ± 2 °C) prior to measurement on the OFDA (Optical Fibre Diameter Analyser, Baxter *et al.*, 1992, IWTO-47-95, Peterson and Gherardi 1996). The OFDA was calibrated using standard wool tops and set to measure 6000 snippets. For each sample two separate OFDA measurements were made and the results were averaged. The OFDA measurements recorded were : mean fibre diameter (MFD), the absolute distribution of fibre diameter as the standard deviation (SD), the relative distribution of fibre diameter as the coefficient of variation of the MFD CV(D), the effective spinning fineness of fibres (the mean fibre diameter adjusted for CV(D), Butler and Dolling 1995), the proportion of fibres with diameter over 30 μm , the incidence of medullated fibres (Med, % by number and % by weight, only recorded for white and light fawn fibre), and fibre curvature (degree/mm).

Following the minicoring of the sample the remaining sample was used to estimate the clean washing yield (cwy) of the greasy sample (IWTO-33-88, modified using duplicate 20 g samples and a moisture regain of 16%).

2.2.2. Additional testing for staple strength and resistance to compression

From the second shearing 100 samples, covering the range in age and mean fibre diameter found on each property, were chosen for further testing. For each increase in mean fibre diameter of approximately 3 μm two samples were chosen at random from each property. These samples were tested for resistance to compression (AS 3535, 1988) and staple strength using the Agritest Staplebreaker (Huacaya). As the shorter Suri staples tended to slip on the Agritest Staplebreaker and many samples were too long for this equipment, Suri samples were retested using an Instron.

2.2.3. Determining the optimum sampling technique for the objective assessment of fleece quality attributes in alpacas

Male and female Huacaya and Suri alpacas ($n = 120$) of varying ages and live weights were randomly selected at shearing on four of the collaborating farms during the first year of this study. Sampling methods were used:

Midside sample (MS); as described in section 2.1.

Saddle grid sample (SGS); following weighing the saddle was laid out on a 3 m^2 table at a uniform thickness. Samples representing the entire area of the fleece were then drawn from the fleece in a random fashion ($n = 30$). The SGS weighed about 50g and several further random draws were taken if the sample weighed less than 50g. The sample was then identified and bagged as described for MS.

Fleece component grid sample; the procedure used for SGS was undertaken for the neck (N) and pieces (P). Note that only 43 alpacas had neck samples taken separately due to the difficulties encountered obtaining the specified samples in some of the shearing sheds. When necks were not separately sampled they formed part of the saddle component.

Each sample was tested as previously described.

2.2.4. Comparative studies of the effect of seasonal conditions on the productivity and fibre quality of Huacaya alpacas and Peppin Merinos grazed on annual pastures

Twelve adult Huacaya alpaca (mean \pm SD; age 5.2 ± 2.7 years, live weight 72.0 ± 9.5 kg) were grazed with ten Merino sheep (age 3 years; live weight 54.0 ± 3.9 kg) of the medium Peppin strain. They grazed a 3.2 ha improved pasture from October 1995 (estimated carrying capacity 12 DSE/ha) at a stocking rate of 10 DSE/ha (based on San Martin and Bryant (1989) adjusted for differences in metabolic live weight to the power of 0.75). Grazing pressure was increased after 12 months to 13 DSE/ha and six months later ten six month old Merino lambs were introduced increasing grazing pressure to an estimated 17.5 DSE/ha. These lambs were removed in mid-September 1997 and the grazing pressure reduced to the original 10 DSE/ha. During the entire period no supplementary feeding was provided.

Each month, or more frequently if required, all animals were weighed on electronic live stock scales to the nearest 0.5 kg and fibre was carefully clipped from the right midside site using a template. At the same time faecal and jugular blood samples were collected, when required, for internal parasite and vitamin and trace mineral determination. Fibre samples were carefully weighed and a random sub sample was taken for measurement on the OFDA. All animals were shorn by a professional shearer in mid November each year. The fleece was

weighed to the nearest 0.05 kg. At shearing a midside sample from the left side of the animal was taken and the measurements described in 2.3.6. were taken.

2.2.5. Statistical analyses

Sampling and testing of alpaca on the survey farms

For each measured parameter, data from all properties and shearings in years 2, 3 and 4 of the study have been pooled. Total fleece greasy weight (GFWt) harvested from each animal was calculated as the sum of the greasy fleece components weighed from each animal. The clean fleece weight (cwt) was calculated as : $cwt = GFWt * CWY$. The least squared mean and standard error (se) were calculated following data transformation. Histograms showing the proportion of fleeces in various classes have been calculated. For some fleece parameters the relationships between the fleece parameter and age at shearing have been determined. Only fleeces determined to be “fully grown” have been included in the data base. Fleeces from cria shorn at ages less than 12 months have been analysed in a separate data base and results for fleece weight, staple length and mean fibre diameter plotted separately. As the numbers of Suri were limited (n = 122), the data for Suri is less reliable than data for Huacaya (n = 972), particularly for older age groups and for some categories of fibre quality. Graph data points with large error bars indicate that only a few measurements were available and that the data was very variable, while points with no error bar indicate that only one measurement was available.

Additional testing for staple strength and resistance to compression

For the fleeces with additional measurements (2.3.4.) the data have been analysed for correlation between measurements and linear regression relationships between fibre characteristics and the additional measurements (SigmaStat, 1993). Only regressions with significant variables are given ($P < 0.05$).

Determining the optimum sampling technique for the objective assessment of fleece quality attributes in alpacas

Comparisons between mean fleece variables were determined using one way analysis of variance (ANOVA). Weighted means were calculated for the range of fleece attributes measured on the OFDA using the appropriate component weight and total fleece weight. Multiple linear regressions were run using Genstat 5 (Genstat, 1983) and non significant variables were progressively removed from the model. The models were of the form:

$$y = ax + b + c(\text{variable 1}) + d(\text{variable 2}) + \dots$$

Where y represented the fleece component being predicted and x represented the SGS or MS.

Other variables included:

breed (Huacaya = 1, Suri = 2)

sex (male = 1, female = 2)

property (1 to 4)

live weight (LWT, kg) age (years)

The models compared fleece measurements obtained on the midside site and on the saddle with measurements obtained on other fleece components and with the calculated values for

the total fleece. Weighted means were calculated for a range of fleece attributes, with values calculated for the total (entire) fleece shown as TF. For example:

$$\text{TFMFD} = ((\text{NMFD} * \text{Ncwt}) + (\text{SMFD} * \text{Scwt}) + (\text{PMFD} * \text{Pcwt}) + (\text{MSMFD} * \text{MScwt})) / \text{TFcwt}$$

Residual SD (RSD), correlation coefficients (r) and the percentage variance accounted for by the different regression models ($R^2 = 100 * r^2$) are given in tables.

Comparative studies of the effect of seasonal conditions on the productivity and fibre quality of Huacaya alpacas and Peppin Merinos grazed on annual pastures

Full fleece shearing data for the two separate years 1996 and 1997, and changes in other measured parameters over various time periods have been analysed by Students paired “t” test or if necessary by Mann-Whitney Rank Sum Test (SigmaStat, 1993) to compare year affects and relative changes between alpaca and sheep. The probability of significant differences is shown under (P) with non-significant differences, where $P > 0.1$, shown as NS.

2.3. RESULTS

2.3.1. Live weight of alpacas

The mean live weight of Huacaya and Suri alpacas of different ages and sexes are given in Table 2. Both breeds grew rapidly. The data do not take into account live weight at different seasons of the year or stages of pregnancy. As one year old alpacas were generally mated the live weight of female tui and adults was greater than that of male alpacas of similar age.

Table 2. The live weight of Huacaya and Suri alpacas at different ages (kg)

Age	Huacaya		Suri	
	Female	Male	Female	Male
Cria	28.6	26.3	29.0	25.8
Weaner	49.5	42.0	44.2	41.9
Tui	68.3	60.6	65.0	56.4
Adult	77.5	80.8	73.2	76.1

The variation in weight of female alpacas increases with age up to 2 years of age due to variation in time of conception. This can be easily seen in Figure 1. The line shows the predicted mean weight of animals sampled or more simply the pattern of growth for Huacaya females from birth to two years of age.

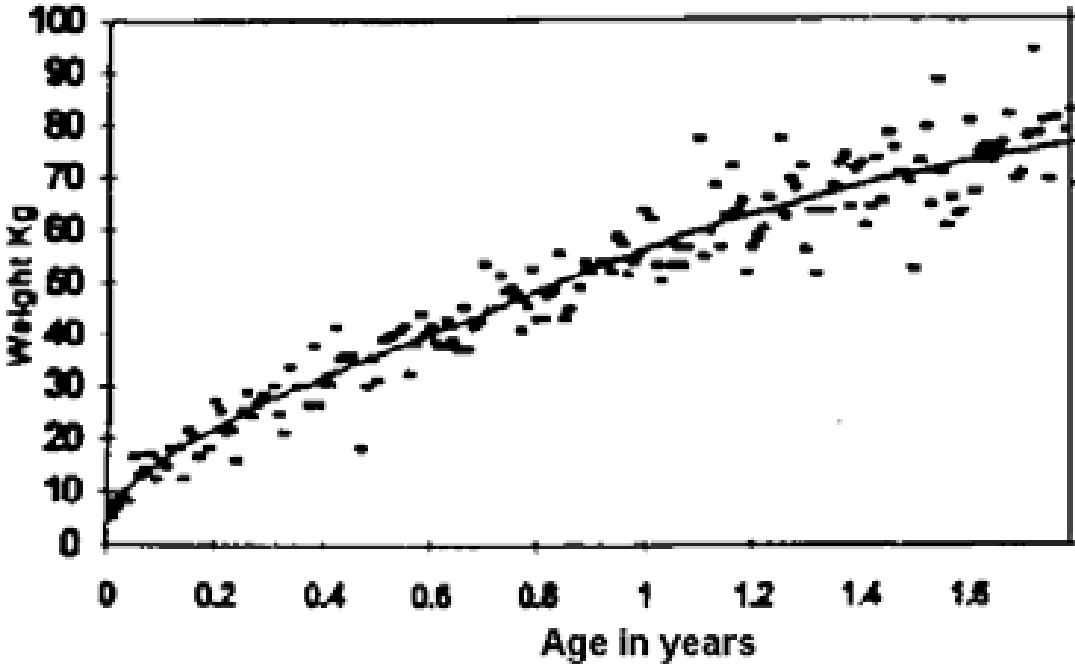


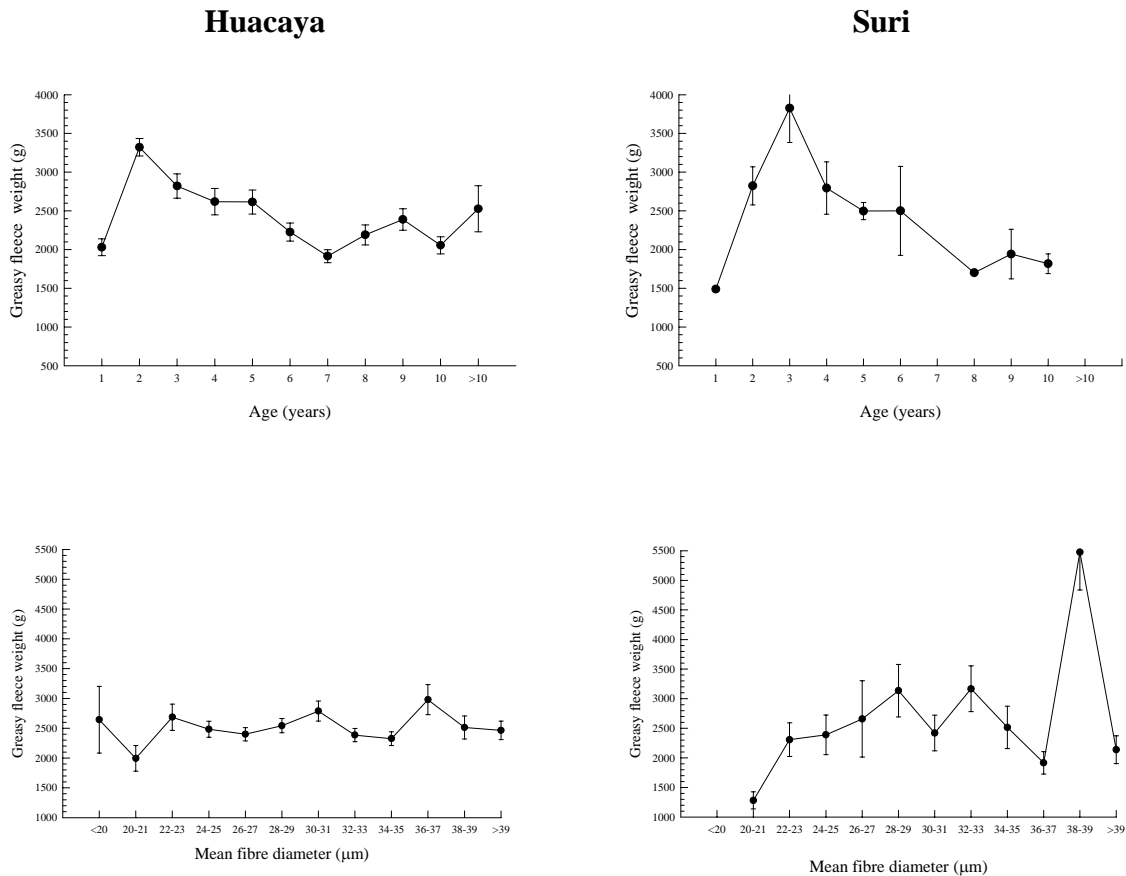
Figure 1. The pattern of growth of female Huacaya alpaca on farms in southern Australia from birth to two years of age (n = 693)

2.3.2. Distribution of fibre production and fibre quality attributes

Fleece weight and fleece component weight

Greasy fleece weights of Huacayas peaked at 2 years of age but then declined with increases in age until about 6 years of age (Figure 2). With Suris greasy fleece weights increased until 3 years of age and then declined until 10 years of age. Mean greasy fleece weights of Huacaya did not appear to be affected as MFD increased from 20 to 40 μm (Figure 2) whereas in Suris greasy fleece weights increased with MFD reaching a peak at 29 to 33 μm (the value for 38-39 μm came from only 2 animals with more than 15 months fibre growth).

Relationships similar to that found for greasy fleece weight and MFD were also found for greasy saddle weight and mean midside fibre diameter (Figure 2).



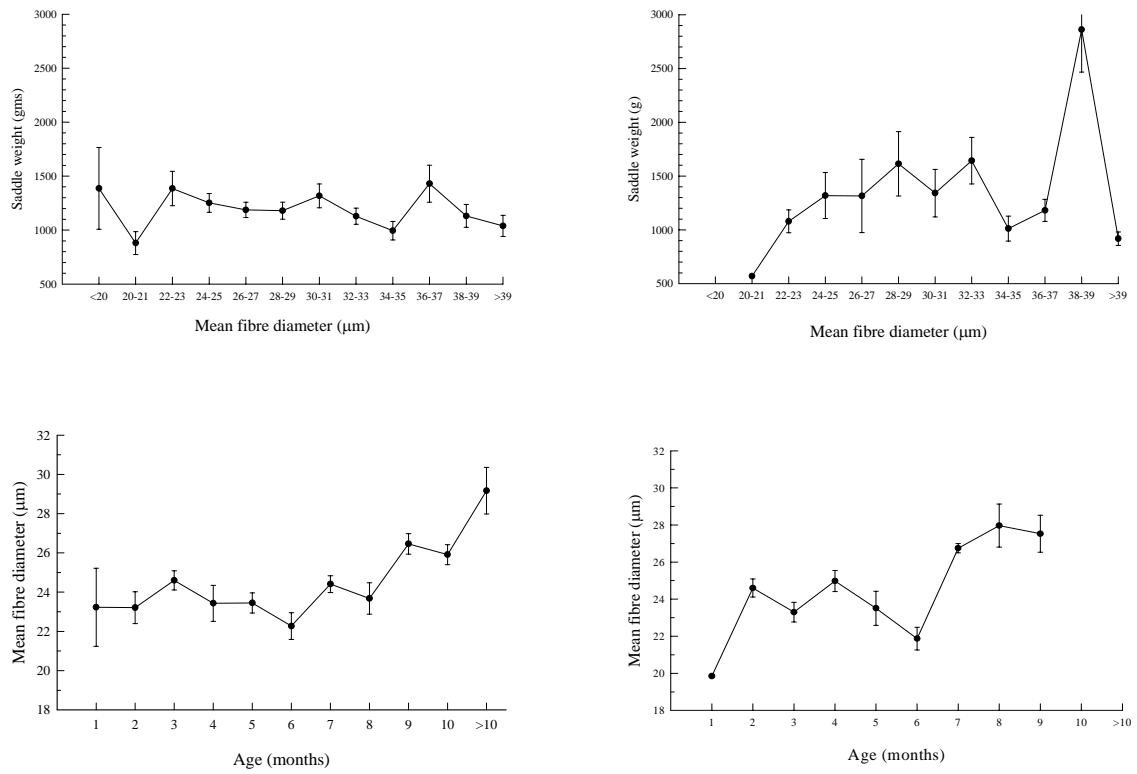


Figure 2. Greasy fleece and saddle weight of Huacaya and Suri alpacas of various ages and mean midside fibre diameters and the mean fibre diameter of cria at various ages

The property mean clean washing yield for the three year period were (mean \pm sd, %) :92.7 \pm 3.9, 94.0 \pm 3.1, 92.1 \pm 3.9, 90.0 \pm 3.7 and 91.3 \pm 3.5 giving an overall mean of 92.0 \pm 1.5.

The proportion of the raw greasy fleece as saddle, neck and piece components was (mean \pm se, %): saddle 55.9 ± 0.87 , neck 16.3 ± 0.50 , pieces 27.8 ± 0.62 with the components of the pieces shown in the figure 3.

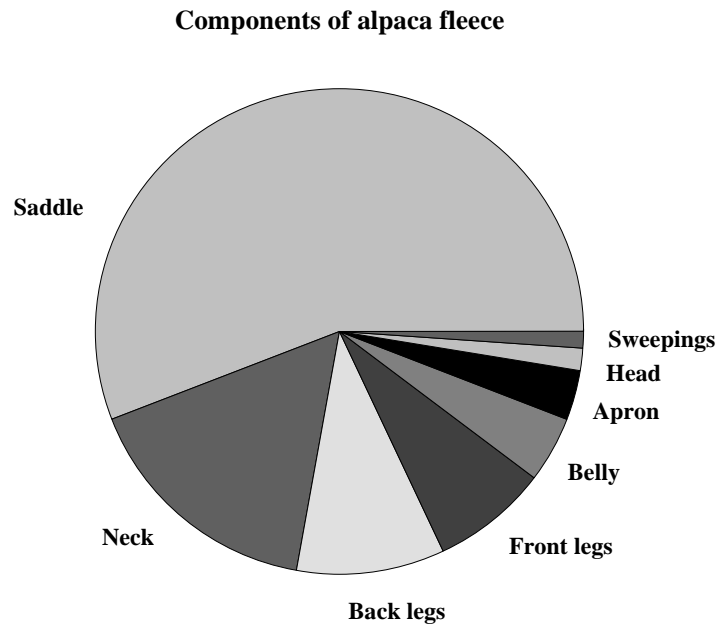


Figure 3. The components of alpaca fleece

Mean fibre diameter, coefficient of variation of mean fibre diameter and spinning fineness.

Between 1 and 8 months of age the MFD of Huacaya cria ranged about 23 to 24 μm and then rose rapidly to 29 μm at ages greater than 10 months (Figure 2). The limited data available for Suris suggested that MFD increased at ages above 6 months of age (Figure 2).

About 10% of Huacayas had fleeces with mean fibre diameters $< 24.0 \mu\text{m}$ while 14% of Suris had fleeces $< 24.0 \mu\text{m}$ (Figure 4). Both Huacayas and Suris had about 50% of fleeces with mean fibre diameter $> 29.9 \mu\text{m}$.

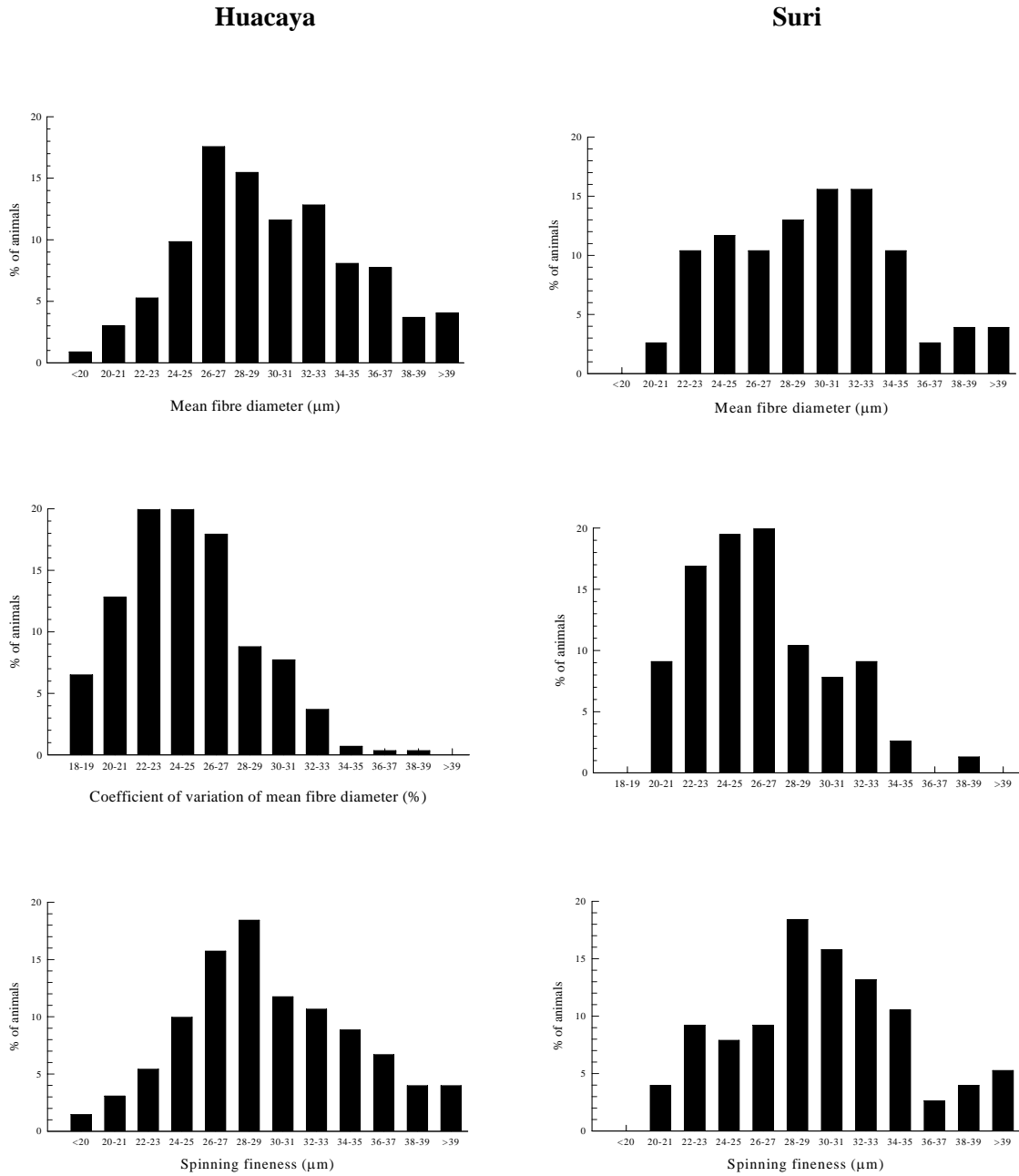


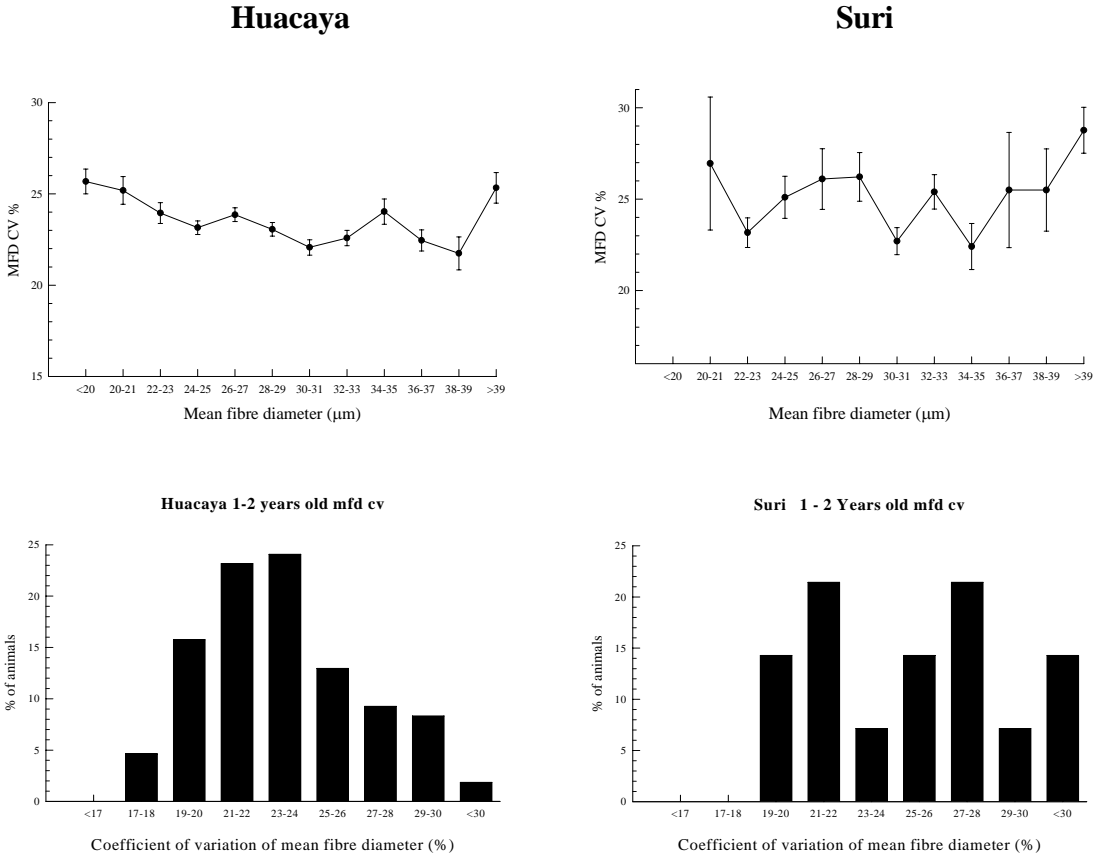
Figure 4. The distribution of mean midside fibre diameter, coefficient of variation of mean fibre diameter and spinning fineness of fibre grown by Huacaya and Suri alpacas in southern Australia

Nearly 40% of all Huacaya fleeces had $CV(D) < 24\%$ and only 14% had $CV(D) > 29.9\%$ (Figure 4). For Suris only 26% had $CV(D) < 24\%$ and 22% had $CV(D) > 29.9\%$. The $CV(D)$ in Huacaya tended to decline as MFD increased from < 20 to $30 \mu\text{m}$ but no such trend was evident in Suri fibre (Figure 5). When age was used to examine the distribution of $CV(D)$ (Figures 5) the mode changed with age in both Huacaya and Suri alpacas. Depending on the age of Huacayas the proportion of animals with $CV(D) < 21.0\%$ ranged from 22 to 39%. The results indicate that the mean $CV(D)$ for Suris was about 1.7% higher than for Huacaya (Table 3).

Table 3. The relationship between age and mean coefficient of variation of mean fibre diameter (CV(D) in Australian Huacaya and Suri alpaca

Age (years)	Coefficient of variation of mean fibre diameter			
	Mean		SD	
	Huacaya	Suri	Huacaya	Suri
1 - 2	24.0	26.0	3.4	4.2
3 - 4	22.7	24.4	4.1	3.4
> 5	23.2	24.6	3.7	4.2

Spinning fineness uses a CV(D) of 24.0% as the typical value for the processing of Merino wool. CV(D) values below 24.0% result in a spinning fineness lower than the MFD and CV(D) greater than 24.0% result in a spinning fineness higher than the MFD. For Huacayas the spinning fineness measure indicates that a higher proportion of fleeces would spin well (< 24.0 μm) compared to the use of only MFD values. For Suris the opposite trend is evident. However for both breeds the proportion of fleeces with spinning fineness > 29.9 μm, when compared to the distribution of mean fibre diameter, (Figure 4) has remained virtually unchanged.



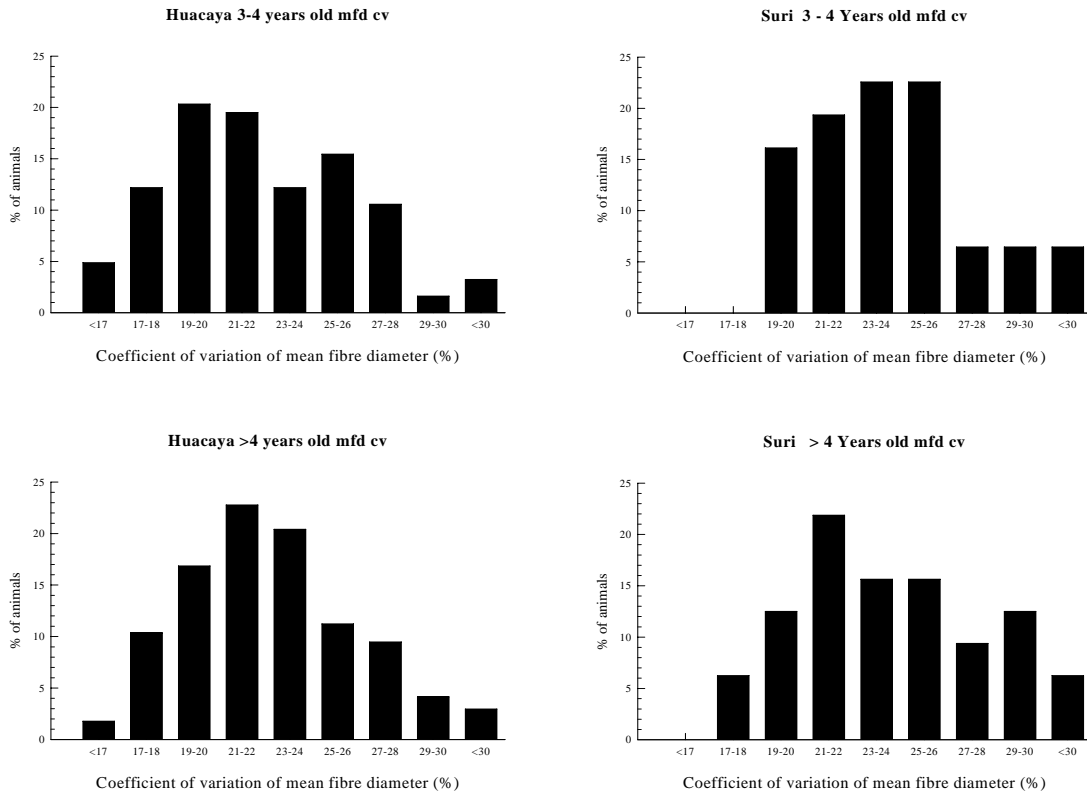


Figure 5. The relationship between of the coefficient of variation of midside mean fibre diameter (CV(D)) and mean fibre diameter and the distribution of CV(D) in fibre grown by different age groups of Huacaya and Suri alpacas

Proportion of fibres with diameters greater than 30.0 μm

Almost all Huacaya and Suris had more than 5% of the measured fibres having a MFD greater than 30.0 μm and 80% of Huacaya and 90% of Suri fleeces had more than 10% of fibres greater than 30 μm (Figure 6).

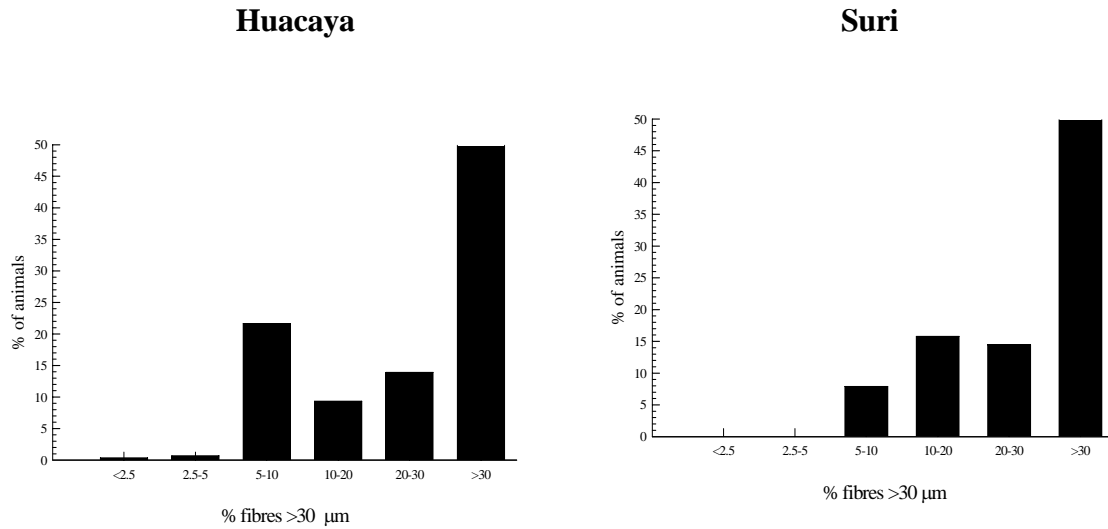
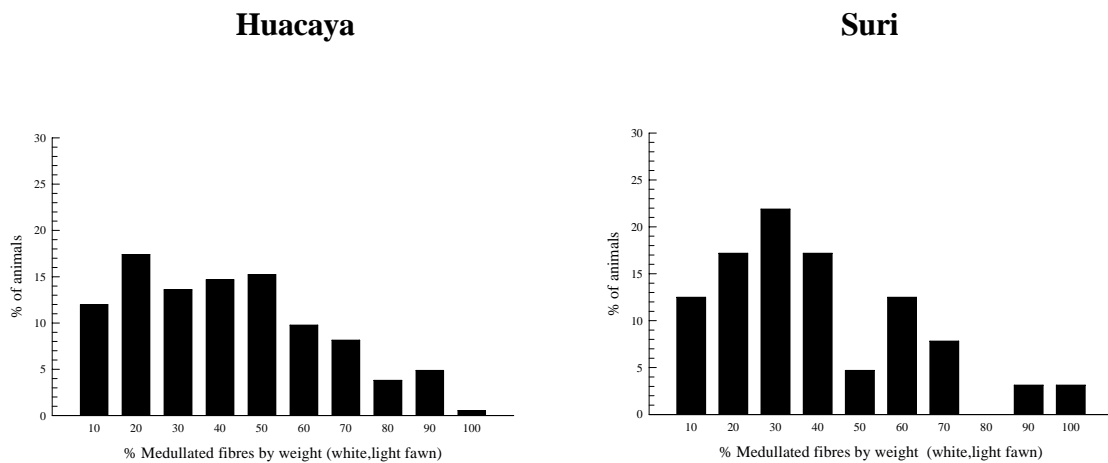


Figure 6. The distribution of the proportion of midside fibres with diameters greater than 30 µm in fibre grown by Huacaya and Suri alpacas Huacaya Suri

Incidence and characteristics of medullated fibres

The percentage by weight of Huacaya and Suri saddle fibre which was medullated was lower than is generally claimed (Figure 7) with almost one third of Huacaya and Suri saddles having less than 20% of their fibres medullated. Only 30% of white Huacaya and Suri fleeces had more than 50% of their fibres medullated. The distribution of the incidence of medullated fibres by weight and by number were almost identical.



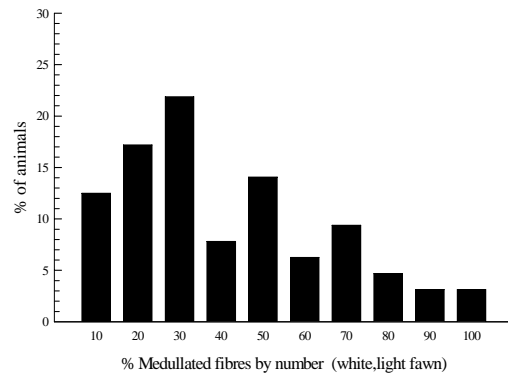
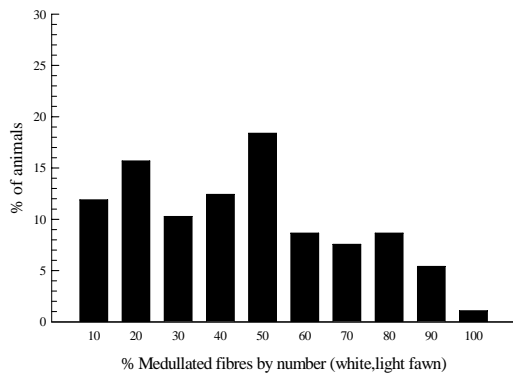
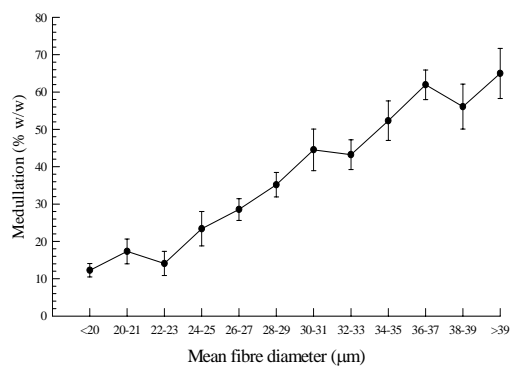


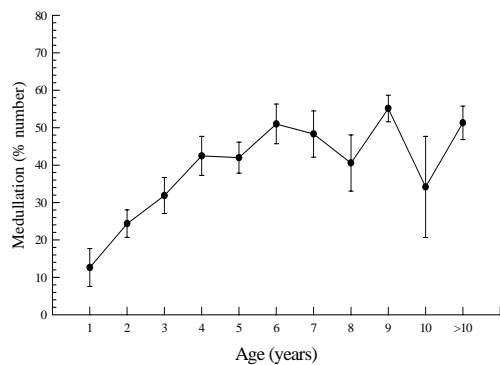
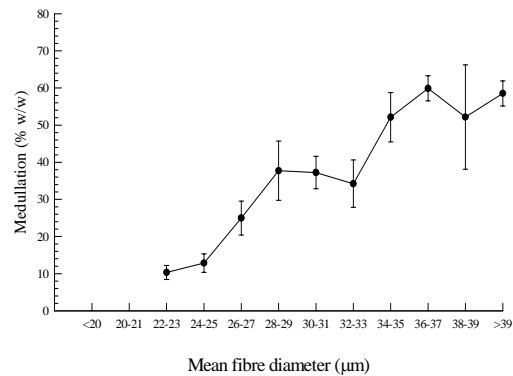
Figure 7. The distribution of the incidence of medullated fibres (by weight and by number) in white and light fawn fibre grown by Huacaya and Suri alpacas

For both Huacaya and Suri alpacas the incidence of medullated fibres increased linearly from 10 to 60% by weight, as the saddle MFD increased from 22 μm to 40 μm (Figure 8). The increase in the weight of medullated fibre can be explained by the increase in the number of medullated fibres and the increase in the MFD of medullated fibres as the MFD of all fibres increased (Figure 9).

Huacaya



Suri



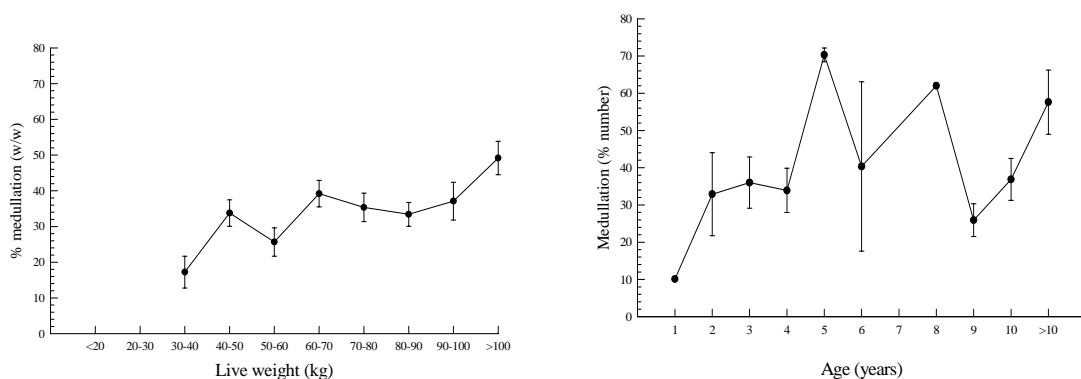


Figure 8. The relationships between the incidence of medullated fibres and mean fibre diameter, live weight or age of Huacaya and Suri alpaca

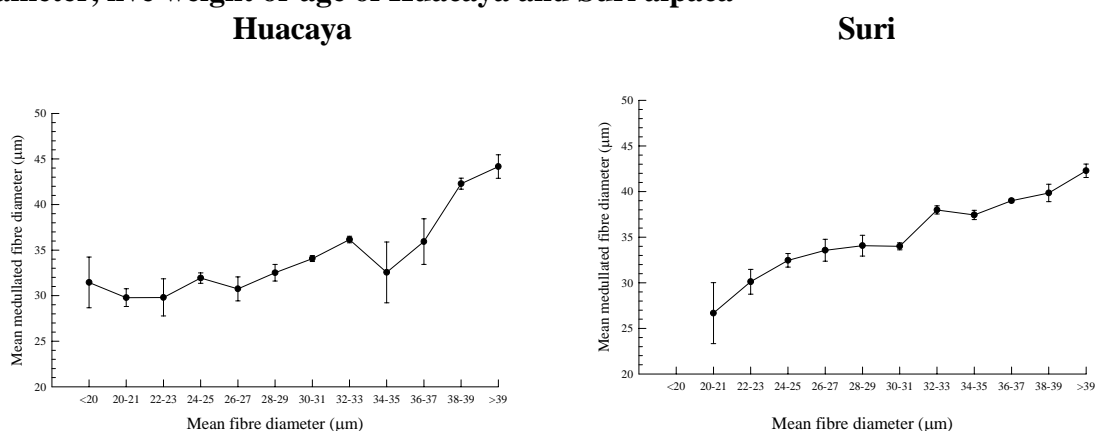


Figure 9. The relationship between mean medullated fibre diameter and mean fibre diameter of Huacaya and Suri alpaca

For Huacayas the incidence of medullated fibres increased as live weight increased and up to the age of 6 years (Figure 8), but from the age of 4 years the incidence of medullated fibre changed little. Regression equations show that for each 10 kg increase in liveweight the incidence of medullation increases 3%. In Suris the live weight data is too variable to form a clear picture and has been omitted but the mean incidence of medullated fibres in animals 5 to 8 years of age was about double that of 1 to 4 year old animals (Figure 8).

The distribution of the ratio of medullated fibre diameter to the mean fibre diameter of all fibres is very similar for Huacayas and Suris with about 80% of animals having a ratio less than 1.3:1 (Figure 10) and less than 5% of animals had a ratio > 1.5:1. The ratio of medullated fibre diameter to the mean fibre diameter declined as the mean fibre diameter of all fibres increased. As Figure 11 shows, the higher ratios occurred in the finer fleeces.

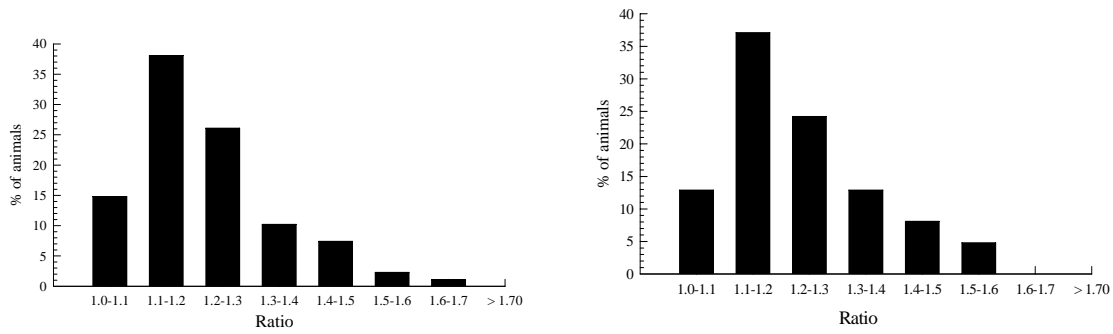


Figure 10. The incidence of different ratios of (mean medullated fibre diameter : mean fibre diameter) of Huacaya and Suri alpaca

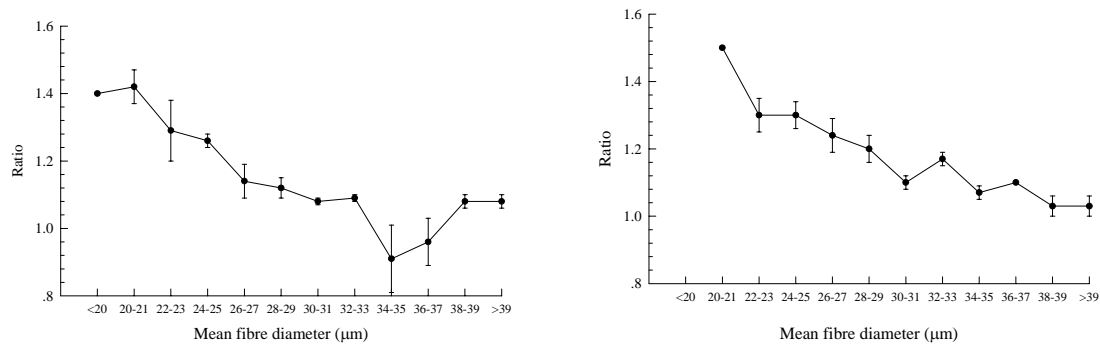


Figure 11. The relationship between the ratio of (mean medullated fibre diameter : mean fibre diameter) of Huacaya and Suri alpaca as mean fibre diameter changes

Staple length

The majority of shorn saddles had staple lengths between 7.5 and 15 cm (Figure 12). However 13% of Huacaya fibre was not suitable for worsted processing (< 7.5 cm) and 20% was too long (> 15 cm). Thirty percent of Suri fibre was too long for most worsted processors (>15 cm).

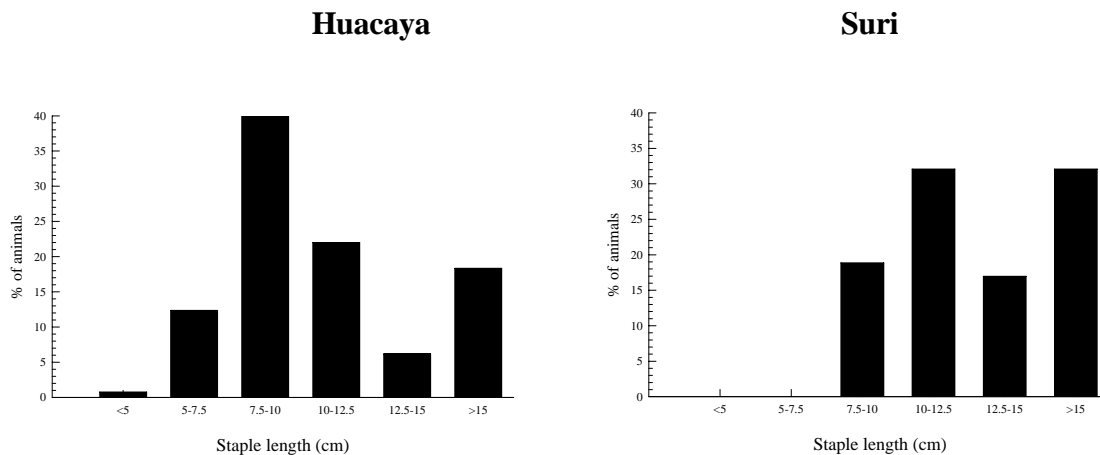


Figure 12. The distribution of midside staple length of fibre grown by Huacaya and Suri alpacas

As with greasy fleece weight, staple length of Huacaya increased up to 2 years of age and then declined reaching a plateau from 6 years of age. In Suris staple lengths reached maximum length at 3 years of age and declined to reach a plateau from 5 years of age (Figure 13). The majority of overlong staples were harvested from 2 year old Huacaya and 2 to 4 year old Suris.

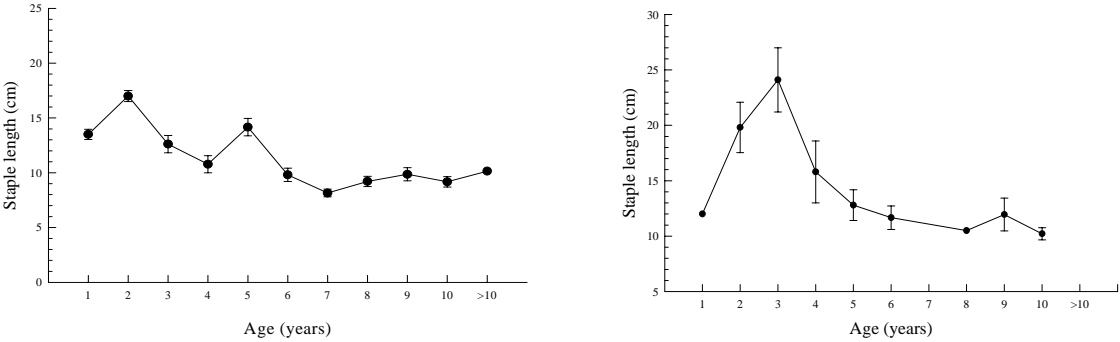


Figure 13. The relationship between age and staple length of Huacaya and Suri alpaca

Midside samples from Huacaya cria, many of whom were not shorn (Figure 14), indicated that staple length reaches 15 cm at about 12 months of age.

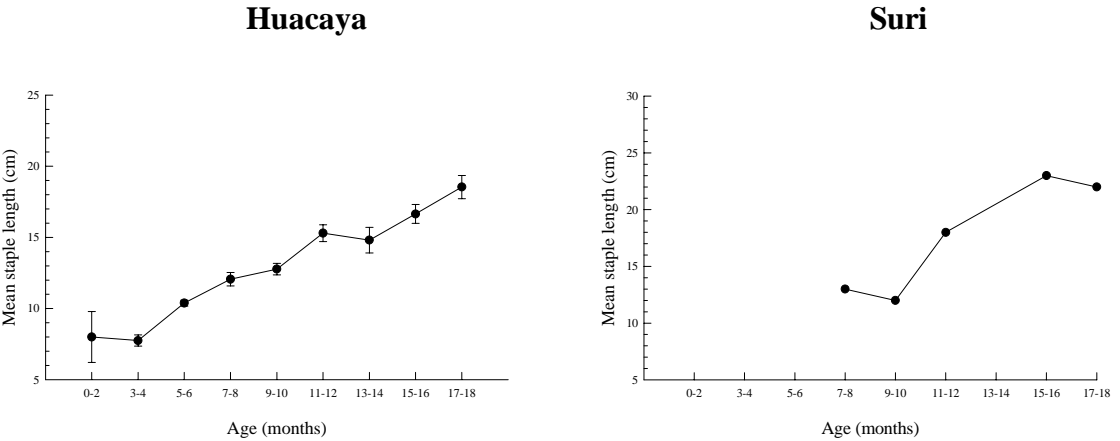


Figure 14. The relationship between age of cria and staple length in Huacaya and Suri alpaca

The longest Huacaya staples came from the finest fleeces (Figure 15). Insufficient data was available for Suris

Huacaya

Suri

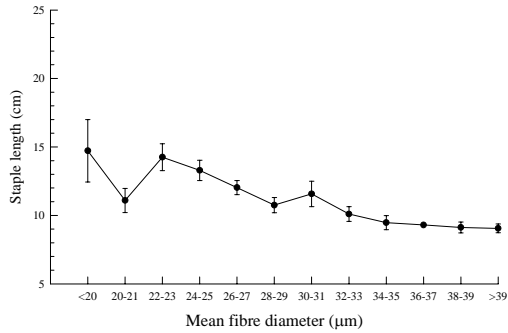


Figure 15. The relationship between mean fibre diameter and staple length of Huacaya alpaca

Fibre curvature

Fibre curvature in Huacaya ranged up to 48 degrees/mm. The distributions of fibre curvature showed that Suri fibre curvature had a lower modal value compared to Huacaya, with 65% of saddles having curvatures of 10 to 20 degrees/mm compared to 55% of Huacaya having curvatures of 20 to 30 degrees/mm (Figure 16).

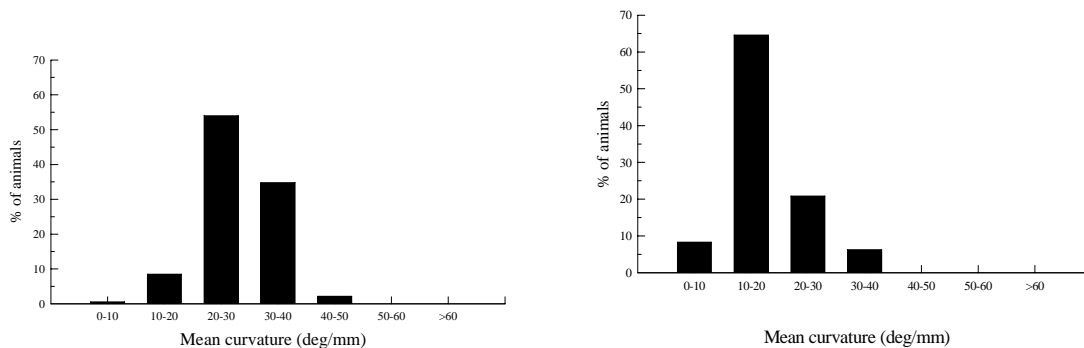


Figure 16. The incidence of and range in fibre curvature in midside fibre grown by Huacaya and Suri alpacas

In Huacaya, fibre curvature was highest in saddles weighing up to 3.0 kg and curvature declined at heavier saddle weights. In Suri, fibre curvature was only half that measured in Huacaya and was highest in saddles weighing up to 1.5 kg and curvature declined at heavier saddle weights (Figure 17).

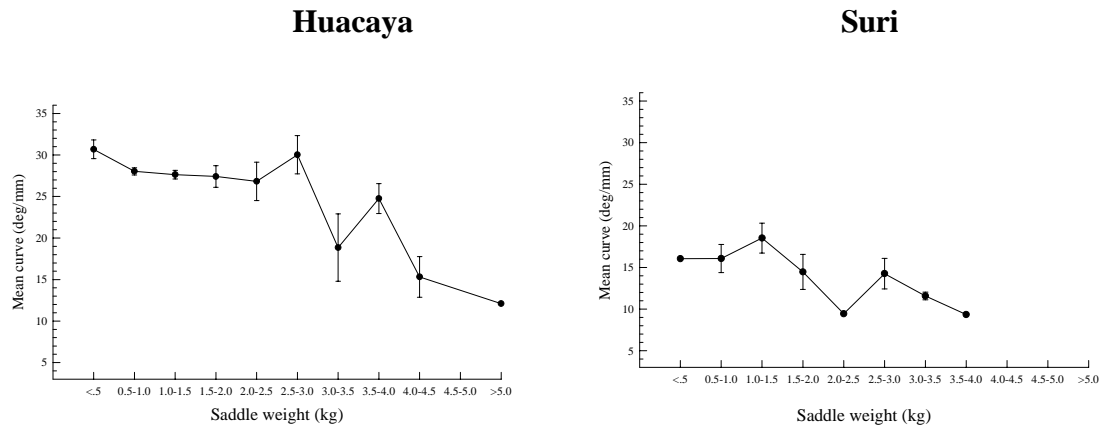


Figure 17. The relationship between mean fibre curvature and weight of saddle grown by Huacaya and Suri alpacas

The live weight of Huacaya had no effect on fibre curvature but in Suris fibre curvature was highest in alpacas weighing 20 to 30 kg with fibre curvature being halved at live weights > 30 kg (Figure 18). These changes were exactly mirrored when fibre curvature was related to age at shearing. Age had no significant affect on Huacaya fibre curvature but in Suris fibre curvature at 1 year of age was about double that recorded at ages of 2 years and greater (Figure 18).

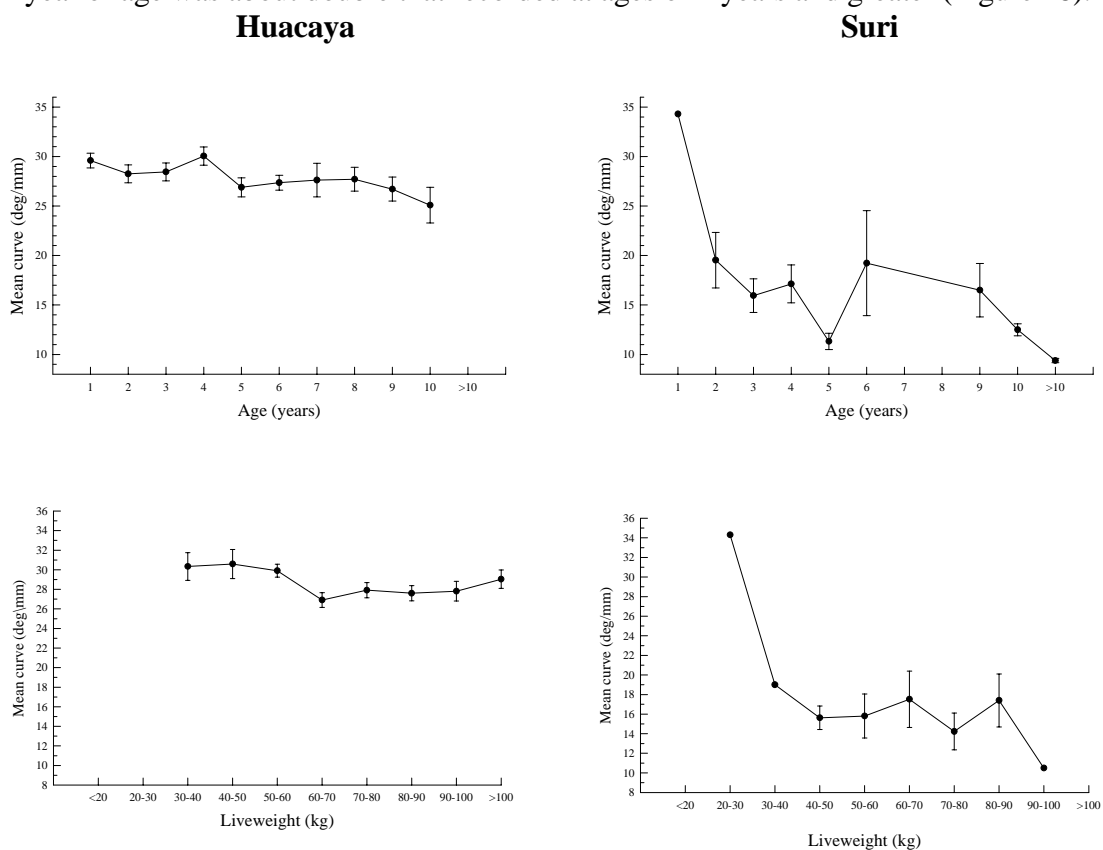


Figure 18. The relationship between mean fibre curvature and age or liveweight of Huacaya and Suri alpacas

2.3.3. External parasites

During laboratory testing of alpaca fibre samples biting lice (*Damalinia breviceps*) were observed in one sample. No other external parasites were seen.

2.3.4. Additional testing for staple strength and resistance to compression

Attributes of fleeces in this data set, correlations between attributes and the best linear or multiple linear regressions relating staple strength and resistance to compression to other fibre attributes are given in Tables 4, 5 and 6. Figures 19, 20 and 21 show the data points and significant relationships between resistance to compression, fibre curvature and mean fibre diameter.

Property differences were not detected in the MFD of samples but there were significant differences between Huacaya alpaca properties with one property having lower values compared to the other three properties for staple strength (68 vs 81 N/ktex, $P < 0.05$), resistance to compression (4.0 vs 4.8 kPa, $P < 0.001$) and curvature (19 vs 31 degree/mm, $P < 0.001$, Figure 19). Suri fibre from one property had higher resistance to compression than the Huacaya fibre from the three higher value properties (5.6 vs 4.8, $P < 0.001$) and a higher curvature (39 vs 31 degree/mm, $P < 0.01$) but the staple strength of the Suri fibre was similar to that on the lower value Huacaya property (63 vs 68 N/ktex, NS).

For both Huacaya and Suri, staple strength declined as staple length increased. Care was taken to observe fibre strength measurements to ensure recordings where fibre slippage in the jaws of the measurement equipment occurred were discarded. However measurements for Suri fibre strength cannot be completely verified as it is suspected that some fibre slippage may have occurred with the Inston. This may explain the significant correlation between Suri staple strength and clean fleece weight and the other attributes closely associated with clean fleece weight such as clean yield and curvature. Consequently all Suri staple strength measurements must be regarded as minimum values.

The determination of crimp frequency (crimps per cm) was too difficult to accurately measure, owing to very poor staple formation and lack of clear crimp definition, and was abandoned. However fibre curvature measurements taken on the OFDA may provide a better objective method of measuring fibre curvature. In the pooled data set increasing fibre curvature was generally related to increased resistance to compression (Figure 19) and on four of the properties increasing mean fibre diameter was related to reduced fibre curvature (Figure 20) but was not related to resistance to compression (Figure 21).

Table 4. Staple strength, resistance to compression and other measured fibre attributes of alpaca samples given additional measurement

Fibre attribute	Mean	SD	Minimum	Maximum
Greasy fleece weight, kg	2.44	1.15	0.41	5.24
Clean washing yield, %	91.6	3.9	82.2	99.0
Mean fibre diameter, μm	28.1	6.0	18.5	45.0
CV(D), %	23.6	3.5	17.1	33.7
Staple length, cm	11.2	4.2	5.0	26.0
Staple strength, N/ktex	76	21	25	140
Staple strength SD	14	8	0.5	39
Curvature, $^{\circ}/\text{mm}$	27.8	10.6	9.9	49.2
Resistance to compression, kPa	4.69	0.75	2.84	6.67

Table 5. Correlation between staple strength (SS), resistance to compression (Rc) and other fibre attributes of Huacaya and Suri alpaca. Bold values are statistically significant, $P < 0.05$

Attribute	Huacaya			Suri		
	SS	Rc	Curvature	SS	Rc	Curvature
Clean fleece weight	0.16 [#]	0.27	-0.07	-0.59	-0.04	0.60
MFD	0.55	0.20	-0.16	-0.13	-0.50	0.46
MFD SD	0.43	0.04	-0.18	0.18	-0.77	0.27
CV(D)	-0.06	-0.24	-0.08	0.40	-0.53	-0.05
Staple length	-0.35	-0.02	-0.23	-0.67	-0.50	0.58
Clean yield	0.16	0.04	-0.14	-0.61	-0.57	0.54
Rc	0.21			0.08		
Curvature	0.12	0.52		-0.51	-0.17	
Curvature SD	0.25	0.27	0.63	-0.11	0.70	0.33

[#] Pairs of variables with positive correlation coefficients and significant P values tend to increase together. For pairs of variables with negative correlation coefficients and significant P values, one variable tends to decrease while the other increases. For other pairs of variables there was no significant relationship.

Table 6. Linear and multiple linear regressions relating staple strength (SS) and resistance to compression (Rc) to other fibre attributes

Dependent variable	Constant (\pm se)	Regression constant	Independent variable	r	R ²	RSD
Suri Rc	7.92 (0.70)	-0.422 (0.112)	MFD SD	0.77	0.59	0.52
Suri Rc	4.03 (0.52)	+0.053 (0.018)	Fibre curvature SD	0.70	0.49	0.59
Suri Rc	6.43 (1.08)	-0.304 (0.127)	MFD SD	0.84	0.70	0.47
		+0.030 (0.018)	Fibre curvature SD			
Huacaya Rc	3.60 (0.20)	+0.037 (0.007)	Fibre curvature	0.52	0.27	0.60
Huacaya SS	26.2 (9.1)	+1.81 (0.31)	MFD	0.55	0.30	17.6
Huacaya SS	7.2 (10.9)	+1.86 (0.31)	MFD	0.61	0.37	16.9
		+0.75 (0.24)	Fibre curvature SD			
Suri SS	105.8 (16.4)	-4.00 (1.49)	Staple length	0.67	0.45	15.5

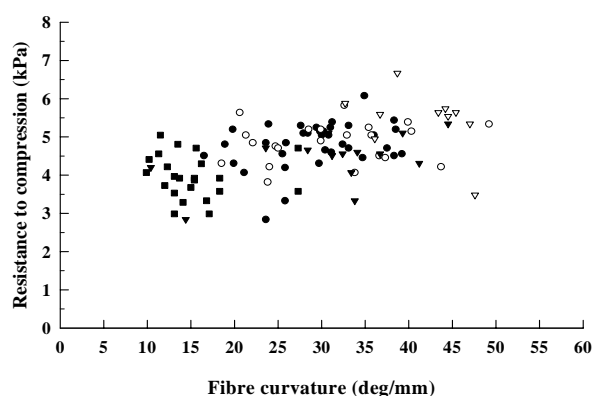


Figure 19. The relationship between mean fibre curvature and resistance to compression of alpaca fibre grown on five different properties in southern Australia

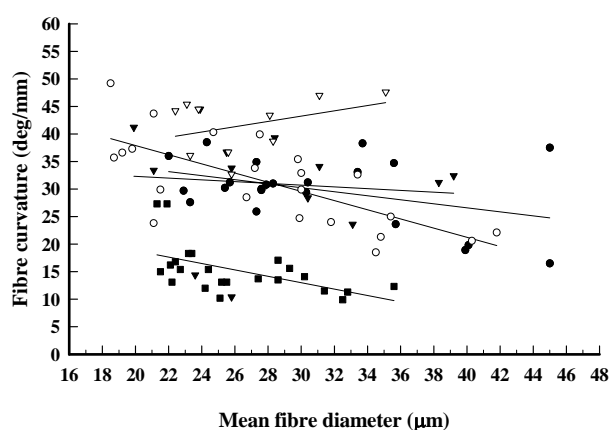


Figure 20. The relationship between mean fibre diameter and mean fibre curvature of alpaca fibre grown on five different properties in southern Australia

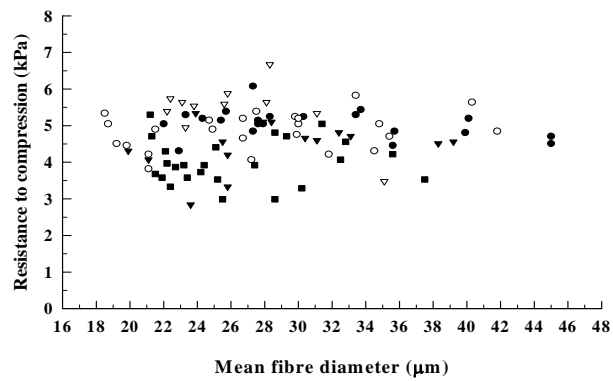


Figure 21. The relationship between mean fibre diameter and resistance to compression of alpaca fibre grown on five different properties in southern Australia

2.3.5. Determining the optimum sampling technique for the objective assessment of fleece quality attributes in Alpacas

Details of the measurement data, derived attributes and other variables are given in Table 7. A complete report is being prepared for publication (Aylan-Parker and McGregor 1999). Significant differences between the means for different samples were detected for MFD, MFDS and CV(D), where the midside sample had lower values than the saddle which in turn had lower values than the pieces ($MS < S < P$; $P < 0.05$). For clean washing yield $MS \approx S < P$, ($P < 0.05$) and the incidence of medullated fibres $MS < P$, ($P < 0.05$).

Table 7. Mean, standard deviation and ranges in measured and derived variables of fleeces used in the measurement of sampling techniques and sampling variance

Variables	Mean	SD	Minimum	Maximum
Age (years)	3.7	2.3	0.3	7.9
Live weight (kg)	66.9	16.5	21.5	123
Weight of fibre (kg)				
Saddle	2.01	1.26	0.33	5.69
Neck	0.74	0.27	0.16	0.93
Pieces	0.86	0.62	0.11	4.54
Total fleece weight	3.13	1.51	0.47	9.25
Mean fibre diameter (μm)				
Midside sample	27.5	4.6	19.2	41.0
Saddle grid sample	29.0	4.9	19.4	42.3
Neck grid sample	28.7	6.4	20.6	45.8
Pieces grid sample	37.6	6.9	21.8	57.6
Total fleece (calculation)	30.9	5.5	20.0	45.3
Mean fibre diameter coefficient of variation, CV(D) (%)				
Midside sample	24.4	4.0	16.3	35.2
Saddle grid sample	27.0	3.5	18.4	35.4
Neck grid sample	28.6	4.3	20.9	37.8
Pieces grid sample	30.6	4.2	23.0	43.8
Total fleece (calculation)	28.0	3.3	20.9	36.5
Clean washing yield (%)				
Midside sample	90.2	3.6	78.0	98.0
Saddle grid sample	91.4	3.4	79.9	99.6
Neck grid sample	88.8	2.6	82.6	92.8
Pieces grid sample	93.6	2.7	86.9	99.6
Incidence of medullated fibre (%)				
Midside sample	25.4	18.1	1.5	73.3
Saddle grid sample	33.1	19.8	1.2	75.0
Neck grid sample	44.5	21.6	6.2	85.5
Pieces grid sample	37.3	19.6	3.6	75.2

Mean fibre diameter

The MSMFD and SMFD were highly correlated (Table 8) with the final model accounting for 88% of the variation in SMFD and a slope of approximately 1. TFMFD was also highly correlated with the MSMFD with the final model accounting for 85% of the variation. Sex was significant ($P < 0.05$) in the final model. The model also had a slope very close to one. TFMFD was found to be more highly correlated with the SMFD. The final model, with the inclusion of sex, accounted for 93% of the variation in TFMFD.

Table 8. Regression models for the prediction of mean fibre diameter (MFD, μm) of fleece components (SGS, saddle grid sample; TF, total fleece) from either midside samples (MS) or SGS and the sex and live weight (LWT) of alpacas

Dependent variable	Constant (\pm se)	Regression constant	Independent variable	r	R²	RSD
SGSMFD	2.62 (0.91)	0.95 (0.03)	MSMFD	0.94	87.9	1.63
TFMFD	2.24 (1.29 [#])	1.05 (0.04)	MSMFD		85.2	
		1.57 (0.49)	+ SEX	0.93	86.6	1.81
TFMFD	1.65 (0.88 [#])	1.03 (0.03)	SGSMFD		91.3	
		1.59 (0.32)	+ SEX		93.0	
		0.02 (0.01)	+ LWT	0.97	93.2	1.38

[#] indicates the constant was not significant ($P > 0.05$)

Mean fibre diameter coefficient of variation

Models predicting S CV(D) and TF CV(D) were moderately correlated with MS CV(D). In contrast, the TF CV(D) was highly correlated with the S CV(D). Sex had a small, but significant effect on the model ($P < 0.05$, Table 9). N CV(D) was poorly correlated with MS CV(D) and S CV(D). For N CV(D) live weight was significant in both models ($P < 0.05$), accounting for an additional 12% of the variation (regression not shown).

Table 9. Regression models for the prediction of mean fibre diameter coefficient of variation (CV(D), %) of fleece components from either midside (MS) or saddle grid samples (SGS)

Dependent variable	Constant (\pm se)	Regression constant	Independent variable	r	R²	RSD
SGS CV(D)	10.2 (1.30)	0.69 (0.05)	MS CV(D)	0.77	59.6	2.23
TF CV(D)	13.9 (1.4)	0.59 (0.05)	MS CV(D)	0.71	50.3	2.31
TF CV(D)	4.15 (1.09)	0.84 (0.04)	SGS CV(D)		80.2	
		1.11 (0.31)	+ SEX	0.91	82.1	1.38

Other fleece parameters

Clean washing yields for the MS, S, N and P were all similar (Table 7) and were very highly correlated with fleece components with slopes not different from 1.0.

The incidence of medullated fibres in the MS was 7% less than in the S, 11% less than in the TF and 18% less than in the P (Table 7). While TFMed and SMed were highly correlated with MSMed, the RSD for these models were particularly high, RSD = 9.7 and 10.6 % respectively, indicating the difficulty in predicting these measures. The TFMed was very highly correlated with SMed, Sex made a small, but significant ($P < 0.05$) improvement in the model.

Sampling variance and 95% confidence limits

Sampling variance for SGS was generally 2 to 4 times greater than the sampling variance for MS with the 95% confidence limits for SGS being about double those of MS for most parameters (Table 9) except for clean washing yield which were similar. Sampling variance for the incidence of medullated fibres in SGS were very high. The 95%CL for MFD of SGS was affected by one outlier, which if removed reduced the 95%CL to 2.8 μm .

Table 10. Sampling variance and 95% confidence limits for midside samples and saddle grid samples in alpacas

Fleece attribute	Midside sampling		Saddle grid sampling	
	Variance (s^2)	95% Confidence limits	Variance (s^2)	95% Confidence limits
MFD	0.7	1.6	3.6	3.7
SD	0.1	0.8	0.7	1.6
CV(D)	1.4	2.3	3.4	3.6
Med %	12.2	6.9	74.8	16.9
CWY	4.4	4.1	6.0	4.8

2.3.6. Comparative studies of the effect of seasonal conditions on the productivity and fibre quality of Huacaya alpacas and Merino sheep grazed on annual pastures

Live weight changes, annual fleece production and fleece quality

A summary of the main results is provided. More detailed progress results have been provided to industry (McGregor 1998) and a full report is being prepared for publication.

Alpacas and sheep gained live weight from the commencement of the study until October 1996 (Figure 22), the gain for sheep being statistically significant ($P < 0.001$) while that for the alpacas was not significant. All animals then lost live weight reaching minima in winter 1997 before commencing live weight gain until late spring 1997. The proportional loss in live weight between these maxima and minima was similar: mean % loss, alpacas 22, sheep 20 (NS); median % loss, alpacas 21, sheep 23 (NS).

Under conditions of slightly improved but restricted provision of green pasture herbage the alpacas showed a greater ability to gain live weight compared to the sheep. In June 1997, alpacas gained 1.7 kg while sheep lost 1.8 kg ($P < 0.001$), and in November 1997, alpacas gained 3.1 kg while sheep lost 0.6 kg ($P < 0.001$).

Between live weight minima in winter 1997 and the maxima in late spring sheep displayed their ability to rapidly compensate for live weight loss by gaining a proportional 32% while alpacas gained 16% ($P < 0.001$). The maximum growth rate for sheep was 315 g/day, when pasture conditions were ideal in September and October 1997, compared to the growth of the alpacas of 101 g/day ($P < 0.001$). As a consequence, in late October 1997, for the first time in the study, there was no significant difference in the live weight of alpacas and sheep (alpacas 68.7 ± 5.0 , sheep 66.4 ± 8.1 kg, NS).

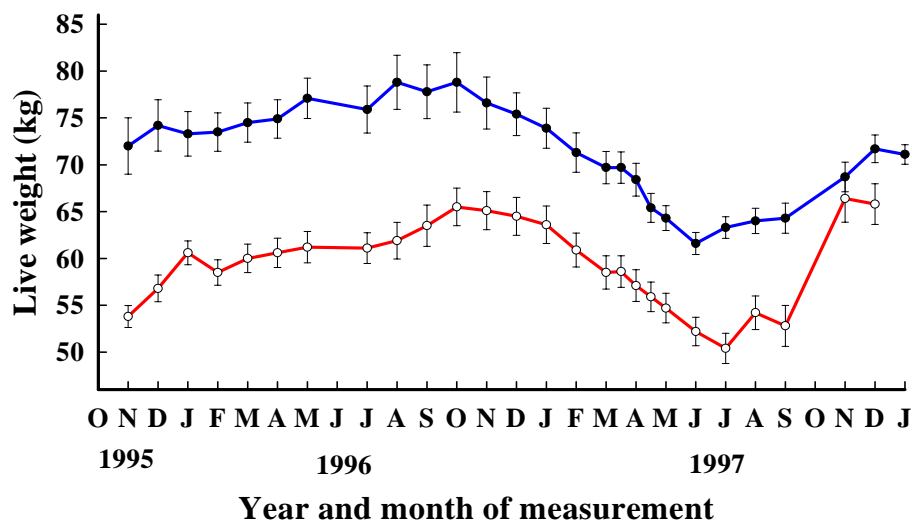


Figure 22. Live weight changes of Huacaya alpaca (●) and Merino sheep (O) grazing the same annual pasture at Attwood, Victoria (mean \pm se)

There was a difference between alpacas and sheep in the effect of the changed nutritional conditions on the total production of fibre. Whereas the alpacas and sheep grew significantly less clean fibre in 1997 (alpacas, $P < 0.002$, sheep, $P < 0.02$, Table 11) the relative decline in clean fleece weight for sheep was only half that of the alpacas (alpacas - 33%, sheep - 17%). The clean weight of the saddle component of the alpaca fleece was also significantly reduced in 1997 compared to 1996: 1.32 ± 0.28 vs 0.87 ± 0.23 , $P < 0.005$).

The adverse nutritional conditions in 1997 resulted in a significant reduction in clean fibre growth, clean washing yield, staple length and mean fibre diameter (MFD) of wool and alpaca, significantly increased MFD CV(D), fibre curvature and resistance to compression of wool and significantly reduced staple strength of wool but not of alpaca (Table 11).

Table 11. Attributes of alpaca and wool shorn from experimental animals in 1996 and 1997 (mean \pm SD), and the significance of differences in the mean values between years

Fibre attribute	Alpaca			Wool		
	1996	1997	P	1996	1997	P
Greasy fleece weight, kg	3.01 \pm 0.63	2.09 \pm 0.42	0.003	5.61 \pm 0.84	4.96 \pm 0.73	NS
Clean washing yield, %	95.2 \pm 2.2	91.5 \pm 2.5	0.006	73.7 \pm 3.2	69.1 \pm 4.1	0.02
Clean fleece weight, kg	2.86 \pm 0.58	1.91 \pm 0.36	0.001	4.12 \pm 0.55	3.42 \pm 0.50	0.02
Mean fibre diameter, μ m	37.5 \pm 2.7	35.2 \pm 2.6	0.09	22.4 \pm 2.4	20.5 \pm 1.9	0.02 [#]
CV(D), %	23.3 \pm 3.2	25.1 \pm 4.0	NS	16.1 \pm 1.3	18.0 \pm 0.8	0.003
Mean medullated fibre diameter, μ m	41.5 \pm 2.2	39.1 \pm 1.5	NS	-	-	-
Medullated fibres, % number	76.4 \pm 1.8	69.3 \pm 8.7	NS	-	-	-
Medullated fibres, % w/w	67.5 \pm 1.1	60.1 \pm 9.9	NS	-	-	-
Staple length, mm	94 \pm 5	77 \pm 7	0.001	96 \pm 7	76 \pm 9	0.001
Staple strength, N/ktex	54 \pm 14	46 \pm 17	NS	54 \pm 4	40 \pm 7	0.001 [#]
Curvature, $^{\circ}$ /mm	24.6 \pm 2.9	26.4 \pm 3.4	NS	97.9 \pm 8.0	105.5 \pm 6.4	0.05
Crimp frequency, /cm	1.2 \pm 0.8	1.1 \pm 0.8	NS	5.8 \pm 0.8	5.7 \pm 1.1	NS
Resistance to compression, kPa	5.05 \pm 0.38	5.09 \pm 0.47	NS	10.00 \pm 0.42	10.40 \pm 0.62	0.06 [#]

[#] Determined using Mann-Whitney Rank Sum Test

Seasonal changes in fibre growth rates and fibre quality

The fibre samples taken from the midside patches showed that:-

- 1) fibre growth rates for wool tended to decline from the start of the study until live weight minima in July 1997 and then increased. Alpaca fibre growth rates were relatively constant until January 1997, then declined until live weight minima before increasing to their previous level.
- 2) seasonal conditions affected the monthly fibre diameter. These changes in the MFD of alpaca closely paralleled changes in fibre growth rate but the MFD minima was reached in April 1997 and the subsequent maxima in September 1997, eight weeks prior to the respective minima and maxima of fibre growth rate or live weight. Similarly with sheep the MFD tended to decline in parallel with a decline in fibre growth rate and MFD minima was reached in May 1997 eight weeks prior to the minima in fibre growth rate. The subsequent MFD maxima in November 1997 coincided with fibre growth rate and live weight maxima.
- 3) seasonal conditions affected the MFD SD of alpaca which tended to increase during the study while the MFD SD of wool remained constant.
- 4) seasonal conditions affected the CV(D) of alpaca which increased from 21% to 24% whereas the CV(D) of wool varied only slightly around 16%. The CV(D) maxima for both fibres during 1997 occurred at the time of MFD minima.
- 5) seasonal conditions did not change the fibre curvature of alpaca but in wool the fibre curvature increased as the study progressed.

Grazing behaviour and productivity

A full description of the changes in pasture composition and grazing behaviour is provided in other reports. The study has shown that alpacas :

- 1) are selective grazers with a strong preference for short green grazed pasture. The alpacas generally avoided grazing long dry grass and avoided grazing green shoots within dead grass clumps preferring to graze very short green grass sprouts.
- 2) lost live weight when pastoral conditions were such that the provision of green pasture was less than 0.5 t DM/ha and
- 3) gained live weight gain when green pasture availability exceeded 0.5 t DM/ha.
- 4) fibre growth rate was reduced when green pasture availability was < 0.5 t DM/ha. When green pasture availability was 0.5 to 1.2 t DM/ha alpaca fibre growth rates were similar to when green pasture availability was in surplus (1.6 to 5.0 t DM/ha).

2.4. DISCUSSION AND IMPLICATIONS FOR INDUSTRY

The fibre research project was designed to provide baseline information about;

- 1) variation in alpaca fibre production and alpaca fibre quality in Australia
- 2) expected supply of differing qualities of Australian alpaca for marketing and processing
- 3) the influence of production variables on alpaca fibre production and quality.

The first two objectives are discussed together.

2.4.1. Production and quality of Australian alpaca fibre

Production and supply of Australian alpaca

The Huacaya alpacas available for this study had an annual fleece production of 2.5 kg/animal/year (Figure 2). These alpaca had much greater live weights than the 45 kg mean live weight reported for peasant farming systems in Peru (Bryant et al, 1989) but were similar to the live weights reported for alpacas farmed in high input systems in Peru and New Zealand where live weights of 56 to 73 kg were measured (Davis et al 1991). Consequently the mean annual production of these Australian alpacas exceeded that reported for peasant systems in Peru, 1.2 kg per animal (only 30% of animals being shorn each year) and also exceeded that reported for high input systems in Peruvian Cooperatives, 1.6 kg per animal (with 60% of animals being shorn) and in New Zealand where 3 year old adult Huacaya alpacas grew 1.7 kg (hembra) and 2.8 kg (machos) at fibre diameters of 28.8 and 30.6 µm respectively.

With the current Australian alpaca population estimated at 20,000 (D. Johnson pers. comm.) the current estimated annual production of alpaca fibre in Australia is $20,000 * 2.5 \text{ kg/head} = 50$ tonnes. This production would consist of approximately 28 tonnes saddle, 8 tonnes neck and 14 tonnes pieces.

Estimates of the supply of differing qualities of saddle fibre being produced by the Australian industry and which need to be sold or processed into textiles can be made by multiplying the

incidence of each measured attribute as shown in the distribution histograms with the estimated production of saddle fibre.

Within the existing alpaca population and under current management systems significant quantities of saddle fibre meet the following quality standards:

- 70% of fibre of suitable length for worsted processing (20 tonne)
- 98% of tested fleeces had sound staple strength (> 35 N/ktex) with a mean value of 76 N/ktex
- 10% of fibre had a mean fibre diameter < 24 μm (approximately 3 tonne)
- nearly 40% of Huacaya fibre had a CV(D) $< 24\%$
- 30% of Huacaya and Suri fibre had $< 20\%$ of their fibre population medullated
- the softness of Australian alpaca, when measured as resistance to compression, was superior to that reported for Merino wool.

Simple adjustments to the farm management system, as discussed in section 2.4.2 of this report, should result in over 90% of the fibre being suitable for worsted processing and significantly greater quantities of fibre with a mean fibre diameter < 24 μm .

It is clear that marketing arrangements for the current alpaca clip have to include the following lines which, in the longer term, may not be economic to maintain at their current size:

- overgrown fibre. With 20% of Huacaya and 30% of Suri fibre exceeding 15 cm a substantial quantity of overgrown fibre is being harvested. Significant amounts of this overgrown fibre is fine fibre from the first shearing of tui aged alpacas. It is a significant waste to have this fine and potentially highest quality tui alpaca fibre consigned to the “overgrown fibre” category. It may be possible to stretch break this fibre, thus providing lower hauteur for spinning but the very high staple strength of Australian alpaca fibre may preclude this option. If overgrown fine fibre is going to remain a feature of the Australian industry then specific arrangements must be made for processing.
- coarse fibre categories. About 70% of Huacaya and Suri alpaca fibre currently fits into the coarse fibre category which has a mean fibre diameter exceeding 29.9 μm . The incidence of coarse fibre is made up of the following:
 - all fibre in the midside distribution histogram (Figure 4) exceeding 29.9 μm representing 50% of total saddle and neck fibre
 - saddle and neck fibre with a mean midside fibre diameter of 28.5 to 30.0 μm . This fibre is included as the study on sampling techniques indicated that the saddle has a mean fibre diameter 1.5 μm greater than the midside sample. This fibre represents 10% of the harvested saddle and neck fibre
 - all the pieces component of the shorn fibre representing about 28% of harvested fibre
 - total fibre in the coarse category is therefore (50 + 10%) of the saddle and neck fibre = 21.6 tonne plus 14 tonne of pieces = 35.6 tonne representing 71% of alpaca fibre currently produced.

Recommendations

- significantly increase animal fibre production by identifying superior sources of genetic material
- determine if recent imports of genetic material, unavailable for this study, are more productive than the present base herd
- evaluate the medullated fibre content of sires before use.

Staple strength

Staple strength of Australian alpaca is currently very high, in part a result of the high mean fibre diameter. Changes to animal management which result in a reduction in mean fibre diameter will lead to a reduction in fibre strength of alpaca but are unlikely to result in commercially significant problems.

Mean fibre diameter coefficient of variation

Improving the spinning performance and the quality of alpaca fibre are important elements in the establishment of a viable alpaca industry in Australia. These outcomes will be assisted by a progressive reduction in the CV(D) of alpaca fibre. A high CV(D) is associated with reduced spinning performance and reduced comfort properties of textiles. By comparison, the CV(D) of Australian Merino wool averages 24%. This study has documented differences in CV(D) between Huacaya and Suri breeds. Suri alpaca fibre had a CV(D) 1.7% higher than that observed for Huacaya. At a common mean fibre diameter of 28 μm this translates into a difference in spinning fineness of approximately 0.4 μm .

Recommendations

It is recommended that the following concepts be adopted by the Australian Alpaca industry:

- in order to produce finer processing alpaca fibre with improved comfort and handling properties the Australian alpaca industry set an objective to lower the spinning fineness in Australian alpaca
- that trading in alpaca fibre be on the basis of spinning fineness
- that alpaca fibre is only tested in laboratories which can provide mean fibre diameter and CV(D) measurements incorporated into a spinning fineness measure
- spinning fineness is used as the basis for assessing alpacas for import
- spinning fineness should be used in fleece competitions and in animal selection and breeding programs.

Incidence of medullated fibres

The Australian alpaca clip has a lower than expected incidence of medullated fibres based on a comparison with Peruvian alpaca textiles and fibre in Peruvian classing warehouses. Medullated fibre contamination is regarded as the most serious fibre quality issue confronting the Peruvian alpaca industry. This may be explained by the methods of fibre preparation used in Peru, where the entire harvested fleece is wrapped into a ball prior to sale and transport, thus allowing medullated fibres in the “pieces” component to contaminate the saddle. The measurements taken in this study showed that the pieces had 33% more medullated fibres than the saddle component. During this study the pieces component was kept separate from the saddle where possible during the harvesting and subsequent handling.

The study on sampling methods indicated that the estimation of the level of medullated fibre within saddles had a large variance. It is important that causes which increase the sampling variance of medullated fibre measurement are identified and methods developed to reduce their influence. Without reliable procedures for measuring the incidence of medullated fibre the

successful development of selection programs to reduce these fibres will be less effective. This is not to imply that the OFDA measurement technique is deficient. The OFDA measurement method was rapid and cost effective. Further improvement in the sample preparation and measurement procedure (replication, sample size etc) are desirable.

Medullated fibres are more noticeable in fine alpaca as the fibre diameter of medullated fibre is up to 40% greater than the MFD for the fleece whereas in coarser fleeces the differential between the fibre types declines to about 10%. It is unlikely that the medullated fibres in fine alpaca will be differentially removed during worsted processing. Differential removal of coarse medullated fibres occurs during specialist de-hairing in cashmere processing where the diameter of the medullated fibres is about 3.5 to 4 times that of the preferred fibres.

Recommendations

It is recommended that the Australian alpaca industry:

- focus on the production of fine alpaca fibre
- continue to develop a comprehensive program of training and education with the objective of reducing the contamination of the saddle fleece with medullated fibres and other contaminants
- continue to develop fleece harvesting guidelines which focus on improving fibre quality by incorporating the relevant findings of these studies
- support research to identify the causes of high sampling variance of medullated fibre measurements and identify methods to reduce their influence.

Resistance to compression, crimp and fibre curvature of Australian alpaca

This study provides the first comprehensive report on the softness of Australian alpaca fibre as measured by its resistance to compression. The study indicates that the resistance to compression of Australian alpaca is much less than that normally reported for Australian Merino wool. As a specific example the results of the controlled grazing study showed large differences in resistance to compression of medium Merino wool and typical adult alpaca.

Fibre curvature measurements declined with increasing Huacaya fleece weight and in Suri were highest in cria with live weights less than 30 kg. Variability in fibre curvature of Suri fibre was related to variation on the resistance to compression of Suri fibre. Huacaya alpaca resistance to compression was clearly related to fibre curvature. The regression equations indicated that reducing the fibre curvature of alpaca tended to reduce resistance to compression. However variation in fibre curvature only accounted for 27% of the variation observed in resistance to compression. Clearly fibre curvature measurements can be used as an indirect measurement index for resistance to compression and curvature measurements taken during other fibre testing will avoid the much more laborious testing requirements for the direct measurement of resistance to compression.

Highly crimped wools are more resistant to compression than low crimped wools of similar mean fibre diameter. Recent studies have shown that low crimp wools have a softer handle which transfers through processing to produce softer, smoother and leaner fabrics (Madeley 1994, Stevens 1994). However in the woollen processing system higher bulk yarns are required and so it may be desirable to breed higher crimped fibre for this end use. Reducing staple crimp

frequency and increasing crimp definition while maintaining other wool characteristics has the potential to increase Hauteur and reduce waste during carding and combing (Stevens and Crowe 1994). These potential commercial benefits of low crimp and fibre curvature are currently of little practical value given the current state of shearing practices in the Australian alpaca industry as discussed in section 2.4.2.

Marketing Australian alpaca and international alpaca specifications

For fibre marketing businesses to develop confidence in their ability to prepare alpaca lots to meet spinners orders some precision in and predicability of this preparation is necessary. This project enabled some preliminary studies to be undertaken in confidence with the Alpaca Fibre Marketing Co-operative. Since these preliminary studies were undertaken further development and standardisation of the fibre preparation protocols have been implemented (I. Knox, per. comm.). Suitable bale sampling methodologies need to be completed using the new preparation protocols before suitable measurement precision will be obtained.

The results of this study provide data which will enable more precision in the preparation of interlotted bales for sale. For example :

- 1) differences in subjective estimation of resistance to compression and subjective handle are likely to be artefacts of other greasy fleece attributes (as discussed in 2.4.2.) and if used in isolation are of little predictive value in estimating mean fibre diameter.
- 2) there should be sufficient fibre to enable a fine line of alpaca to be prepared with the objective of producing 21 to 23 μm yarn.
- 3) provided the neck is of sufficient length it can be combined with the saddle for classing into fibre diameter categories.
- 4) it will be necessary to have four staple length lines; short fibre less than 7 cm, a medium line of 7.5 to 10 cm which will receive about 40% of the fibre, a 10 to 15 cm line (if processors can deal with some fibre up to 18 cm then the amount of fibre in this line will be increased and the amount of overgrown fibre will be minimised), and an overgrown line of fibre longer than 18 cm.
- 5) it may be possible to place some pieces from very fine fleeces into a short staple length line of medium fibre diameter.

The International Alpaca Association (IAA) is an association of commercial businesses and breeders whose office is based in Arequipa, the centre of the Peruvian alpaca trading and processing industry. The IAA have registered Alpaca Trade Marks for the use by licensees on products which meet certain quality standards (Anon 1997). To use the IAA Alpaca Trade Marks the alpaca or unbristled llama fibre must have a mean fibre diameter no greater than 28 μm . Alpaca fibre not meeting this specification may, subject to the quality control standards determined by the IAA, use the IAA HUARIZO MARK.

The implications of the IAA definitions are that only those fleeces which can be classed into lots, which after processing into alpaca textiles, have a mean fibre diameter of less than or equal to 28 μm can be labelled with an IAA Alpaca Trade Mark. Consequently all other fibre grown by alpacas could only bear the IAA Huarizo Trade Mark. These IAA definitions conveniently fit with the current production systems, animal types and alpaca fibre produced in the Altiplano region of Peru and Bolivia. It is clearly another matter as to whether the IAA Trade Mark definitions are appropriate to fibre grown by alpacas in Australia under very different environmental, social and economic systems. The IAA Trade Mark definitions make reference to only one quality matter of importance to alpaca processors and consumers ignoring quality

attributes such as the incidence of medullated fibres, the incidence of contaminated fibre and fibre diameter variability.

Given the relatively small range observed in the resistance to compression of alpaca it is unlikely during greasy fleece classing of alpaca that sufficient and repeatable differences could be detected to reliably create two or more lines of softness. It is important to note that resistance to compression measurements are conducted on clean scoured fibre samples under controlled moisture conditions. In the shorn raw fleece coarse soil particles, grease, moisture absorbed in the suint as well as perceived differences in fibre diameter will confound subjective attempts to estimate softness of handle. Indeed attempts to use differences in resistance to compression to estimate mean fibre diameter are also of no statistical value (Figure 21).

Recommendations

It is recommended that the Australian alpaca industry:

- continue to develop and define the quality standards by which fibre grown by alpacas in Australia and processed into textiles can use an appropriate Alpaca mark
- develop a data base documenting the quality attributes of Australian alpaca
- engage the IAA in discussions regarding the suitability of the present IAA Trade Mark specifications
- develop testing procedures to enable the main determinants of processing performance of pooled alpaca lots to be determined.

2.4.2. The influence of production variables on alpaca fibre production and quality

Shearing management

The conduct and timing of shearing is of critical importance to improving the financial performance and production of quality fibre. Shearing practices also impact significantly on the ability of processors to obtain the premium qualities of alpaca fibre required for apparel.

Age at first shearing

Data shows that most of the finest fleeces harvested are categorised as overgrown. This is occurring because first shearing is often being delayed until 17 to 24 months of age. In this study it was clear that both Huacaya and Suri cria have fibre of excessive length (exceeding 15 cm) for worsted processing at 12 months of age. Measurements showed that shearing at 8 months of age would produced staple lengths of 12 to 13 cm with mean fibre diameter of approximately 24 μm . Given the relationship between mean fibre diameter and staple strength such finer fibre would be expected to have a lower staple strength although still adequate for processing.

Recommendations

It is recommended that the Australian Alpaca industry:

- in order to maximise production of fine baby alpaca fibre with a mean fibre diameter of about 24 μm and of acceptable length for worsted processing that suitable management practices be developed which allow cria be shorn at approximately 8 months of age without endangering their welfare
- all cria should be shorn prior to their staple length reaching 15 cm (which in this study was prior to 12 months of age).

Shearing management alpacas

Present management practices are such that they result in fleece weights of alpacas being the greatest at 2 to 3 years of age with most of the alpaca fibre harvested from these animals being classed as overgrown. This is partly because age at first shearing has been delayed and partly because alpacas up to this age are not physiologically stressed from mating, pregnancy or lactation.

One of the major impediments to improved fibre harvesting is the inefficiency of present shearing practices. The present shearing method for alpacas has a high labour unit requirement and a low productivity rate, resulting in significantly higher costs for alpaca production compared to the wool, mohair and cashmere industries.

Recommendations

It is recommended that the Australian Alpaca industry:

- alpaca managers adopt shearing intervals which allow fibre from tuis and young adults to be classed in standard fleece lines (< 15 cm)
- shearing strategies be developed for tuis and young adult alpacas aimed at maximising the harvest of high quality fibre of acceptable fibre length
- alternative methods are developed to substantially lower the cost of alpaca fibre harvesting.

Management of breeding alpacas

The progressive decline in fleece weight from 3 years of age indicates that the effects of physiological stresses are reducing the growth of fibre. The physiological stresses from pregnancy and lactation and age related changes in the maturation, activity and senescence of skin fibre follicles are likely to be the main contributors to this decline in fibre growth.

While the generally excellent provision of pastures during this study would indicate that the nutrition of the alpacas was maintained at very high levels, the study of staple strength showed clear between property differences in fibre attributes. The results of the controlled grazing of alpacas and Merino sheep also demonstrated that seasonal changes in nutrition affected fibre growth and fibre quality of non-breeding alpaca. The Australian alpaca industry should expect that as more commercial grazing pressures become adopted through out the industry and with improved mating management resulting in more alpacas of breeding age experiencing physiological stress during pregnancy and lactation that the quality of alpaca fibre will alter.

Clearly fibre quality traits also showed a steady decline after alpacas reached 3 years of age with:

- mean fibre diameter increasing
- staple length declining
- incidence of medullated fibres increasing.

Until such a time that alpaca producers implement animal culling practices which remove poorer quality fibre from the market, the alpaca industry should expect the actual quantity of poorer quality fibre offered for sale to increase.

2.4.3. Optimising sampling techniques

In order to effectively assess the fibre quality of alpacas the most appropriate sampling technique is required. This study sampled a cross section of the base breeding population including different sexes, breeds and properties with a wide variation in live weight (21 to 123 kg) and age (0.5 to 7.9 years) with MFD of saddles ranging from 19.4 to 39.8 μm , with CV(D) ranging from 18 to 35%.

Usefulness of midside sampling

Regression analyses showed that samples taken from the midside site were good predictors of :

- saddle, neck and total fleece MFD. While the SMFD was a slightly better predictor for TFMFD than MSMFD, both methods were highly correlations with TFMFD and so ranking animals would be equally effective suggesting that MS would appear to be quite adequate.
- saddle, neck, and total fleece yield and clean fleece weight. Slopes for all models including those with saddle clean washing yield as a predictor were similar indicating that the dust, dirt and grease content must have been fairly equally distributed over the body.
- sex, age and liveweight were of little additional value in predicting any of the measured fibre quality attributes studied. Male alpacas tended to have coarser total fleeces, mainly as a result of having relatively coarser pieces compared to the female alpacas. The neck was also coarser in the males in this study compared to the female alpacas. Older alpacas also tended

to have coarser necks than younger alpacas. Therefore the MS tended to underestimate the MFD of the total fleece of males and older animals compared to females and younger animals.

- Neither breed type or property accounted for sufficient variation in fleece quality traits in this study and were not significant in any model.
- Generally, the alpacas with heavier live weights (which were mostly the older animals and particularly the males) had courser pieces with a higher percentage of medullated fibres, than the animals of lower live weight. Therefore the total fleece characteristics were underestimated in the heavier, rather than lighter animals if liveweight was not included in the model.

2.4.4. Advantages of saddle grid sampling

Prediction of coefficient of variation of mean fibre diameter

This experiment indicates that there is a large variation in CV(D) over the body. In each case the fleece components (saddle, neck and total fleece) were poorly correlated with the MSCV. Thus unlike Merino sheep, where the variation over the body is small enabling a single MS staple to be used to adequately predict the fleece CV(D) (Fleet *et al.*, 1993), the MSCV is an inappropriate sampling site from which to estimate the saddle fleece CV(D). Clearly the reason for this is that in alpacas there is significant variation in the MFD over the body and this variation is associated with an increased variation in CV(D). The SGS was a better predictor for CV(D) because it contains samples drawn from a larger surface area and thus taking more of the between fleece staple and between location variation into account. This study clearly indicates that breeders wishing to improve CV(D) and/or spinning fineness measurements should use the SGS.

Prediction of medullation fibre attributes

The SGS was a better predictor of total fleece medullated fibre attributes than the MS. The structure of the alpaca fleece is such that there is a high percentage of coarse, medullated fibres on the extremities of the shorn fleece, namely in the pieces comprising the legs, belly and apron. It is therefore not surprising that the MS, could not accurately predict the medullated fleece characteristics. However there is a very high sampling variance in SGS estimates of medullated fibre attributes.

Sampling variance and 95% confidence limits of fleece tests results

Confidence limits (CL) for MFD ($\pm 1.6 \mu\text{m}$) show that alpaca breeders and advisers need to exercise caution when interpreting fibre test results and in applying them in selection programs. Small differences ($< 1.0 \mu\text{m}$) in MFD, based on one test result, are not valid grounds upon which to discriminate against animals. This interpretation has even greater weight when using SGS to select animals. In some breeding programs it may be preferable to use the MS for the selection of alpacas for all fibre attributes given the reduced variance in fibre test results.

The greater variance in medullated test measurements is partly due to the following; greater variability in the distribution of medullated fibres over the saddle compared to the midside sample, random differences in the effectiveness of separation of pieces the shorn fleece from the

saddle components and the smaller number of samples in the medullated fibre test owing to the restriction on the test method to white fleeces.

The relatively large variance for clean washing yield suggests that the practice of some commercial test houses in making only one estimate for clean washing yield is fraught with danger, especially if the results of such testing are to be used in genetic selection programs.

Until the 95% CL for medullated fibre attributes can be reduced the effectiveness of selection against these attributes will be reduced.

Practical issues in using the midside sample and saddle grid sample

The MS is easy to locate and does not require shearing the entire fleece, which in some situations is desirable. Such situations include; testing of fleeces prior to shearing to aid fleece classing and lot building, testing of sires and breeding stock prior to mating, selling of animals in mid winter, testing of cria and tui before their first shearing, live animal fleece judging competitions.

Recommendations

It is recommended that provided alpacas are measured in similar age and sex groups:

- the midside sampling technique be used if alpacas are to be selected for characteristics such as low mean fibre diameter and high fleece weight
- saddle grid sampling be used if alpacas are to be selected for mean fibre diameter coefficient of variation, incidence of medullated fibres and other characteristics of medullated fibre
- alpaca breeders and advisers need to be cautious in discriminating against animals on the basis of small differences in test results given the large 95% confidence limits observed for all fibre test attributes
- clean washing yield measurement methods should use duplicate samples and results which are outliers in a population should be retested.

2.4.5. Influence of production variables on alpaca fibre production and quality

The grazing conditions encountered during this study are commonly experienced in grazing districts in the moderate to high rainfall regions. Nutritional conditions ranged from abundant to limited green pasture availability.

Live weight change and management

This study showed that in general when nutritional conditions resulted in:

- sheep losing live weight alpacas also lost live weight
- sheep gaining live weight alpacas also gained live weight

The study provides some evidence that alpacas can be:

- more responsive in live weight gain to slight increases in pasture quality or availability than Merino sheep under conditions when green pasture availability was very low.
- The study also illustrates that adult alpacas can effectively compete with sheep when green pasture availability is relatively low (0.5 to 1.2 t DM/ha) but:
- alpacas are less responsive in live weight change to large increases in green pasture availability. When green pasture availability was < 0.5 t DM/ha alpaca fibre growth rate was reduced but when green pasture availability was 0.5 to 1.2 t DM/ha alpaca fibre growth was similar to when green pasture availability was in surplus (1.6 to 5.0 t DM/ha). These observations may have some direct applicability regarding the choice of suitable grazing environments for alpacas.
- Under present management practices, on the majority of alpaca properties, alpacas are grazed with excessive provision of green pasture. Grazing alpacas on under-grazed long rank pastures during spring will not only cause damage to pastures, but it will result in reduced pasture productivity and lost opportunities to convert quality pasture into animal products.

Effect of adverse nutritional conditions on fleece growth and quality

This study showed that in general when nutritional conditions resulted in adult alpacas losing live weight they also grew less fibre. When fibre growth declined it was associated with a decline in fibre diameter and clean fibre content of greasy fleeces.

Whereas the annual fleece growth of adult Huacaya alpacas was affected to a greater extent than the annual fleece growth of Peppin Merino sheep, in terms of fibre quality measurements the alpaca fleece was little affected by a significant reduction in nutritional conditions whereas the fibre quality measures of wool were all significantly affected.

The study also illustrated that the simplistic concept that alpaca fibre diameter increases with age is not reliable. As alpacas age under good nutrition mean live weight increases, but under nutritional conditions leading to alpacas losing live weight, live weight is much more likely to account for more variation in fibre diameter than age.

These experimental alpacas had an annual fleece production of 3.0 kg in the excellent grazing year and 2.1 kg in the drought year. This compares to a mean greasy fleece production observed on the 4 commercial stud farms for 5 to 7 year old Huacayas of 1.9 to 2.6 kg annually. It appears therefore that the productivity of the experimental animals was typical of farmed Australian alpacas.

Recommendations

The practical recommendations are that:

- to optimise alpaca fibre growth alpacas should be managed so that the provision of green herbage exceeds 0.5 t DM/ha but does not exceed 1.2 to 1.6 t DM/ha
- alpaca farmers should increase the effective use of their pasture by the addition of more grazing live stock and/or the making of pasture hay
- further studies be undertaken into the effects of the provision of pasture and feed supplements on alpaca live weight change, productivity and fibre quality.

3. PHENOTYPIC AND GENETIC PARAMETERS FOR SOME PRODUCTION TRAITS IN YOUNG AUSTRALIAN ALPACAS

R.W. Ponzoni

3.1. SUMMARY

Phenotypic and genetic parameters for young Australian alpacas are presented and compared with alpaca reports in the literature, as well as with estimates for Merino sheep. The traits studied were greasy and clean fleece weight (GFW and CFW), fibre yield (YLD), mean fibre diameter (FD), standard deviation and coefficient of variation of FD (SDFD and CVFD), staple length (SL) and live weight (LW). Most mean values fell within those found in the literature, except for YLD, which was greater in our study. YLD, FD, SDFD, SL and LW were greater than for Merino sheep, whereas the opposite was true for GFW and CFW. The heritability was high (0.37 or greater) for all traits. The estimate for LW fell within the range in the literature, whereas for GFW and SL our values were greater. Relative to those for SA Merino sheep our estimates were greater for GFW, CFW, CVFD and LW, whereas they were lower for the remaining traits, except for SL, which had the same value. Phenotypic correlations from the literature were in broad agreement with ours. Those from SA Merino hoggets, except for some correlations involving YLD and SL, were in remarkable agreement with ours. The practical implications of the findings are discussed.

3.2. INTRODUCTION

Phenotypic and genetic parameters are part of the 'building blocks' required in the design of effective livestock genetic improvement programs. There is currently no published information dealing with this aspect of alpacas in Australia, and very little world wide.

In this paper we report results of a preliminary analysis of young alpaca records, we compare them with other reports in the literature, and we comment on the likely implications of our findings. We also contrast the alpaca phenotypic and genetic parameters with those derived from Merino sheep.

3.3. MATERIAL AND METHODS

The data were collected over four years (1994 to 1997) in five cooperating herds (two in South Australia and three in Victoria). The 1994 records were discarded because of uncertainty about the duration of the preceding period of fibre growth. The majority of the alpacas recorded were Huacaya, although some properties had Suri as well. The latter were discarded for the present study. Animals included in the analysis were over one year old and under two years old at shearing time (category usually called 'tuis').

Individual, sire and dam identities were known for most animals. An animal model was fitted using the computer program ASREML (Gilmour 1997), including property (1 to 5), year of record (1995 to 1997) and sex (female or male) as fixed effects. The data set used in the analysis consisted of 435 records, with 40 sires represented, six of which were used in more than one property.

Greasy fleece weight (GFW) was recorded during shearing, and a sample from the mid-side of each animal was taken for the measurement of mean fibre diameter (FD), standard deviation of FD (SDFD), coefficient of variation of FD (CVFD), fibre yield (YLD) and staple length (SL). Live weight (LW) was recorded off shears.

3.4. RESULTS

Table 12 shows the mean and phenotypic standard deviation of the traits studied. For comparative purposes we show the corresponding range of values in the work reviewed by Chavez (1991) and in that reported by Wuliji *et al.* (1992), as well as estimates from South Australian (SA) Merino sheep (ewe hoggets, 16 months old and 12 months of wool growth). We found no reports on SDFD or CVFD for alpacas in the work reviewed. Other mean values fell within those reported in the literature, with the exception of YLD, which was considerably greater in our study. Relative to SA Merino sheep the alpaca means were greater for all traits, except GFW, CFW and CVFD. The phenotypic standard deviations were greater in alpacas for all traits, except GFW, CFW and YLD. Note that YLD was about 20 per cent greater in alpacas than in SA Merino sheep, but it had less phenotypic variation.

Table 12. Means and phenotypic standard deviations (σ_P)

Trait	This study		Other Alpaca reports (Chavez 1991, Wuliji <i>et al.</i> 1992)	SA Merino hoggets ^A	
	Mean	σ_P	Range	Mean	σ_P
GFW (kg)	3.12	0.762	1.7 to 3.64	6.07	0.935
YLD (%)	92.7	2.73	82.0 to 84.7	71.9	5.01
CFW (kg)	2.85	0.702	1.6 to 3.05	4.36	0.736
FD (μm)	25.7	2.97	23.4 to 27.3	22.2	1.93
SDFD (μm)	6.21	1.11	n.a. ^B	5.36	0.753
CVFD (%)	165	40.0	124 to 215	115	11.8
SL (mm)	63.7	12.1	40.6 to 67.8	49.2	5.53
LW (kg)					

^A Data from SA Merino project described by Gifford *et al.* (1993)

^B Not available

Table 13 shows heritability estimates (and their s.e.) for the characters studied, as well as comparative alpaca data from the literature, and estimates for SA Merino sheep. The heritability was high for all traits. Few estimates or suggested values were found in the literature. Our estimate for LW fell within the range reported in the literature, whereas for GFW and SL our values were greater. Relative to those for SA Merino sheep our estimates were greater for GFW, CFW, CVFD and LW, whereas they were lower for the remaining traits, except for SL, in which case we obtained the same value.

Overall one could suggest that in Australian alpacas there is greater scope for selection for GFW and CFW than in SA Merino sheep, whereas the opposite may be true for YLD. With regards to other traits the opportunities would be comparable. Note however, that our estimates for alpacas have large standard errors, and our 'preferred' or 'accepted' parameter values may change when more information becomes available. By contrast, the estimates for SA Merino sheep have much lower standard errors. Note also that because our alpaca data were collected on private properties in which we had very limited control over the husbandry of the animals, there could be biases contributing to our parameter estimates.

Table 13. Heritabilities and standard errors (s.e.)

Trait	This study		Other Alpaca reports (Chavez 1991, Charry <i>et al.</i> 1997)	SA Merino hoggets	
	h^2	s.e.	Range of h^2	h^2	s.e.
GFW	0.83	0.35	0.21 to 0.38	0.41	0.06
YLD	0.37	0.32	n.a.	0.66	0.05
CFW	0.79	0.36	n.a.	0.42	0.06
FD	0.67	0.30	n.a.	0.72	0.06
SDFD	0.66	0.32	n.a.	0.68	0.06
CVFD	0.90	0.30	n.a.	0.71	0.06
SL	0.63	0.48	0.43	0.63	0.06
LW	0.56	0.34	0.27 to 0.69	0.43	0.06

Table 14 shows the phenotypic correlations among the traits studied. We also estimated genetic correlations, but with the limited size of our data set these had very large standard errors (often greater than the estimate itself). By contrast, phenotypic correlations can be estimated much more accurately, and may in the interim be interpreted as good indicators of the magnitude and sign of their genetic counterparts (Lynch and Walsh 1997, p.639). Consequently, we decided on presenting and discussing only phenotypic correlations.

Very few estimates were available in the literature, but for the cases that there were, there was broad agreement with ours. Regarding the phenotypic correlations in SA Merino hoggets, with the exception of some correlations involving YLD and SL, there was remarkable agreement with our alpaca estimates. The exceptions may be explained by the greater (and less variable) YLD in Alpacas (Table 12), and by a degree of uncertainty about the number of months of fibre growth associated with some SL records.

The very high correlation between GFW and CFW suggests that there would be little justification for measuring YLD and CFW in genetic evaluation services for alpacas (note that our estimate of the genetic correlation also was 0.99).

Table 14. Phenotypic correlations and their standard errors (r_p and s.e., respectively)

Traits	This study		Other Alpaca reports (Chavez 1991)	SA Merino hoggets	
	r_p	s.e.	Range of r_p	r_p	s.e.

GFW with						
YLD	-0.10	0.11	n.a.	-0.07	0.02	
CFW	0.99	0.01	n.a.	0.89	0.01	
FD	0.25	0.11	n.a.	0.27	0.02	
SDFD	0.10	0.11	n.a.	0.21	0.02	
CVFD	-0.03	0.11	n.a.	0.06	0.02	
SL	0.58	0.08	0.25 to 0.30	0.21	0.02	
LW	0.32	0.10	0.40 to 0.58	0.40	0.02	
YLD with						
CFW	0.02	0.11	n.a.	0.38	0.02	
FD	0.21	0.09	0.27	0.06	0.03	
SDFD	0.18	0.09	n.a.	-0.11	0.03	
CVFD	0.05	0.09	n.a.	-0.16	0.02	
SL	-0.08	0.10	n.a.	0.23	0.02	
LW	-0.08	0.10	n.a.	0.05	0.03	
CFW with						
FD	0.29	0.10	n.a.	0.27	0.02	
SDFD	0.15	0.11	n.a.	0.15	0.02	
CVFD	-0.02	0.11	n.a.	-0.01	0.02	
SL	0.58	0.08	n.a.	0.30	0.02	
LW	0.32	0.10	n.a.	0.40	0.02	
FD with						
SDFD	0.65	0.06	n.a.	0.45	0.02	
CVFD	0.01	0.10	n.a.	-0.15	0.03	
SL	0.19	0.11	n.a.	0.34	0.02	
LW	0.29	0.09	n.a.	0.23	0.02	
SDFD with						
CVFD	0.76	0.04	n.a.	0.81	0.01	
SL	0.26	0.17	n.a.	-0.01	0.03	
LW	0.03	0.10	n.a.	-0.01	0.03	
CVFD with						
SL	0.20	0.11	n.a.	-0.24	0.02	
LW	-0.18	0.10	n.a.	-0.17	0.02	
SL with						
LW	0.12	0.11	0.12	0.23	0.02	

3.5. CONCLUDING REMARKS

The results presented and briefly discussed in this paper provide the first phenotypic and genetic parameters for Australian alpacas. Note that the information examined in the present study was collected in a different set of environmental conditions from that experienced in the alpaca studies found in the literature, and also from the SA Merino study. Realising that this fact reduces the certainty with which we can make comparative inferences about means and

parameters is important. Nevertheless, there are some messages that may be safely drawn from our study:

Average production levels GFW (or CFW) and FD require attention if Australian alpacas are to become competitive as fibre producing livestock. GFW was well below that of SA Merino, whereas the opposite was true for FD. By contrast, YLD and SL were at such high levels that further emphasis in those traits would not be justified. In refining the emphasis placed in the various fibre traits in alpacas, it would be necessary to ascertain whether their relative importance in processing and in final product attributes is the same as for wool.

3.5.1. Heritabilities

Even after allowing for possible sources of (positive) bias in some of the estimates, one may conclude that there is abundant genetic variation and hence scope for genetic improvement in fibre production and quality among Australian alpacas.

3.5.2. Correlations

With a few exceptions earlier discussed, the phenotypic correlations in alpacas showed a remarkable agreement with those in Merino sheep. As is the case with the latter, the antagonism between GFW (and CFW) and FD was present, but it was not strong enough that it would prevent the simultaneous improvement of both traits by selecting for an appropriate index.

It is concluded that our study provides sufficient pointers to confidently proceed with the development and implementation of scientifically based genetic improvement programs for Australian alpacas. The information gathered in such a program would not only constitute an invaluable tool for breeders in their selection and mating decisions, but it would also have great research value, contributing to refinements in our phenotypic and genetic parameter estimates for Australian alpacas.

3.6. PHENOTYPES RESULTING FROM HUACAYA BY HUACAYA, SURI BY HUACAYA AND SURI BY SURI ALPACA CROSSINGS

3.6.1. Introduction

Two distinct phenotypes can be identified among alpacas (*Lama pacos*), the Huacaya and the Suri (Calle Escobar 1984, Bustinza Choque 1985, Wheeler 1991, Novoa and Wilson 1992). Most (~90 per cent) Alpacas belong to the Huacaya type. Huacayas can be distinguished from Suris by their fleece characteristics. The Huacaya's fibre is sometimes crimped, and may be described as similar to that of Corriedale or of strong wool Merino sheep. The staples grow perpendicular to the skin surface. By contrast, the Suri fleece has a longer and lustrous fibre, which 'hangs' from the skin surface as in Lincoln sheep or Angora goats. The Suri staples show ringlet formations characteristic of Angora goats, and these part along the back of the animal exposing the skin.

When crosses are made between Huacaya and Suri alpacas the progeny distinctly fall into one or the other type (Calle Escobar 1984). This suggests the presence of a major gene influencing the trait. Novoa and Wilson (1992) indicate that Suri could be dominant over Huacaya, whereas Calle Escobar (1984) suggests that the opposite could be true. Both references stress that further matings should be rigorously studied. Note that there is anecdotal information (e.g. Anonymous 1994, C. Tuckwell - personal communication) about a third type (Chili), which is not well documented and is not dealt with here.

In this paper we report results from an alpaca research project described by Tuckwell *et al.* (1996). It is suggested that the trait is controlled by a single gene (or by an haplotype) and that the Suri allele is dominant over the Huacaya allele.

3.6.2. Materials and methods

The data analysed here are part of a broader alpaca study involving five cooperating producers (Tuckwell *et al.* 1996). Full pedigrees were kept on the animals involved in the project, and the phenotype (Huacaya or Suri) of progeny and of both parents was recorded. A total of 204 mating records (and their corresponding progeny) were available for analysis. The mating combinations were: 145 Huacaya sire by Huacaya dam, 24 Suri sire by Huacaya dam, and 35 Suri sire by Suri dam. There were no Huacaya sire by Suri dam matings.

Initially, sex of the progeny and the interaction of sex with mating combination were included in a linear model to ascertain whether there was significant sex effect, and (or) a significant sex by mating combination interaction on progeny phenotype. Both effects were non significant ($P > 0.6$) and were ignored in all later analyses.

A single gene (*AIF*, for alpaca fleece) mode of inheritance was postulated, with two alleles: AIF^h and AIF^s , the latter being dominant over the former. Deviations from the expected phenotypic ratios among the progeny resulting from the different mating combinations were tested by chi-square (corrected for continuity).

3.6.3. Results

Huacaya sire by Huacaya dam matings resulted in 145 Huacaya and no Suri progeny. A single phenotype among the progeny suggests that the parents are homozygous. Also, because no Suri phenotypes were produced from Huacaya sire by Huacaya dam matings one may assume that the AlF^h allele is recessive. The results fit with the hypothesis of a single gene and dominance of the AlF^S allele over the AlF^h allele.

Suri sire by Huacaya dam matings resulted in 13 Huacaya and 11 Suri progeny. These numbers do not deviate significantly ($\chi^2_{1\text{ df}} = 0.21$, $P=0.65$) from a 1:1 ratio. A 1:1 ratio suggests control by a single gene and that one of the parents (the Suri sires in this case) is heterozygous.

Suri sire by Suri dam matings resulted in 6 Huacaya and 29 Suri progeny. These numbers do not deviate significantly ($\chi^2_{1\text{ df}} = 1.4$, $P=0.24$) from a 1:3 ratio. A 1:3 ratio suggests control by a single gene and that both parents (Suri sires and dams) are heterozygous.

We examined the progeny of each Suri sire in our data base. Under the postulated mode of inheritance, a single Huacaya progeny from a Suri sire would be proof that the sire is heterozygous (i.e. carrier of the AlF^h gene). Out of a total of 11 Suri sires in our data base, 9 could be deemed heterozygous using this criterion. The other 2 sires had too few (1 and 3) progeny to be classified as homozygous or heterozygous. Suri dams had insufficient number of progeny to ascertain their genotype, but one may assume that among them the gene frequency is similar to that among sires (i.e. most, if not all, dams are heterozygous). Heterozygosity among Suris could be due to frequent crossing with Huacaya or to heterozygous advantage. We know that crosses between the two phenotypes are frequent, but we are not aware of evidence regarding the possibility of heterozygous advantage.

3.6.4. Discussion

Results from Huacaya by Suri matings have been reported by Novoa and Wilson (1992) and by Flint (1996). Although we lack depth of knowledge about the data sets involved, some comparisons may be made with our findings. Huacaya by Huacaya matings only produced Huacaya offspring in Novoa and Wilson's study, which is in agreement with our findings. However, out of 8446 such matings Flint (1996) reports that 0.45 per cent produce Suri progeny. This is not consistent with our hypothesis that Huacayas are homozygous recessive, but such a small percentage of Suri progeny could be accounted for by errors in recording parental and progeny phenotypes, or when entering the data for analysis. Suri by Huacaya matings result in a 1:1 ratio in Flint's data ($\chi^2_{1\text{ df}} = 0.06$, $P=0.8$), but the deviation from the expected values borders significance ($\chi^2_{1\text{ df}} = 3.08$, $P=0.08$) in Novoa and Wilson's report. Note, however, that in the latter case there are only 12 progeny resulting from this mating combination. In both, Flint's and Novoa and Wilson's reports there is a significant ($P<0.01$) departure from a 1:3 ratio among progeny from Suri by Suri matings, due to an excess of Suri phenotypes. Unfortunately, neither study attempts to ascertain the genotypes of the parents, and the results could be simply due to the presence of a fraction of homozygous Suri parents. In summary, the results presented by Novoa and Wilson (1992) and by Flint (1996) are not in

complete agreement with ours, but the discrepancies have possible explanations and the evidence is not sufficient to disprove our hypothesis.

We conclude that our results are consistent with the postulated mode of inheritance (a single gene and two alleles, AlF^S dominant over AlF^h). The model was chosen because it is the simplest possible one. Note, however, that the same results could be obtained if the trait were not controlled by a single gene, but by a group of very closely linked genes (haplotype) that were inherited together. Further analyses of data should contribute to a greater understanding of the genetic mechanisms involved in the expression of the Huacaya and Suri phenotypes.

In the meantime, rules and regulations drawn up by the Australian Alpaca Association regarding the registration and status of Huacaya and Suri animals resulting from different mating combinations should take into account current knowledge about the inheritance of this Alpaca feature.

3.6.5. Summary

Data on 145 Huacaya sire by Huacaya dam, 24 Suri sire by Huacaya dam and 35 Suri sire by Suri dam mating records (and their corresponding progeny) were used to determine the mode of inheritance of the Huacaya and Suri feature in alpacas. The results indicated control by a single gene (or by an haplotype), and dominance of the allele responsible for the Suri type (AlF^S) over that responsible for the Huacaya type (AlF^h).

Keywords: Alpaca, Huacaya, Suri, crosses, inheritance.

4. BIOCHEMISTRY

G. J. Judson

4.1. SURVEY OF BLOOD MINERAL, TRACE ELEMENT AND VITAMIN CONCENTRATIONS OF ALPACAS IN SOUTHERN AUSTRALIA

4.1.1. Introduction

Deficiencies reported to endanger health and productivity of the grazing ruminant in southern Australia include those of the minerals calcium, magnesium, phosphorus, sodium and sulphur, the trace elements cobalt, copper, selenium, iodine, manganese and zinc and the vitamins A, B, D and E (McDonald and Caple 1983; Judson *et al.* 1987). Severe deficiencies can result in clinical signs which are specific, for example white muscle disease as a result of selenium or vitamin E deficiency, steely wool or swayback as a result of copper deficiency, and grass tetany as a result of magnesium deficiency. However, the problem encountered in the field is more likely to be a marginal deficiency which is not readily identifiable. For example, reduced growth rate in apparently healthy young cattle as a result of copper deficiency, reduced wool production and growth rate of lambs due to selenium deficiency and reduced wool production even when 'steeliness' is not apparent in copper deficiency. Marginal deficiency is often more costly than severe deficiency because the former may go unnoticed and hence not be corrected.

Laboratory tests can be helpful in determining the cause of an ill thrifty condition or in identifying marginal disorders affecting productivity. Blood is often convenient to sample, and diagnostic tests have been developed for assessing the mineral, trace element and vitamin status of the animal. This study was undertaken to establish typical values for a number of minerals, trace elements and vitamins in blood of apparently healthy alpacas at pasture in southern Australia.

4.1.2. Materials and methods

Farms and animals

Of the five alpaca herds selected for study two (SA1, SA2) were in South Australia and three (V1, V2, V3) in Victoria (Figure 22). The herds were predominantly Huacayas at farms SA1, SA2, V1 and V2 and Suris at farm V3. Alpacas selected for sampling were from four age groups, crias (< 6 months of age), weaners (6-12 months), tuis (12-24 months) and adults (> 24 months).

Blood and pasture sampling

Blood samples for chemical analyses were collected from the jugular vein of 20-30 alpacas on each farm on five occasions in 1994-5 and this sampling procedure was repeated in 1995-6 on four of the farms. Blood samples were collected into 7-ml heparinised tubes ('Vacutainer ')

Reference 367735, Becton Dickson) for trace element analyses and into 9 ml heparinised tubes ('Vacuette ' Greiner Labortechnik) for other chemical analyses.

At the time of blood sampling, pasture samples for chemical assay were collected from at least 1 m² of the area where animals were grazing. Samples of any hay or pellet supplements fed to alpacas were also collected for analyses.

Chemical procedures

An aliquot of whole blood was stored at 4 °C for selenium analysis and for other assays, the blood cells were removed by centrifugation and the plasma stored at –20 °C until assayed for trace and major elements and vitamins. Pasture and feed samples for vitamin E assay were stored at –20 °C and samples for mineral assay were dried at 60 °C before milling to a fine powder using a ring grinder with a zirconium head.

Plasma samples were assayed for vitamin B₁₂ using a radioactive assay kit (Solid Phase No Boil, Diagnostic Products Corporation, USA) as described by Judson *et al.* (1991). Plasma vitamin D (25-hydroxycholecalciferol) was determined using a competitive protein-binding procedure as described by Morris *et al.* (1984). Plasma copper and zinc assays were performed using atomic absorption spectrophotometry as described by Cavanagh and Judson (1994). Plasma vitamins A and E and feed vitamin E were assayed using a high pressure liquid chromatograph as described by Judson *et al.* (1991) and selenium concentrations in blood and feed were assayed by a fluorimetric procedure as described by Koh and Benson (1983). Plasma calcium, inorganic phosphorus and magnesium were measured colorimetrically using a Cobas Mira random access analyser (F. Hoffmann La Roche Co.) and commercial kits (Trace Scientific Ltd, Melbourne). Mineral and trace element concentrations in acid-digested feed samples were assayed using an inductively coupled plasma mass spectrophotometer.

Samples used in assays for quality control purposes included serum from Nycomed Pahrma, Norway for blood and plasma trace elements, serum from Randox United Kingdom and Trace Scientific Ltd. for major elements, and rye grass (Commission of the European Communities, reference material No. 281) and hay (International Atomic Energy Agency, reference material V-10) for feed major and trace elements. For vitamin B₁₂ assays plasma samples supplied by Diagnostic Products Corporation and bovine and ovine plasma samples prepared in the laboratory were used for quality control.

Statistical analyses

Separate statistical analyses were performed on blood data of Huacayas collected for two years (farms SA1, SA2 and V2) and for one year (farm V1) and of Suris collected for two years (farm V3). A linear model was fitted to the blood data of Huacayas and Suris and included the effects of location (Huacayas at farms SA1, SA2 and V2), animal nested within location, age, sampling time and two-way interactions. In order to standardise variances log transformations were undertaken for vitamins D, E and B₁₂ before statistical analysis. The anti-logarithmic values of these vitamins however, are used in this report.

Reference limits corresponding to the 0.95 and 0.05 fractiles of the distribution were established.

Pasture and supplements

Pasture was grass dominant at all sites except SA2 where alpacas had access to lucerne dominant pasture. Hay was provided, usually from late summer to winter, to animals on all farms except V1, and 'alpaca' pellets containing minerals, trace elements and vitamins A, D and E were provided to all animals at farms V2 and V3: 'horse' pellets of lower manganese content were also given to alpacas at farm V3 during the second year of the study. Injections of a multi-vitamin preparation containing A, D and E were given to alpacas at all farms as follows: SA1 - to selected alpacas after the July sampling in 1995; SA2 - to all alpacas in May, 1996; V1 - to crias and weaners after the June, 1995 sampling; V2 - to crias after the June, 1995 sampling, and V3 - to all animals after the July, 1995 sampling. Vitamin B₁₂ injections were given to selected alpacas at farm SA1 after the June, 1996 sampling and to all alpacas at farm SA2 in May, 1996.

The ranges in concentrations of major and trace constituents in pasture grazed by alpacas are given in Tables 15 and 16 respectively. Also included in these tables are the ranges in these constituents in hay and pellet supplements offered to the alpacas. The minimum desirable concentrations of major and trace constituents in feed for camelids have not been established although it is generally assumed that requirements are similar to ruminants (Van Saun 1966). Tables 15 and 16 give the minimum desirable levels and the maximum tolerable levels of major and trace constituents in feed for ruminant livestock.

Table 15 Range in mineral levels (g/kg dry matter) and dry matter content (% fresh weight) of pasture, hay and pellet supplements at two alpaca farms in South Australia (SA1, SA2) and three in Victoria (V1, V2, V3).

For each farm, ranges are given for pasture sampled in winter-spring (W-Sp) and in summer-autumn (Su-A). Ranges are also shown for the 'alpaca' and 'horse' pellets fed to alpacas

Farm/Seasons (No.Samples)	Calcium	Phosphorus	Chlorine	Magnesium	Potassium	Sodium	Sulphur	Dry matter
Pasture								
SA1								
W-Sp (17)	3.6-8.5	2.2-5.9	14-50	1.7-3.8	15-46	2.4-7.3	1.9-4.6	10-70
Su-A (4)	3.2-5.0	1.0-1.6	4-6	1.0-1.4	4-9	0.8-1.5	1.0-1.5	76-94
SA2								
W-Sp (8)	4.2-6.8	2.4-7.6	7-33	2.2-3.6	12-51	2.5-20.0	2.4-4.3	10-71
Su-A (7)	2.3-11.5	1.7-3.3	2-17	2.0-3.5	4-31	1.0-5.7	1.6-4.3	25-95
V1								
W-Sp (5)	2.4-5.9	3.1-5.1	17-28	2.4-3.2	20-37	3.5-6.8	2.4-3.5	10-24
Su-A (1)	4.9	1.7	9	2.9	7	3.9	1.8	41
V2								
W-Sp (24)	1.8-8.2	1.1-5.9	6-28	1.7-3.5	9-47	1.0-12.5	1.1-4.6	9-66
Su-A (5)	1.5-4.5	0.8-1.5	3-6	1.7-2.0	5-8	1.3-1.4	0.7-1.6	70-93
V3								
W-Sp (9)	2.6-4.9	2.2-4.3	6-20	1.7-2.5	11-42	0.5-1.1	1.5-3.7	13-37
Su-A (5)	4.1-5.6	0.9-1.5	3-7	1.5-2.4	5-12	0.5-1.0	0.9-1.4	90-93
Hay								
SA1 (5)	6.2- 15.7	1.5-2.4	15-26	1.8-4.1	19-30	2.9-10.6	1.8-3.8	84-95
SA2 (6)	1.5-9.4	1.3-2.4	4-19	1.2-2.8	11-19	2.2-5.4	1.0-1.8	88-92
V2 (4)	2.1-18.2	2.0-2.4	3-21	1.7-2.9	15-28	0.8-3.0	1.7-2.4	79-93
V3 (4)	6.0-16.6	1.7-3.0	3-14	2.4-2.8	24-42	0.4-1.2	1.8-4.3	86-93
Pellets								
V2 alpaca (3)	17-25	11-14	7-9	8-9	11-12	3-4	2-3	89-95
V3 alpaca (4)	15-19	11-13	6-8	6-8	11	3-4	2-3	85-92
horse (1)	11	5	8	2	9	3	2	89
Desirable level in feed for:								
Sheep*	1.5-2.6	1.3-2.5	1.0	1.2	5.0	0.7-0.9	2.0	
Cattle*	1.9-4.0	1.8-3.2	2.0	1.9	5.0	0.8-1.2	1.5	
Maximum tolerable level in feed for:								
Sheep	20	6	55	5	30	35	4	
Cattle	20	10	24-55	5	30	16-35	4	

*Where a range is given, the higher values are for rapidly growing or lactating animals (SCA 1990) **NRC (1980)

In general the concentrations of the major elements, apart from calcium, were usually higher in the winter-spring pasture than in the summer-autumn pasture (Table 15). All minerals in pasture and hay, apart from chlorine and potassium, were at times below the desirable concentration in feed for sheep and cattle. In general the pellets had higher concentrations of calcium, phosphorus and magnesium than found in pasture (Table 15).

There were no clear seasonal differences in trace element levels in pasture (Table 16) but this is not unexpected since the composition of pasture samples as well as the paddocks where samples were collected varied between visits. At all farms pasture selenium and cobalt concentrations

were on occasions below the desirable level in feed for livestock. Copper, zinc and vitamin E were also below the desirable level in feed for livestock on one or more farms at times during the study. Iron and manganese concentrations were above the minimum desirable level at all farms on all occasions and on selected farms exceeded the maximum tolerable level in feed for livestock. The high iron concentrations were probably as a result of soil contamination of the pasture sample.

Table 16 Range in trace element and vitamin E levels (mg/kg dry matter) in pasture, hay and pellet supplements at alpaca farms in South Australia (SA1, SA2) and in Victoria (V1, V2, V3).

For each farm, ranges are given for pasture sampled in winter-spring (W-Sp) and in summer-autumn (Su-A). Ranges are also shown for the 'alpaca' and 'horse' pellets fed to alpacas.

Farm/Season (No. samples)	Cobalt	Cop- per	Iron	Mang- anese	Molybd- enum	Selenium	Zinc	Vitamin E
Pasture								
SA1								
W-Sp (17)	0.04-1.70	4-9	86-1004	52-211	0.3-1.4	0.03-0.10	19-42	39-332
Su-A (4)	0.01-0.08	4-5	226-337	52-108	0.1-0.4	0.06-0.10	14-21	1-41
SA2								
W-Sp (8)	0.08-0.67	6-14	236-2897	32-63	0.6-2.0	0.03-0.09	31-48	24-112
Su-A (7)	0.02-0.63	7-19	493-3721	35-107	0.3-1.3	0.05-0.36	33-65	3-189
V1								
W-Sp (5)	0.08-0.68	6-8	208-1282	118-365	0.7-2.3	0.03-0.07	32-40	42-158
Su-A (1)	1.07	5	417	324	0.6	0.04	34	30
V2								
W-Sp (24)	0.01-1.62	4-15	87-2700	113-1052	0.1-0.9	0.03-0.16	17-119	6-231
Su-A (5)	0.03-0.11	2-6	128-565	167-400	0.1-0.3	0.03-0.10	11-30	4-104
V3								
Sp-W (7)	0.01-1.25	5-15	281-8160	523-1066	0.1-0.3	0.03-0.09	35-57	31-225
Su-A (5)	0.07-2.44	4-6	190-3304	790-1053	0.1-1.2	0.04-0.07	26-38	14-101
Hay								
SA1 (5)	0.01-0.28	2-4	42-109	12-48	0.2-1.2	0.08-0.17	10-36	7-69
SA2 (6)	0.04-0.28	2-8	113-485	20-112	0.1-0.8	0.02-0.11	11-25	4-17
V2 (4)	0.05-0.62	4-11	65-111	35-201	0.1-0.4	0.02-0.03	13-26	2-13
V3 (4)	0.03-0.64	5-12	120-356	26-54	0.0-0.8	0.03-0.06	23-29	7-47
Pellets								
V2 alpaca (3)	0.2-2.0	22-33	827-1379	206-284	1.4-1.9	0.4-1.5	455-613	217-519
V3 alpaca (4)	0.2-1.9	28-44	761-986	193-236	1.7-1.9	1.7-2.3	457-676	238-550
horse (1)	0.5	14	253	103	0.3	0.2	119	33
Desirable level in feed for:								
Sheep*	0.11	5	40	15-25	0.1?	0.05	20-30	15-20
Cattle*	0.11	7-10	40	15-25	0.1?	0.05	20-30	15-60
Maximum tolerable level in feed for:								
Sheep**	10	25	500	1000	10	2	300	1000?
Cattle**	10	100	1000	1000	10	2	500	1000?

*Where a range is given, the higher values are for rapidly growing or lactating animals (SCA 1990).

**NRC (1980)

High concentrations of manganese were consistently recorded at farm V3 and occasionally at farm V2. Reduced growth rates have occurred in lambs on diets containing manganese in excess of 400 mg/kg dry matter although there is some evidence that growth rates of calves were not affected when given diets containing 800 mg/kg dry matter of manganese (NRC 1980). High intakes of iron can reduce the toxic effects of manganese but will also reduce the availability of copper. Copper concentrations in pasture at farms SA1 and V2 were sufficiently low (< 5 mg/kg dry matter) to indicate that pasture production may respond to applications of copper.

The hay supplements had similar trace element concentrations to that observed in pasture although zinc, iron and vitamin E concentrations were usually lower. Pellets fed at recommended rates would provide significant quantities of cobalt, selenium, zinc and vitamin E (Table 15). However, the pellets sold for feeding to alpacas (alpaca pellets) also contained high concentrations of manganese which should not be given to alpacas on farms V2 and V3.

Minerals and vitamin D blood tests

Statistical evaluation of the data for Huacayas at farms SA1, SA2 and V2 indicated a significant farm by time of sampling interaction ($P < 0.001$) for all plasma minerals and vitamin D (25-hydroxycholecalciferol). Time of sampling significantly affected ($P < 0.001$) all plasma minerals and vitamin D values in Suris at farm V3 and in Huacayas at farm V1 except for plasma calcium ($P > 0.05$).

Table 17. Least square mean values for plasma constituents collected from Huacayas at four farms (SA1, SA2, V1, V2) and Suris at one farm (V3).

For each farm, the first and second values are for samples collected in 1994-95 and 1995-96 respectively. Means in each row followed by the same superscript are similar ($P > 0.05$).

Least square mean values are given for 14-43 alpacas on SA1; 11-23 on SA2; 12-21 on V1; 15-35 on V2, and 12-24 on V3.

Constituent/ Farm	November	February	June	July	August
Calcium, mmol/L					
SA1	2.43 ^a /2.35 ^{ab}	2.26 ^b /2.44 ^a	2.31 ^b /2.32 ^{ab}	2.31 ^b /2.31 ^b	2.37 ^{ab} /2.39 ^{ab}
SA2	2.48 ^{bc} /2.47 ^{bc}	2.35 ^c /2.51 ^{abc}	2.43 ^c /2.66 ^a	2.43 ^c /2.46 ^{bc}	2.62 ^{ab} /2.41 ^c
V1	2.22 ^a /2.22 ^a	2.32 ^a / -	2.25 ^a / -	2.28 ^a / -	2.35 ^a / -
V2	2.30 ^d /2.43 ^{abcd}	2.29 ^d /2.50 ^{ab}	2.54 ^{ab} /2.41 ^{abcd}	2.45 ^{abc} /2.32 ^{cd}	2.55 ^a /2.39 ^{bcd}
V3	2.19 ^c /2.32 ^{abc}	2.29 ^{bc} /2.46 ^a	2.43 ^{ab} /2.42 ^{ab}	2.25 ^{bc} /2.49 ^a	2.28 ^{bc} /2.44 ^{ab}
Phosphorus, mmol/L					
SA1	2.46 ^{ab} /2.38 ^{ab}	2.39 ^{ab} /2.60 ^{ab}	2.68 ^a /2.11 ^{bc}	1.84 ^{cd} /1.18 ^e	1.47 ^{de} /1.47 ^{de}
SA2	2.10 ^{cd} /2.99 ^a	2.25 ^{bcd} /2.67 ^{abc}	1.86 ^{de} /2.79 ^{ab}	1.46 ^{ef} /2.30 ^{abcd}	1.20 ^{ef} /1.85 ^{de}
V1	2.36 ^b /2.65 ^{ab}	2.90 ^a / -	2.26 ^b / -	2.34 ^b / -	1.57 ^c / -
V2	2.55 ^a /2.58 ^a	2.29 ^{ab} /2.31 ^{ab}	2.29 ^{ab} /1.61 ^c	1.96 ^{bc} /1.33 ^c	2.32 ^{ab} /1.48 ^c
V3	2.27 ^a /2.13 ^a	2.44 ^a /2.49 ^a	2.24 ^a /2.30 ^a	2.19 ^a /1.25 ^b	2.53 ^a /1.27 ^b
Magnesium, mmol/L					
SA1	0.90 ^a /0.65 ^{ef}	0.72 ^{def} /0.69 ^{ef}	0.78 ^{cd} /0.78 ^{cd}	0.82 ^{bc} /0.77 ^{cde}	0.89 ^{ab} /0.81 ^{bcd}
SA2	0.71 ^{bc} /0.80 ^{ab}	0.79 ^{ab} /0.74 ^{abc}	0.78 ^{ab} /0.85 ^a	0.80 ^{ab} /0.82 ^{ab}	0.68 ^c /0.71 ^{bc}
V1	0.84 ^{cd} /0.77 ^d	0.89 ^{abc} / -	0.85 ^{bcd} / -	0.93 ^{ab} / -	0.94 ^a / -
V2	0.88 ^{ab} /0.75 ^d	0.85 ^{abc} /0.83 ^{abcd}	0.77 ^{cd} /0.91 ^a	0.82 ^{abcd} /0.88 ^{ab}	0.81 ^{bcd} /0.87 ^{abc}
V3	0.90 ^a /0.88 ^{ab}	0.89 ^{ab} /0.88 ^{ab}	0.87 ^{ab} /0.93 ^a	0.70 ^c /0.80 ^{bc}	0.89 ^{ab} /0.94 ^a
Vitamin D, nmol/L					
SA1	64 ^b /61 ^b	286 ^a /261 ^a	54 ^{bc} /77 ^b	31 ^c /55 ^{bc}	19 ^d /18 ^d
SA2	139 ^{bc} /80 ^c	246 ^a /251 ^a	39 ^d /189 ^{ab}	24 ^{de} /106 ^{bc}	18 ^e /32 ^{de}
V1	74 ^b /75 ^b	286 ^a / -	124 ^b / -	80 ^b / -	28 ^e / -
V2	83 ^{de} /106 ^{cde}	285 ^a /205 ^{ab}	150 ^{bc} /61 ^e	167 ^{bc} /55 ^e	114 ^{cd} /26 ^f
V3	146 ^b /292 ^{ab}	299 ^a /267 ^{ab}	78 ^c /63 ^{cd}	37 ^d /43 ^d	45 ^{cd} /33 ^d

A summary of the effects of time of sampling on plasma concentrations of the minerals and vitamin D is given in Table 17. In general there were no marked seasonal trends in plasma

calcium or magnesium concentrations across farms. Mean calcium values were consistently above the minimum value of 2.0 mmol/L considered normal for ruminants. However, because plasma calcium levels are usually controlled within a narrow range they are not always a reliable guide to the calcium status of the animal. That is, an animal may be relying on its bone reserves of calcium to meet current requirements and to maintain normal plasma calcium levels.

Mean plasma magnesium levels were consistently above those values considered adequate for cattle but not always above those levels considered adequate for sheep. Animals usually have limited body reserves of magnesium that can be mobilised to cover dietary inadequacies, hence plasma magnesium levels will fall rapidly when animals are on diets of low available magnesium content.

Indications of a seasonal trend in plasma phosphorus and vitamin D concentrations were apparent on most farms, with lower values being recorded in the winter months (Table 17). On occasions, individual plasma phosphorus levels in alpacas were less than 0.5 mmol/L. It is likely that the hypophosphataemia was secondary to a vitamin D deficiency and not due to an inadequate dietary intake of phosphorus. Mean vitamin D levels in winter on most farms were below those values considered normal for sheep and cattle (Table 17). Crias born at the end of summer would be particularly vulnerable during the following winter to rickets as a result of vitamin D deficiency

Statistical analyses indicated that age of Huacayas affected plasma levels of calcium ($P < 0.001$), phosphorus ($P < 0.001$) and vitamin D ($P < 0.001$) at farms SA1, SA2 and V2 and of calcium ($P < 0.01$), phosphorus ($P < 0.001$) and magnesium ($P < 0.01$) at farm V1. For Suris only plasma phosphorus levels were altered ($P < 0.001$) by age.

The decline in plasma calcium and phosphorus levels with increasing age is shown in Table 18. The higher values in the young animals are of significance particularly for plasma phosphorus levels if this constituent is to be assayed to assess whether crias are at risk to vitamin D deficiency.

Table 18. Effect of age on plasma constituents collected from Huacayas at farms SA1, SA2 and V2 in 1994-96 and from farm V1 in 1994-95 and from Suris at farm V3 in 1994-96.

Least square mean values (number of observations) are given for samples collected on ten occasions from farms SA1, SA2 V2 and V3 and on six occasions from farm V1. Means in each row followed by the same superscript are similar ($P > 0.05$).

Constituent/ Farms	Cria	Weaner	Tuis	Adult
<i>Plasma calcium, mmol/L</i>				
SA1, SA2, V2	2.50 ^a (114)	2.47 ^a (87)	2.43 ^a (62)	2.27 ^b (219)
V1	2.38 ^a (11)	2.27 ^{ab} (15)	2.25 ^{ab} (6)	2.18 ^b (50)
V3	2.44 ^a (29)	2.40 ^a (35)	2.36 ^a (32)	2.24 ^a (90)
<i>Plasma phosphorus, mmol/L</i>				
SA1, SA2, V2	2.58 ^a (114)	2.20 ^b (87)	1.93 ^{bc} (62)	1.66 ^c (219)
V1	2.91 ^a (11)	2.55 ^{ab} (15)	2.05 ^{bc} (6)	1.86 ^c (50)
V3	2.62 ^a (29)	2.22 ^b (35)	2.04 ^{bc} (32)	1.56 ^c (90)
<i>Plasma magnesium, mmol/L</i>				
SA1, SA2, V2	0.79 ^a (114)	0.79 ^a (87)	0.77 ^a (62)	0.84 ^a (219)
V1	0.82 ^a (11)	0.85 ^a (15)	0.89 ^{ab} (6)	0.93 ^b (50)
V3	0.82 ^a (29)	0.87 ^a (35)	0.86 ^a (32)	0.93 ^a (90)
<i>Plasma vitamin D, mmol/L</i>				
SA1, SA2, V2	58 ^a (109)	72 ^{ab} (88)	86 ^{bc} (61)	106 ^c (222)
V1	135 ^a (11)	82 ^a (15)	74 ^a (6)	71 ^a (50)
V3	80 ^a (28)	80 ^a (33)	101 ^a (32)	108 ^a (88)

Trace elements and vitamins

A summary of the mean values for trace elements and vitamin levels in blood of alpacas is given in Table 19. Statistical analyses of the Huacaya data for farms SA1, SA2 and V2 indicated a significant farm by time of sampling interaction ($P < 0.001$) for all trace elements and vitamins. For the Huacayas at farm V1, time of sampling significantly affected ($P < 0.001$) plasma concentrations of zinc and vitamins A and E and blood selenium concentration. For Suris at farm V3, time of sampling affected plasma concentrations of zinc ($P < 0.001$) and vitamins E ($P < 0.001$) and A ($P < 0.05$) and blood selenium concentration ($P < 0.05$).

There was no clear seasonal effect apart from an indication of a lower plasma vitamin E level in August during the first year of the study (Table 19). Mean plasma copper levels were usually less than those values indicative of adequacy of these elements in ruminants (Table 22) but are probably indicative of a normal copper status for this species (Grace *et al* 1994). Mean plasma zinc values (Table 19) were markedly lower than normal values for healthy ruminants (Table 22). Low copper and zinc values in plasma or serum have also been observed in apparently healthy llamas (Espinoza *et al.* 1982; Bechert and Smith 1996) but values reported for camels in

general were similar to values for healthy ruminants (Faye and Bengoumi 1994). The low zinc levels warrant further investigation as to whether plasma zinc levels in alpacas are a useful indicator of zinc intake.

Table 19. Least square mean values for plasma constituents collected from Huacayas at four farms (SA1, SA2, V1, V2) and Suris at one farm (V3).

For each farm and each sampling occasion, the first and second values are for samples collected in 1994-95 and 1995-96 respectively. Least square mean values are given for 14-43 alpacas on SA1; 11-23 on SA2; 12-21 on V1; 15-35 on V2, and 12-24 on V3.

Constituent/ Farm	November	February	June	August
Plasma copper, $\mu\text{mol/L}$				
SA1	7.8 ^{bc} /6.7 ^{de}	8.3 ^{ab} /8.1 ^{abc}	7.3 ^{cd} /6.8 ^{de}	8.9 ^a /6.1 ^e
SA2	8.0 ^a /7.1 ^{ab}	7.9 ^a /5.7 ^b	7.0 ^{ab} /7.0 ^{ab}	6.4 ^b /6.9 ^{ab}
V1	7.3 ^a /5.9 ^a	8.1 ^a / -	8.1 ^a / -	7.9 ^a / -
V2	7.7 ^{bc} /6.3 ^d	8.9 ^a /6.7 ^{cd}	7.8 ^{bc} /8.3 ^{ab}	7.5 ^{bc} /7.7 ^{bc}
V3	8.2 ^a /6.4 ^a	9.1 ^a /8.2 ^a	6.8 ^a /9.2 ^a	9.3 ^a /8.8 ^a
Plasma zinc, $\mu\text{mol/L}$				
SA1	5.7 ^a /5.3 ^a	3.4 ^{cd} /4.0 ^{bc}	4.1 ^b /3.3 ^d	5.3 ^a /4.4 ^b
SA2	3.4 ^{bc} /3.4 ^{bc}	6.0 ^a /2.8 ^c	4.1 ^b /3.7 ^{bc}	3.6 ^{bc} /3.3 ^c
V1	3.8 ^b /5.3 ^a	3.7 ^b / -	4.7 ^a / -	4.8 ^a / -
V2	4.7 ^a /4.7 ^a	3.3 ^c /3.7 ^{bc}	3.8 ^{bc} /4.7 ^a	4.4 ^{ab} /4.0 ^{ab}
V3	7.1 ^a /4.7 ^{bc}	3.3 ^d /4.0 ^{cd}	3.7 ^{cd} /5.2 ^b	4.8 ^{bc} /4.2 ^{bcd}
Blood selenium, $\mu\text{mol/L}$				
SA1	1.30 ^c /0.89 ^e	1.26 ^{cd} /1.46 ^{ab}	1.36 ^{bc} /1.65 ^a	1.01 ^{de} /1.53 ^{ab}
SA2	0.94 ^c /1.68 ^b	2.22 ^a /2.15 ^a	2.35 ^a /1.65 ^b	2.30 ^a /1.19 ^c
V1	0.52 ^c /0.49 ^c	0.65 ^b / -	0.86 ^a / -	0.59 ^{bc} / -
V2	2.15 ^b /2.05 ^b	1.75 ^c /2.51 ^a	1.92 ^{bc} /2.15 ^b	2.06 ^b /1.67 ^c
V3	1.28 ^{abc} /1.67 ^a	1.40 ^{ab} /1.43 ^{ab}	1.43 ^{ab} /0.93 ^{bc}	1.32 ^{abc} /0.83 ^c
Plasma vitamin E, mg/L				
SA1	3.3 ^a /2.3 ^{bc}	2.4 ^{bc} /2.3 ^{bc}	2.6 ^b /2.6 ^b	2.0 ^c /2.6 ^b
SA2	2.9 ^{ab} /2.5 ^{abc}	2.7 ^{abc} /3.0 ^a	2.2 ^c /2.5 ^{abc}	1.6 ^d /2.3 ^{bc}
V1	3.4 ^{bc} /2.9 ^{cd}	4.3 ^a / -	3.8 ^{ab} / -	2.4 ^d / -
V2	3.5 ^{bc} /3.0 ^c	5.2 ^a /3.6 ^{bc}	3.9 ^b /3.3 ^{bc}	3.2 ^c /3.4 ^{bc}
V3	3.6 ^a /2.3 ^{bc}	3.7 ^a /3.7 ^a	2.4 ^{bc} /3.1 ^{ab}	2.0 ^c /2.6 ^{bc}
Plasma vitamin A, $\mu\text{g/L}$				
SA1	668 ^{ab} /528 ^b	616 ^{ab} /708 ^{ab}	696 ^{ab} /703 ^{ab}	649 ^{ab} /728 ^a
SA2	562 ^c /704 ^{bc}	755 ^{bc} /697 ^{bc}	676 ^{bc} /879 ^{ab}	681 ^{bc} /1068 ^a
V1	534 ^b /538 ^b	565 ^b / -	701 ^a / -	500 ^b / -
V2	576 ^c /604 ^{bc}	746 ^{ab} /693 ^{abc}	714 ^{abc} /829 ^a	637 ^{abc} /678 ^{abc}
V3	557 ^a /573 ^a	665 ^a /753 ^a	599 ^a /912 ^a	750 ^a /793 ^a
Plasma vitamin B₁₂, pmol/L				
SA1	283 ^{ab} /241 ^{bc}	290 ^{ab} /188 ^{cd}	148 ^d /217 ^{bc}	407 ^a /185 ^{cd}
SA2	222 ^a /126 ^a	150 ^a /159 ^a	227 ^a /218 ^a	140 ^a /167 ^a
V1	265 ^a /148 ^a	281 ^a / -	218 ^a / -	251 ^a / -
V2	336 ^{ab} /482 ^a	339 ^{ab} /278 ^b	252 ^b /398 ^{ab}	350 ^{ab} /461 ^a
V3	341 ^a /270 ^a	330 ^a /239 ^a	266 ^a /216 ^a	278 ^a /285 ^a

Mean blood selenium levels were lower in alpacas on farm V1 (0.52 – 0.86 $\mu\text{mol/L}$) than in alpacas on other farms and were close to the minimum normal levels in the blood of ruminants (Table 22). On other farms where pasture selenium levels were low (Table 16), the pellet

supplements provided an additional source of selenium. Hill and others (1992) in New Zealand reported that blood selenium concentrations ranged from 0.1 to 2.7 $\mu\text{mol/L}$ in alpacas on pastures of low selenium content (0.01-0.03 mg/kg dry matter): some of the alpacas on these pastures, however, had access to supplements containing selenium.

Mean plasma vitamin E and A levels given in Table 19 were usually above those values considered inadequate for ruminants (Table 22): plasma levels of these vitamins are usually depressed in ruminants on dry pasture although this depression was not evident in the present study. Plasma vitamin B₁₂ levels in sheep and to a lesser extent in cattle are used as an indicator of the adequacy of cobalt in the diet. The cobalt is required for the synthesis of vitamin B₁₂ by ruminal microorganisms and it is the vitamin not the cobalt that is required by the host tissues. In alpacas the mean vitamin B₁₂ levels (Table 19) appear to be intermediate between values considered normal for sheep and cattle (Table 22).

Statistical analyses indicated that age had a significant effect on plasma copper levels in Huacayas at farms SA1, SA2 and V2 ($P < 0.001$), in Huacayas at farm V1 ($P < 0.01$) but not in Suris at farm V3 ($P > 0.05$). Blood selenium levels were also affected by age in Huacayas at farms SA1, SA2 and V2 ($P < 0.001$), in Huacayas at farm V1 ($P < 0.01$) and in Suris at farm V1 ($P < 0.001$). Plasma vitamin B₁₂ was also affected by age ($P < 0.05$) in Huacayas at farms SA1, SA2 and V2.

Table 20. Effect of age on plasma constituents collected from Huacayas at farms SA1, SA2, V1 and V2 and Suris at farm V3.

Least square mean values (number of observations) are given for samples collected on ten occasions from farms SA1, SA2, V2 and V3 and on six occasions from farm V1. Means in each row followed by the same superscript are similar ($P > 0.05$).

Constituent/ Farms	Cria	Weaner	Tuis	Adult
Plasma copper, $\mu\text{mol/L}$				
SA1, SA2, V2	6.4 ^a (85)	7.0 ^b (90)	7.4 ^b (89)	8.7 ^c (338)
V1	6.0 ^a (8)	6.8 ^a (12)	8.2 ^{ab} (6)	8.9 ^b (60)
V3	7.7 ^a (24)	7.5 ^a (31)	8.5 ^a (26)	9.3 ^a (95)
Plasma zinc, $\mu\text{mol/L}$				
SA1, SA2, V2	4.3 ^a (83)	4.0 ^a (86)	4.1 ^a (87)	4.1 ^a (337)
V1	4.4 ^a (8)	4.0 ^a (12)	4.9 ^a (6)	4.5 ^a (60)
V3	4.5 ^a (24)	4.4 ^a (31)	4.7 ^a (26)	4.8 ^a (95)
Blood selenium, $\mu\text{mol/L}$				
SA1, SA2, V2	1.46 ^a (84)	1.57 ^{ab} (86)	1.80 ^{bc} (87)	2.03 ^c (335)
V1	0.56 ^a (8)	0.54 ^a (12)	0.66 ^{ab} (6)	0.74 ^b (60)
V3	0.97 ^a (24)	1.01 ^a (31)	1.22 ^a (26)	1.94 ^b (95)
Plasma vitamin E, mg/L				
SA1, SA2, V2	2.6 ^a (84)	2.8 ^a (89)	2.8 ^a (84)	3.0 ^a (310)
V1	3.3 ^a (8)	3.2 ^a (12)	3.2 ^a (6)	3.4 ^a (60)
V3	2.7 ^a (20)	2.9 ^a (32)	2.9 ^a (26)	3.0 ^a (86)
Plasma vitamin A, $\mu\text{g/L}$				
SA1, SA2, V2	681 ^a (84)	707 ^a (89)	718 ^a (84)	693 ^a (306)
V1	594 ^a (8)	538 ^a (12)	593 ^a (6)	546 ^a (60)
V3	676 ^a (19)	722 ^a (31)	729 ^a (26)	674 ^a (86)
Plasma vitamin B₁₂, pmol/L				
SA1, SA2, V2	312 ^a (87)	257 ^{ab} (92)	191 ^b (89)	226 ^a (339)
V1	279 ^a (8)	212 ^a (12)	163 ^a (6)	275 ^a (56)
V3	325 ^a (24)	289 ^a (32)	246 ^a (26)	249 ^a (93)

Table 20 shows the general increase with age in plasma copper and blood selenium levels respectively. In a number of species, including sheep and cattle, low plasma copper levels are present at birth but generally increase to normal adult values by about one week of age (Suttle).

Reference values

It is apparent from above that many factors can influence the concentration of a blood constituent including location, age of animal, time of sampling as well as nutritional deficiency. It would be useful to define a range of values or limits to serve as reference for each blood constituent.

The reference limits define an interval and values within it are considered normal. The reference value can be used to evaluate the state of health of a single alpaca or the herd and would constitute a basic requirement for preliminary knowledge.

The total number of blood samples collected from Huacayas and Suris during the period of the study were respectively 228 and 1 from SA1; 157 and 65 from SA2; 86 and 20 from V1; 211 and 28 from V2, and 6 and 186 from V3.

The mean and median concentrations and the reference limits for minerals and vitamin D and for trace elements and vitamins in blood of alpacas are given in Tables 21 and 22 respectively. It was found that breed had no effect for all blood constituents apart from plasma phosphorus and vitamin D concentrations. However, the effect of breed on vitamin D became non-significant when the nine plasma values above 750 nmol/L were removed from the data set of 473 values.

The reference limits indicate, apart from plasma phosphorus and vitamin D values (Table 21), typical values found in apparently alpacas. However, the reference limits obtained in the present study do not define the extreme limits of values consistent with health, these extreme values are often only established in experimental studies to assess productivity responses to supplementation. Included in Tables 21 and 22 are normal values for the blood constituents in sheep and cattle.

Table 21. Means, medians and reference limits of minerals and vitamin D in alpacas

Reference limits: 0.95 fractile is the upper limit and 0.05 fractile is the lower limit

Constituent/ Age group	Number of samples	Mean	Median	Reference limits
<i>Plasma calcium, mmol/L (normal values: sheep > 2.0; cattle > 2.0)</i>				
Cria	177	2.48	2.47	2.18-2.80
Weaner	163	2.40	2.38	2.16-2.63
Tuis	110	2.38	2.37	2.16-2.63
Adult	407	2.27	2.25	2.03-2.57
<i>Plasma phosphorus, mmol/L (normal values: sheep > 1.3; cattle > 1.3)</i>				
Huacaya				
Cria	128	2.53	2.80	0.69-3.86
Weaner	105	2.40	2.55	1.01-3.46
Tuis	68	2.08	2.15	0.83-3.10
Adult	268	1.94	1.98	0.80-2.92
Suri				
Cria	49	2.63	2.79	0.91-3.43
Weaner	58	2.52	2.55	0.78-3.54
Tuis	42	2.39	2.42	1.67-3.00
Adult	139	2.03	2.05	1.08-2.93
<i>Plasma magnesium, mmol/L (normal values: sheep >0.8; cattle > 0.6)</i>				
Cria	176	0.79	0.80	0.63-0.73
Weaner	163	0.87	0.82	0.66-1.00
Tuis	108	0.85	0.85	0.67-1.01
Adult	398	0.88	0.87	0.65-1.09
<i>Plasma vitamin D, nmol/L (normal values: sheep > 25; cattle > 50)</i>				
Cria	174	112	74	12-334
Weaner	161	146	107	12-400
Tuis	109	153	104	8-430
Adult	408	183	126	16-520

Table 22. Means, medians and reference limits of trace elements and vitamins in alpacas

Reference limits: 0.95 fractile is the upper limit and 0.05 fractile is the lower limit

Constituent/ Age groups	Number of samples	Mean	Median	Reference limits
<i>Plasma copper, $\mu\text{mol/L}$ (normal values: sheep > 8; cattle > 8)</i>				
Cria	133	6.8	6.4	4.7-10.3
Weaner	162	7.3	7.3	4.8-9.9
Tuis	133	8.1	7.8	5.3-11.6
Adult	549	8.7	8.5	6.1-12.3
<i>Plasma zinc, $\mu\text{mol/L}$ (normal values: sheep > 9; cattle > 9)</i>				
All ages	962	4.5	4.3	2.9-6.4
<i>Blood selenium, $\mu\text{mol/L}$ (normal values: sheep > 0.5; cattle > 0.25)</i>				
Cria	132	1.32	1.33	0.49-2.21
Weaner	158	1.39	1.30	0.53-2.67
Tuis	133	1.83	1.77	0.59-3.34
Adult	546	1.89	1.93	0.66-3.13
<i>Plasma vitamin E, mg/L (normal values: sheep > 0.5; cattle > 2.0)</i>				
All ages	929	2.3	2.1	0.9-4.5
<i>Plasma vitamin A, $\mu\text{g/L}$ (normal values: sheep > 300; cattle > 300)</i>				
All ages	923	703	675	439-1050
<i>Plasma vitamin B12, pmmol/L (normal values: sheep > 400; cattle > 50)</i>				
Cria	136	389	290	160-960
Weaner	164	323	245	100-890
Tuis	134	237	185	80-690
Adult	544	348	220	80-980

4.1.3. Conclusions

In the first instance it is preferable to test the animal rather than the pasture to ascertain the mineral, trace element or vitamin status of the animal. Problems in predicting mineral deficiencies in animals from pasture analyses include obtaining a representative sample of that eaten, in determining the availability of the mineral and the effects of soil ingestion. Soil ingestion can have adverse and beneficial effects on the trace element status of the animal. For example, the ingestion of soil may be a significant if not a major source of cobalt intake of sheep on autumn-winter pastures. The deficiency is not always the result of an inadequate level of the nutrient in the diet but can be due to other dietary factors which may reduce the availability of the nutrient. For example excessive intakes of molybdenum, sulphur or iron will lower the availability of dietary copper, and magnesium deficiency can result from excessive intakes of potassium. Once a deficiency has been established in an animal, pasture tests, however, are useful in helping to resolve whether the deficiency is the result of a lack of the nutrient in the feed or due to its low availability. Pasture tests are also of value when no suitable animal test is available, for instance in assessing whether stock are at risk to manganese deficiency or toxicity.

This study shows that factors such as time of sampling, location and age can markedly affect the mineral, trace element and vitamin levels in the blood of alpacas. These findings will be of value in establishing typical blood values for healthy alpacas in southern Australia.

4.2. VITAMIN D DOSES FOR ALPACAS (*LAMA PACOS*)

4.2.1 Introduction

A syndrome of lameness, limb deformities (rickets) and poor growth rates associated with low blood phosphorus concentrations has been observed in alpacas and llamas in the USA (Smith and Van Saun 1996; Van Saun *et al.* 1996) and in alpacas in New Zealand (Hill *et al.* 1994). Due to the seasonal incidence of the problem (largely winter) it has been suggested that vitamin D deficiency may have been the major cause of the rickets. The vitamin plays an important role in controlling calcium and phosphorus utilisation in the body, and in early stages of vitamin D deficiency blood phosphorus concentrations will readily decrease whereas blood calcium concentrations, which are tightly controlled, will decrease in severe deficiency. Vitamin D synthesis in the skin as a result of solar radiation is likely to be reduced in the winter months, particularly in animals with thick fleeces.

McMillan *et al.* (1995) reported that plasma vitamin D concentrations in adult alpacas in western Victoria declined from about 250 nmol/L in autumn to about 50 nmol/L during the winter months. A survey of alpacas on two farms in South Australia and three in Victoria (Judson 1996) also showed a marked seasonal variation in plasma vitamin D concentrations with the lowest values being recorded during the winter months. On four of the five farms mean plasma vitamin D concentrations in winter varied from 23 to 45 nmol/L: individual values of less than 25 nmol/L were occasionally associated with plasma phosphorus concentrations of less than 1.0 mmol/L. While the minimum plasma vitamin D concentration associated with vitamin D inadequacy is not known, clinical signs of rickets have been observed in juvenile camelids with plasma vitamin D concentrations of less than 15 nmol/L (Van Saun *et al.* 1996). Vitamin D adequacy in sheep and cattle is usually associated with plasma vitamin D concentrations above 25 and 50 nmol/L respectively (Puls 1994).

Alpaca owners in southern Australia are concerned about the risk of vitamin D deficiency in their animals during the winter. A common procedure is to administer the vitamin to alpacas in early winter. Although this practice appears to be widely adopted, there is little information on the dosage and frequency of treatment required for maintaining vitamin D adequacy during the winter. From limited observations with llamas in the USA (Smith and Van Saun 1996) and alpacas in western Victoria (McMillan *et al.* 1995) it appears that an intramuscular injection of 1330 to 2,000 IU vitamin D/kg bodyweight should maintain plasma vitamin D concentrations above 50 nmol/L for at least two months.

Because of the widespread use of vitamin D in alpacas we investigated the duration of the effectiveness of two dosages of the vitamin in crias and adult female alpacas at pasture in south eastern South Australia.

4.2.2. Materials and methods

Site details

The farm (SA1) selected for the experiment is near Penola (latitude 37° 20' south, about 60 m above sea level) in the south east of South Australia. The climate is predominantly winter rainfall, with an average annual rainfall of about 700 mm. The long-term values for the average daily hours of sunshine at the nearby Struan Research Centre, South Australian Research & Development Institute (latitude 37°10' south) for each month, starting with January were 9.3, 9.3, 6.8, 5.3, 4.0, 3.3, 4.4, 5.1, 4.9, 6.9, 7.4 and 8.6.

Animals and treatments

Fifteen crias (nine males and six females) and 15 adult females were made available for the study, which started on the 27 May, 1997. The crias were born between November, 1996 and February, 1997 and the age of the females ranged from 2 to 6 years. For each age group and gender (crias), animals of similar bodyweight and predominant colour were placed in blocks of three. For the crias, the colours were white (3 blocks), medium brown (1 block) and black (1 block) and for the adults the colours were white (1 block), medium brown (1 block), grey (1 block) and black (2 blocks).

From each block, alpacas were allocated at random to one of three treatments, namely: 0 IU/kg – no vitamin D treatment; 1,000 IU/kg – single injection of 1,000 IU vitamin D/kg bodyweight, or 2,000 IU/kg – single injection of 2,000 IU vitamin D/kg bodyweight. The vitamin was given as a single injection under the skin at week 0 of the experiment (27 May, 1997). The drug administered was a multi-vitamin solution ('Duphafrol Forte ADE Vitamin Injection', Heriot Agvet), that contains 50,000 IU vitamin D3, 500,000 IU vitamin A and 50 IU vitamin E per millilitre of solution. When given at the two dosages of 1,000 and 2,000 IU vitamin D/kg the respective quantities of vitamin A administered were 10,000 and 20,000 IU/kg and of vitamin E were 1 and 2 IU/kg.

The alpacas were run as part of a single mob for the experimental period of 16 weeks (27 May - 19 September). The alpacas were on green pasture and lucerne or meadow hay was provided ad libitum. No other feed supplements were given during the study. Dams of crias used in this study were not given any vitamin D supplement during the experimental period. Alpacas were weighed immediately before treatment and at 2, 4, 7, 11 and 16 weeks after treatment.

Blood collection and analysis

Blood samples were obtained from the jugular vein from all alpacas at the time of weighing and also at 2 and 7 days post-treatment. The blood samples, collected into 10 mL heparinised tubes ("Vacurette" Greiner Labortechnik), were centrifuged immediately to remove blood cells and the plasma samples were stored at -20°C. All plasma samples were assayed for vitamins D, E and A, phosphorus, calcium and magnesium concentrations and alkaline phosphatase activities. Plasma vitamin D (25-hydroxycholecalciferol) concentration was determined using a competitive protein-binding procedure as described by Morris *et al.* (1984) and high-pressure liquid chromatography (Judson *et al.* 1991) was used to measure vitamin E (alpha-tocopherol) and A (retinol). Concentrations of plasma inorganic phosphorus, calcium, magnesium and alkaline phosphatase were assayed using commercially available kits (Trace Scientific Ltd, Melbourne) and a Cobas Mira (F. Hoffmann La Roche & Co.)

Analysis of data

Statistical analysis was performed using repeated measures analysis of variance (GenstatTM, 'AREPMEAS', Genstat 5.41 Rothamsted Experimental Station, UK) with the pretreatment measurements used as covariates. Commonly, the structure within repeated measures data is made up of high correlations due to measurements being made on the same animal, serial correlations due to measurements being made successively and fluctuations in the variance with time. To accommodate these factors, a correction factor, known as the Greenhouse-Geisser epsilon, was applied to adjust the degrees of freedom for calculating the critical value of the F-distribution for the time main effect and treatment by time interaction. Differences between means were tested using the least significant difference (LSD) procedure.

4.2.3. Results

Bodyweights

Of the 15 crias allocated to the experiment, one female was withdrawn from the untreated group after week 7 with suspected rickets and given an injection of vitamin D. The signs included inward bent knees, arching of the back and an unusual gait. A male cria from the group that received 2,000 IU/kg group died at week 6 of the experiment (the suspected cause of death was juvenile lymphosarcoma), and another male from this group was transferred to another farm at week 13.

At the start of the experiment the range in bodyweights of the crias was from 18 to 32 kg and the adults from 52 to 78 kg. Mean bodyweight of adult females was not affected by treatment ($P > 0.05$) but was affected by time ($P < 0.01$). During the experiment, bodyweight (mean \pm SD) of females increased from 65.0 ± 8.2 (n=15) to 76.0 ± 11.2 (n=15) kg. There was a significant time by treatment interaction ($P < 0.05$) for bodyweight of crias (Figure 23). The mean bodyweights of crias in the 1,000 IU/kg and 2,000 IU/kg groups were similar ($P > 0.05$) at all stages of the experiment and were greater ($P < 0.05$) than the mean bodyweights of untreated crias at weeks 7, 11 and 16 of the experiment.

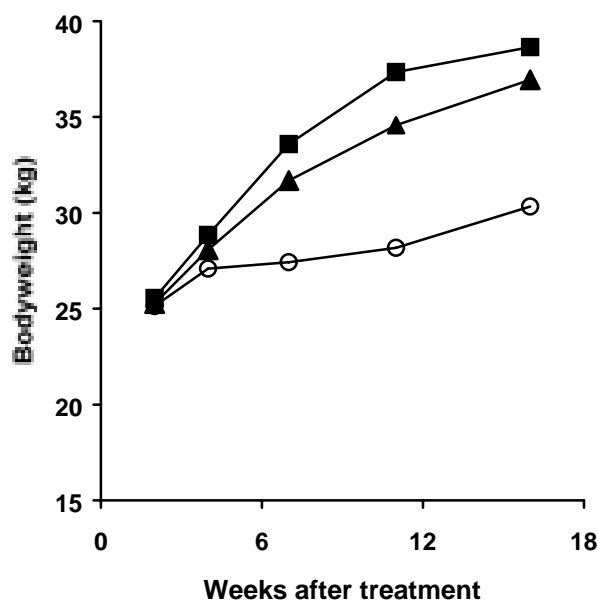


Figure 23. Changes in the covariate-adjusted mean bodyweight of crias following subcutaneous injection of vitamin D at 0 (O), 1,000 (▲) and 2,000 (■) IU/kg bodyweight. The least significant difference ($P = 0.05$) for the treatment x time interaction was 3.0 kg (same time comparisons).

Increased mean weight gains of crias in response to either of the vitamin D supplements were observed between weeks 4 and 7 and 7 and 11 of the experiment (Table 23). During weeks 2 to 4 and 11 to 16 the mean weight gains of crias were similar ($P > 0.05$) for all treatment groups. The poor weight gain of the crias in the 2,000 IU/kg group during weeks 11 to 16 of the experiment was due to two of the three remaining crias in this group losing weight.

Table 23. Covariated-adjusted mean weight gains (kg) of crias given 0, 1,000 or 2,000 IU vitamin D/kg bodyweight at week 0 of the experiment.

Least significant differences ($P = 0.05$) were 2.05 kg (same time comparisons) and 1.73 kg (same dose comparisons).

Treatment groups	Weeks after treatment			
	2 - 4	4 - 7	7 - 11	11 - 16
0 IU/kg	2.2	0.6	0.6	2.2
1,000 IU/kg	2.7	3.5	2.8	2.3
2,000 IU/kg	3.2	4.0	3.2	0.8 (n=3)

Plasma vitamin D and phosphorus

At the start of the experiment the plasma vitamin D concentrations were variable and ranged from 11 to 115 nmol/L in the crias and from 39 to 437 nmol/L in the adult females. The effect of vitamin D treatment on the mean plasma vitamin D concentrations in crias and adults is shown in Figure 24. The mean plasma vitamin D values in untreated crias declined from about 40 nmol/L at day 2 to plateau out at about 15 nmol/L from week 7 of the experiment, whereas in the untreated females, mean plasma vitamin D values were markedly higher than in the untreated crias and the values continued to decline during the experimental period; from about 145 nmol/L to 28 nmol/L at week 16.

Statistical analysis of the plasma vitamin D values in crias indicated a significant treatment by time interaction ($P < 0.05$). The injection of 1,000 IU vitamin D/kg bodyweight raised the mean plasma vitamin D value above the mean value for untreated crias from 2 days to 4 weeks after treatment, whereas the larger dose of vitamin D increased mean vitamin D values from 2 days to 7 weeks after treatment (Figure 24). At week 7 two crias from the 1,000 IU group had plasma vitamin D concentrations of 5 and 31 nmol/L and one cria in the 2,000 IU group had a concentration of 33 nmol/L. At week 11 all crias apart from one in the 1,000 IU group and two in the 2,000 IU group had plasma vitamin D values below 25 nmol/L.

The plasma vitamin D concentrations in adult female alpacas were affected by treatment ($P < 0.05$) and by time ($P < 0.01$). The overall covariate-adjusted mean concentrations for plasma vitamin D in the 0 IU/kg, 1,000 IU/kg and 2,000 IU/kg groups were respectively 90, 175 and 218 nmol/L (LSD ($P=0.05$) = 67.4 nmol/L) suggesting that both dosages of vitamin D were effective in raising mean plasma vitamin D concentrations for the period of the experiment (Figure 24).

Mean plasma phosphorus concentrations in crias and adults were also affected by vitamin D treatment (Figure 25). Statistical analysis indicated a significant treatment by time interaction ($P < 0.05$) for crias and a significant effect of treatment ($P < 0.5$) and of time ($P < 0.05$) in adults. The difference in mean phosphorus concentrations between untreated and treated animals was most noticeable for crias during the early stages of the experiment and for the adults during the later stages of the experiment. Mean plasma phosphorus concentrations in the untreated crias were below 1.3 mmol/L at weeks 7 and 11 of the experiment. The vitamin D treatments maintained mean plasma phosphorus concentrations in crias above 1.5 mmol/L for the period of the experiment except for the 1,000 IU/kg treatment when the mean concentrations at week 11 was 1.34 mmol/L (Figure 25). At week 16 one cria in the 1,000 IU/kg group and two in the 2,000 IU/kg group had plasma phosphorus concentrations below 1.2 and 0.9 mmol/L respectively.

The response in plasma phosphorus concentrations to 1,000 or 2,000 IU vitamin D/kg bodyweight was similar in the adults and significantly greater ($P < 0.05$) than the mean concentrations in the untreated alpacas. The overall covariate-adjusted mean concentrations for plasma phosphorus in the alpacas in the 0 IU/kg, 1000 IU/kg and 2000 IU/kg groups were respectively 1.6, 2.3 and 2.3 mmol/L (LSD ($P = 0.05$) = 0.43 mmol/L). Mean plasma phosphorus values in the untreated adults were below 1.5 mmol/L from week 7 of the experiment. At week 11 two females in the untreated group had plasma phosphorus values below 0.5 mmol/L. The vitamin D treatments maintained plasma phosphorus concentrations above 1.5 mmol/L in all adults for the period of the experiment.

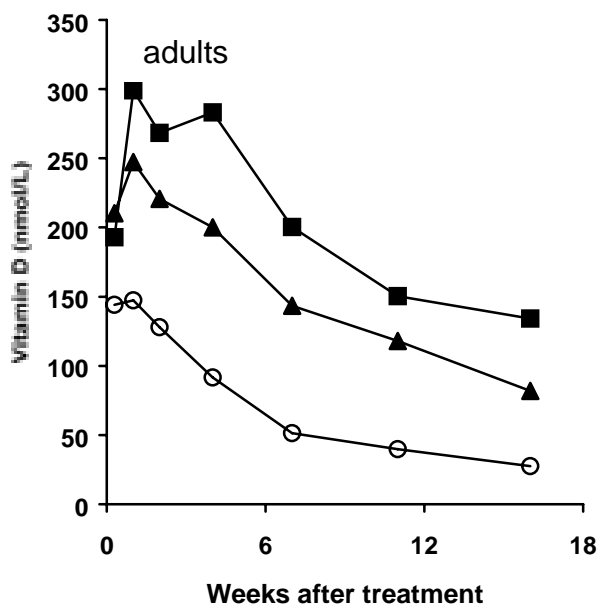
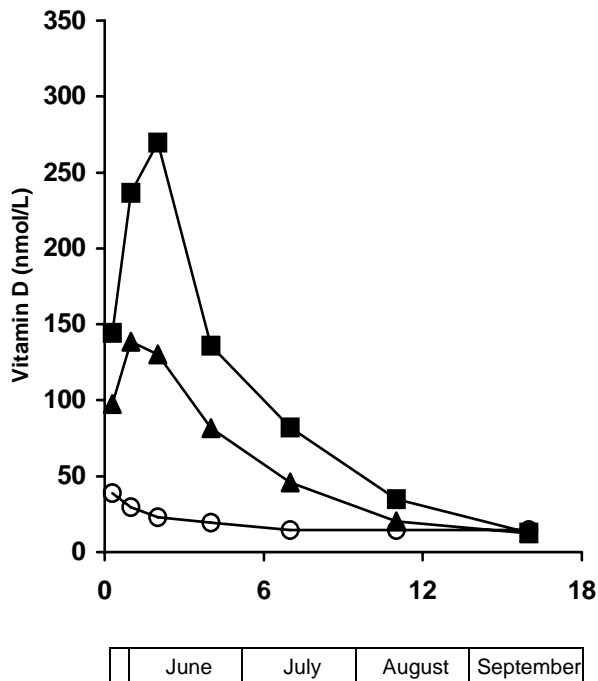


Figure 24. Changes in the covariate-adjusted mean plasma vitamin D concentrations in crias and adult alpacas following subcutaneous injection of vitamin D at 0 (O), 1000 (△) and 2000 (■) IU/kg bodyweight. The significant time x treatment interaction for crias gave a least significant difference ($P = 0.05$) for the same time comparison of 50.0 nmol/L.

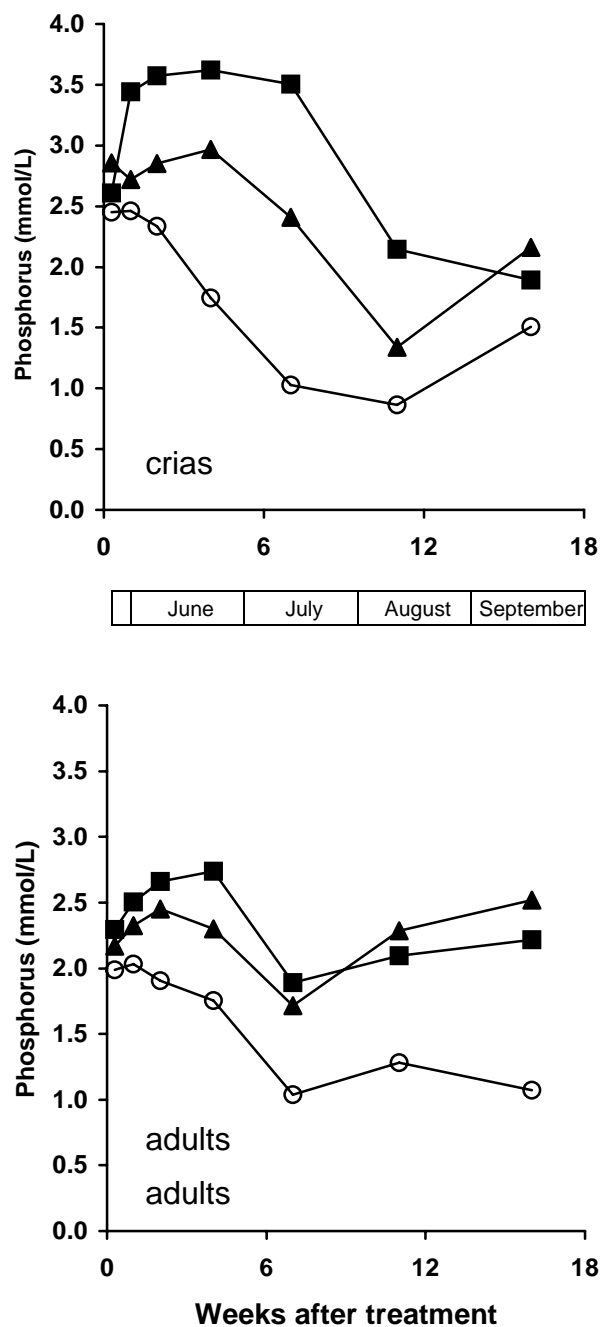


Figure 25. Changes in the covariate-adjusted mean plasma phosphorus concentrations in crias and adult alpacas following subcutaneous injection of vitamin D at 0 (O), 1000 (□) and 2000 (▲) IU/kg bodyweight. The significant time x treatment interaction for crias gave a least significant difference ($P = 0.05$) for the same time comparison of 0.789 mmol/L.

Other plasma constituents

Plasma alkaline phosphatase activity and plasma concentrations of vitamins A and E and calcium were unaffected by treatment ($P > 0.05$) and by treatment by time interactions ($P > 0.05$) apart from a treatment effect ($P < 0.05$) on plasma calcium values in crias: the overall covariate-adjusted mean values for plasma calcium in crias in the 0, 1,000 and 2,000 IU/kg vitamin D groups were respectively 2.48, 2.49 and 2.60 mmol/L (LSD ($P = 0.05$) = 0.90). Most plasma constituents were, however, affected by time (Table 23).

Table 24. Covariated-adjusted mean values for calcium, vitamins E and A and alkaline phosphatase in crias and adult female alpacas given different vitamin D treatments.

The P value gives the statistical significance of time effect. SED, standard error of difference with 66 and 72 degrees of freedom for crias and adults respectively.

Plasma constituent/ alpaca group	Weeks after treatment							P value ^a	SED ^b
	0.3	1	2	4	7	11	16		
Plasma calcium (mmol/L)									
Crias	2.51	2.56	2.52	2.60	2.64	2.35	2.49	$P < 0.05$	0.034
Adults	2.29	2.38	2.38	2.43	2.44	2.23	2.35	$P < 0.01$	0.030
Plasma vitamin E (mg/L)									
Crias	1.4	1.0	1.6	1.1	1.2	1.8	1.9	$P < 0.05$	0.11
Adults	1.3	1.0	1.7	1.3	1.2	1.8	2.2	$P < 0.01$	0.10
Plasma vitamin A ($\mu\text{g/L}$)									
Crias	618	590	626	770	694	638	641	$P < 0.05$	30.9
Adults	680	623	696	844	842	820	825	$P < 0.01$	33.4
Plasma alkaline phosphatase activity (IU/L)									
Crias	208	202	210	248	195	203	182	$P < 0.05$	11.8
Adults	87	93	88	100	92	86	75	$P > 0.05$	5.9

4.2.4. Discussion

Crias born during late summer-autumn in southern Australia appear to be particularly vulnerable to vitamin D deficiency during their first winter (McMillan *et al.* 1995). The present study demonstrates that this disorder was associated with reduced growth rate of crias, particularly during weeks 4 and 11 of the experiment (late June – mid August) and in one female cria (born mid summer) other signs of rickets were also evident (Figure 26). It has been suggested that juvenile camelids can be at risk of vitamin D deficiency when plasma vitamin D and phosphorus concentrations are < 15 nmol/L and < 1.5 mmol/L respectively (Van Saun *et al.* 1996). The reduced growth rates of crias in the present study were associated with mean concentrations for plasma vitamin D of < 20 nmol/L and plasma phosphorus of < 1.3 mmol/L. Plasma alkaline phosphatase activity can increase due to osteoblastic activity in rickets in other species (Capen and Rosol 1989) but vitamin D treatment had no effect ($P > 0.05$) on mean plasma alkaline phosphatase activity in alpacas in the present study (Table 23).



Figure 26. Cria 643 with suspected rickets from untreated group (week 7 of experiment). The cria had a plasma vitamin D concentration of 7 nmol/L, a plasma phosphorus concentration of 0.55 mmol/L and a plasma alkaline phosphatase activity of 243 IU/L.

There were no clinical signs of rickets in the adult females not given the vitamin D injections. Mean plasma vitamin D values in this group did not fall below 50 nmol/L until the end of the experiment in early spring (Figure 24) although the two black females in this group had plasma vitamin D values below 20 from week 11 of the experiment. These two females may have been at risk of vitamin D deficiency because the low vitamin D values were associated with a marked drop in plasma phosphorus concentrations to values below 0.5 mmol/L. The normal range for plasma phosphorus concentrations in adult alpacas is not known but it likely to be less than in crias. From a survey of alpacas in southern Australia (Judson 1996), typical plasma phosphorus values were 2.4-2.9 mmol/L for crias and 1.2 to 2.1 mmol/L for adults.

The present study indicates that single injections of 1000 and 2000 IU vitamin D/kg bodyweight maintained an adequate vitamin D status of crias (ie mean plasma vitamin D concentrations > 50 nmol/L) for about 7 weeks and between 7 and 11 weeks respectively (Figure 24). Adult alpacas were less susceptible than crias to vitamin D inadequacy. It appears that untreated females may have been at risk to vitamin D inadequacy (mean plasma vitamin D concentrations below 50 nmol/L) in late winter to early spring (Figure 24). Injections of 1000 or 2000 IU vitamin D/kg bodyweight were found to significantly increase mean plasma vitamin D concentrations above those in the untreated females for 16 weeks. At 16 weeks post-treatment one grey female given 1,000 IU/kg of vitamin D and one black and one mid brown female given 2,000 IU/kg had plasma vitamin D values below 50 nmol/L suggesting that the effective life of the supplement was less than 16 weeks in the darker animals. The effect of coat colour on vitamin D status of alpacas is not clear. For instance, the variability of the plasma vitamin D concentrations in adult females before treatment may in part be influenced by coat colour. The range of plasma vitamin

D concentrations (nmol/L) for adults allocated to the white, medium brown, grey and two black blocks were respectively 117 – 437 (n=3); 80 – 271 (3); 133 – 220 (3), and 39 – 177 (6). Coat colour did not seem to be important in the crias as all untreated animals were at risk to vitamin D deficiency. Age may have a more significant effect on vitamin D status of crias at the beginning of winter, the older animals having a greater opportunity to build up vitamin D reserves during the summer-autumn seasons (McMillan *et al.* 1995).

The vitamin supplement used in the present study is an oil-based emulsion containing vitamins E and A as well as vitamin D. In this study there was no evidence of a response in plasma vitamins A and E concentrations to the injections of 10,000 and 20,000 IU vitamin A/kg bodyweight and 1 and 2 IU vitamin E/kg bodyweight. The poor availability of vitamins A and E when given in an oily suspension agrees with other findings in sheep. Little or no responses have been observed in plasma vitamin concentrations in sheep given 15 to 120 IU vitamin E/kg (Judson *et al.* 1991; Fry *et al.* 1996) subcutaneously or 30,000 IU vitamin A/kg bodyweight (Hidioglou and Batra 1996) intramuscularly. The need to provide these vitamins to alpacas on green feed is questionable. The minimum plasma concentration of vitamins A and E indicative of adequacy in alpacas is not known. The plasma concentrations of these vitamins observed in the present study (Table 24) were usually above the minimum values indicating adequacy in sheep and cattle. For prevention of vitamin D inadequacy in alpacas it would be preferable to have a product suitable for subcutaneous administration containing only vitamin D at a concentration of ... 50,000 IU/ml.

For alpacas in southern Australia, a single injection of 1,000 IU vitamin D/kg bodyweight to crias in late autumn and again in mid winter and to adult females in mid winter should ensure vitamin D adequacy. Increasing the dosage to 2,000 IU/kg bodyweight will probably increase the period of adequacy but will not eliminate the need for a second injection in crias.

4.3. BLOOD MINERALS, TRACE ELEMENTS AND VITAMINS OF ALPACAS AND SHEEP GRAZING THE SAME PASTURE

4.3.1. Introduction

The survey of alpacas at pasture in southern Australia showed that a number of blood constituents differed from values normally encountered in healthy ruminants. In particular, plasma zinc and copper in all age groups were generally lower than observed in ruminants whereas plasma phosphorus in young alpacas were usually higher than observed in ruminants.

We are not aware of any reports of a direct comparison of the mineral, trace element and vitamins in blood of alpacas and ruminants although inter-species differences have been observed with sheep and llamas (Espinoza *et al.* 1982) and sheep and guanacos (Illingworth *et al.* 1998) grazing the same pasture.

The present study was undertaken to compare blood constituents in sheep and alpacas grazing the same pasture.

4.3.2. Materials and methods

Site and animals

The experiment was conducted at the Victorian Institute of Animal Science, Attwood, which is located 18 km north-northwest of Melbourne (37°40'S; 144°53'E), altitude 135 m ASL (V5).

The animals used in the experiment were nine Merino wethers (3 years old), five alpaca wethers (2 – 11 years old) and five alpaca males (2 – 6 years old). The alpacas were introduced to the experimental site in 1994 and the sheep in September, 1995. The animals grazed and were usually weighed at monthly intervals. No supplementary feed was given during the period of the experiment (November, 1995 – August, 1997) and the animals were shorn mid November of each year.

The experimental site was a 3.2 ha of improved pasture composed mainly of annual rye grass with smaller amounts of subterranean clover, fog grass, brome grass, silver grass, barley grass, couch grass and capeweed. To increase grazing pressure, the animals were excluded from 25% of the area from October, 1996 until the end of the experiment.

Blood and pasture sampling

Blood samples for chemical analyses were collected from the jugular vein of each animal on 12 occasions at 1 – 3 monthly intervals during the period of the experiment. Blood samples were collected into 7-ml heparinised tubes ('Vacutainer' Reference 367735, Becton Dickson) for trace element analyses and into 9 ml heparinised tubes ('Vacuette' Greiner Labortechnik) for other chemical analyses.

At the time of blood sampling, pasture sample for estimation of mass and mineral and vitamin E content were collected from 1 m² of the grazed area. The sample was weighed and a subsample was stored at –20°C for vitamin E analysis and another subsample for mineral analysis were dried at 60°C. The dried sample was ground to a fine powder using a ring grinder with a zirconium head. Results were expressed on a dry matter (DM) basis.

Chemical procedures

An aliquot of whole blood was stored at 4°C for selenium analysis and for other assays, the blood cells were removed by centrifugation and the plasma stored at –20°C until assayed for trace and major elements and vitamins

Plasma samples were assayed for vitamin B₁₂ using a radioactive assay kit (Solid Phase No Boil Assay, Diagnostic Products Corporation, USA) as described by Judson *et al.* (1991). Plasma vitamin D (25-hydroxycholecalciferol) was determined using a competitive protein-binding procedure as described by Morris *et al.* (1984). Plasma copper and zinc assays were performed using atomic absorption spectrophotometry as described by Cavanagh and Judson (1994). Plasma vitamins A and E and feed vitamin E were assayed using a high pressure liquid chromatograph as described by Judson *et al.* (1991) and selenium concentrations in blood and feed were assayed by a fluorimetric procedure as described by Koh and Benson (1983). Plasma calcium, inorganic phosphorus and magnesium were measured colorimetrically using a Cobas Mira random access analyser (F. Hoffmann La Roche Co.) and commercial kits (Trace

Scientific Ltd, Melbourne). Mineral and trace element concentrations in acid-digested feed samples were assayed using an inductively coupled plasma mass spectrophotometer.

Samples included in assays for quality control purposes included serum from Nycomed Pahrma, Norway for blood and plasma trace elements, serum from Randox United Kingdom and Trace Scientific Ltd. for major elements, and rye grass (Commission of the European Communities, reference material No. 281) and hay (International Atomic Energy Agency, reference material V-10) for feed major and trace elements, were used for quality control purposes. For vitamin B₁₂ assay plasma sample supplied by Diagnostic Products Corporation and bovine and ovine plasma samples prepared in the laboratory were used for quality control.

Statistical analysis

The alpaca results were subjected to an analysis of variance to test for differences between males and wethers. If differences were found then alpaca males and wethers were compared with sheep. An analysis of variance of a randomised design was used to compare the two species over time. Differences between means was compared using the least significance difference procedure.

4.3.3. Results and Discussion

Pasture

During 1995 the pasture had been under-grazed and combined with excellent rainfall, the availability of green herbage, as indicated in Table 25 by the mass of pasture and the low dry matter content, was high until November, 1996. In 1997 the availability of green herbage was low and a weak autumn break occurred in May. The increased grazing pressure at the time prevented the build up of herbage.

Table 25. Mass of pasture on offer and the major and trace nutrient content of the pasture at different times during the experimental period

Constituent	Sampling times										
	1995 Dec	1996 →							1997 →		
		Feb	May	Jun	Jul	Sep	Nov	Feb	May	Jun	Jul
Pasture											
Dry matter (DM), %	28.5	61.1	24.5	15.2	11.4	12.6	33.4	85.6	85.6	40.6	20.5
Mass, g DM/m ²	167	134	99	85	56	88	181	64	56	23	14
Major nutrients*, g/kg DM											
Protein (110)	115	89	175	176	221	207	76	47	110	103	222
Calcium (1.5-2.6)	6.9	4.1	3.4	2.5	5.2	5.8	3.4	3.2	3.0	3.6	4.0
Phosphorus (1.3-2.5)	2.5	1.7	3.2	2.6	4.7	3.5	2.0	1.1	1.4	1.7	3.1
Chlorine (1.0)	17.2	6.5	12.5	18.0	20.7	26.3	9.9	3.1	3.6	3.6	13.3
Magnesium (1.2)	2.4	1.7	2.1	1.6	2.3	2.3	1.8	1.3	1.2	1.3	2.1
Potassium (5.0)	24.2	12.8	24.6	22.5	36.9	45.4	14.0	4.1	6.2	8.4	24.5
Sodium (0.7-0.9)	3.4	1.2	2.1	2.1	5.3	5.9	2.2	1.1	1.0	1.0	4.5
Sulfur (2.0)	2.3	3.0	3.8	2.3	3.0	2.7	1.8	1.2	1.2	1.5	2.5
Trace nutrients*, mg/kg DM											
Cobalt (0.11)	0.01	0.05	0.08	0.05	0.22	0.17	0.13	0.19	0.01	0.40	0.14
Copper (5)	8.2	6.3	7.6	7.6	7.5	6.8	5.5	5.0	4.3	6.9	8.7
Iron (40)	269	207	389	292	840	267	134	380	1325	1333	1396
Manganese (15-25)	136	166	184	125	143	172	245	300	288	247	182
Molybdenum (0.1?)	0.3	0.4	0.7	0.1	0.8	1.0	1.3	0.9	0.7	0.9	1.8
Selenium (0.05)	0.16	-	0.23	0.14	0.14	0.07	0.14	0.18	0.15	0.18	0.07
Zinc (20-30)	45	38	40	36	51	54	33	39	49	66	45
Vitamin E (15-20)	56	79	125	43	72	68	32	4	5	19	50

* In brackets the desirable level in feed for sheep. Where a range is given, the higher values are for rapidly growing or lactating sheep

The pasture analysis indicates that the protein content of the herbage was markedly below the minimum desirable level for sheep in February, 1997 and that phosphorus was also below the desirable level at this stage.

Of the trace nutrients, cobalt was below the desirable level for sheep for much of the first year of the experiment and again in May of the second year when copper was also low. The vitamin E content of the autumn pasture in 1997 was low which is not unexpected as vitamin E is usually low in dry herbage.

Liveweight

Figure 27 gives the mean liveweights of alpaca wethers, alpaca males and sheep during the period of the experiment. One male alpaca that was difficult to handle was replaced with another male in November, 1996. One sheep with suspected kidney dysfunction was removed from the experiment in February, 1997 and replaced with another wether: the blood results of the former wether were not considered in the statistical analysis.

Alpacas were significantly heavier ($P < 0.001$) than the sheep at all stages of the experiment. Animals gained weight from the commencement of the study until October, 1996 and then lost

weight during the remainder of the experimental period (Figure 27). The decrease in weight coincided with the exclusion of animals from about 25% of the grazed area from October. At this stage to further increase the grazing pressure additional sheep were introduced.

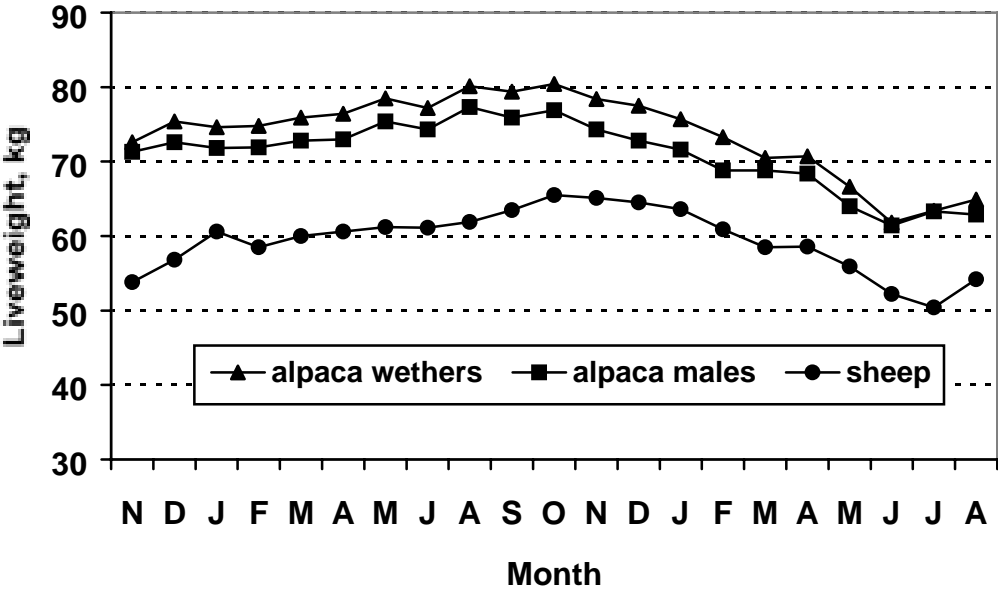


Figure 27. Mean liveweights of alpacas and sheep from November (N) 1995 until August (A) 1997. Mean values are for 5 alpaca wethers, 4 alpaca males and 9 sheep wethers. No weights were recorded in June, 1996.

Major constituents and vitamin D

Plasma calcium concentrations in alpaca males and alpaca wethers were similar ($P > 0.05$). Statistical analysis indicated that the mean concentration of 2.52 mmol/L in sheep was greater than the mean concentration of 2.26 mmol/L in alpacas ($P < 0.001$). At each sampling time, the mean value for sheep was greater ($P < 0.01$) than the mean value for alpacas (Figure 28).

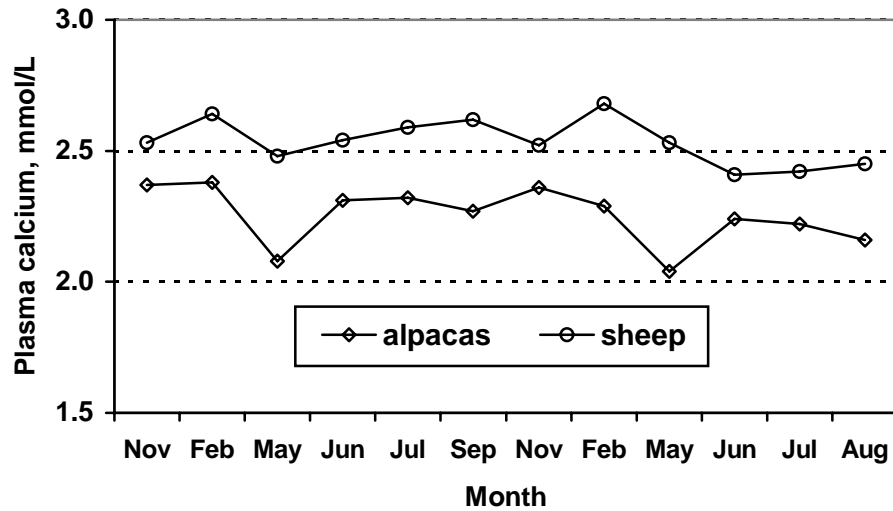


Figure 28. Mean plasma calcium concentrations in alpacas and sheep from November 1995 until August 1996

A significant proportion of the plasma calcium in ruminant blood is bound to albumin. Statistical analysis showed that mean plasma albumin concentration in alpaca wethers (42.8 g/L) was greater ($P < 0.05$) than in alpaca males (41.8 g/L) and that these values were greater ($P < 0.001$) than the mean concentration of 34.2 g/L in sheep. At each sampling occasion (Figure 29), the mean value in sheep was less than the mean value in alpaca wethers ($P < 0.001$) and in alpaca males ($P < 0.01$). It appears that the higher calcium concentrations in sheep than in alpacas (Figure 28) was not due to a higher albumin concentration. The lower albumin concentrations in both species in the second year of the study (Figure 29) coincided with weight loss as a result of increased grazing pressure.

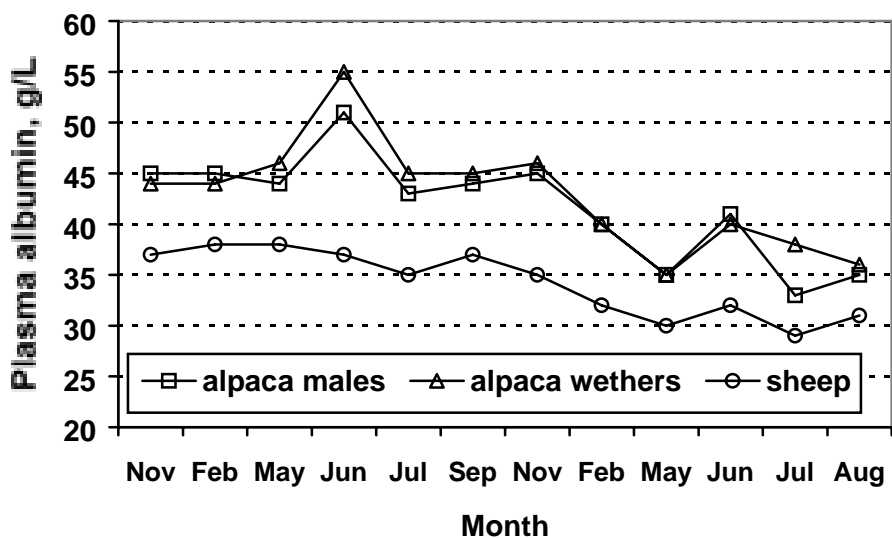


Figure 29. Mean plasma albumin concentrations in alpaca males and wethers and sheep.

Mean plasma phosphorus concentrations in alpaca males and wethers were similar ($P > 0.05$). The mean concentration was greater ($P < 0.001$) in alpacas than in sheep (1.76 v 1.46 mmol/L). In general, the mean values for alpacas were greater than for sheep ($P < 0.05$) during late spring and summer (Figure 30).

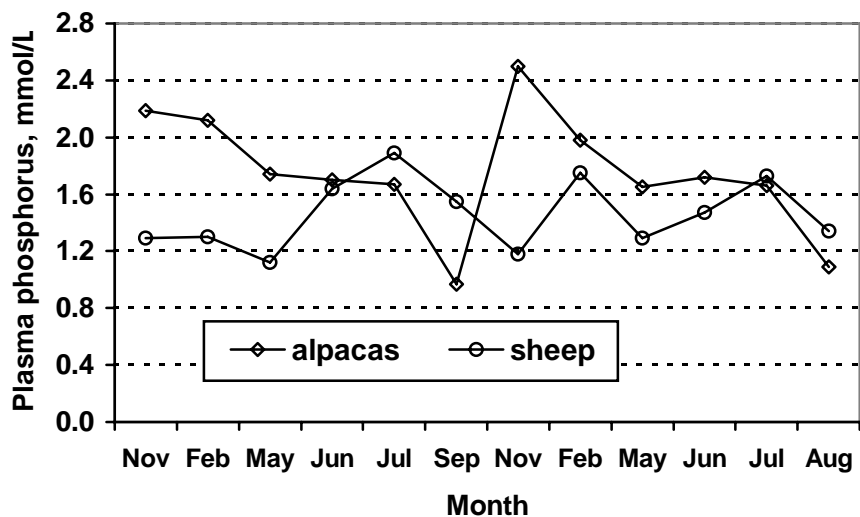


Figure 30. Mean plasma phosphorus concentrations in alpacas and sheep.

The variation in plasma phosphorus concentrations may in part reflect the variation in vitamin D status of the animal, particularly in alpacas. Mean plasma vitamin D concentrations in alpaca males and wethers were similar ($P > 0.05$) and the overall mean concentration was greater ($P < 0.001$) in alpacas than in sheep (163 v 79 nmol/L). The plasma vitamin D concentrations in alpacas, unlike sheep, showed a marked seasonal change with higher concentrations in the late spring to autumn (Figure 31).

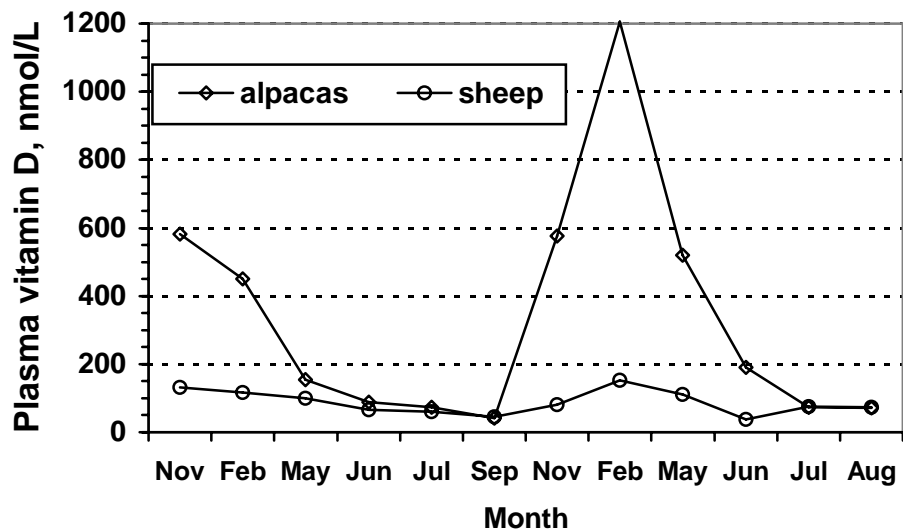


Figure 31. Mean plasma vitamin D concentrations in alpacas and sheep from November 1995 to August 1997.

The mean plasma magnesium concentration was greater ($P < 0.001$) in alpaca males than in alpaca wethers (0.88 v 0.84 mmol/L) and these values were greater ($P < 0.001$ and $P < 0.01$ respectively) than the mean concentration of 0.76 mmol/L in sheep. At each sampling occasion, mean concentrations in alpaca males were greater than in sheep ($P < 0.01$) except in May, 1997 whereas the mean concentrations in alpaca wethers were greater than in sheep ($P < 0.01$) except in May in both years and in September, 1996 and August, 1997 ($P > 0.05$) (Figure 32).

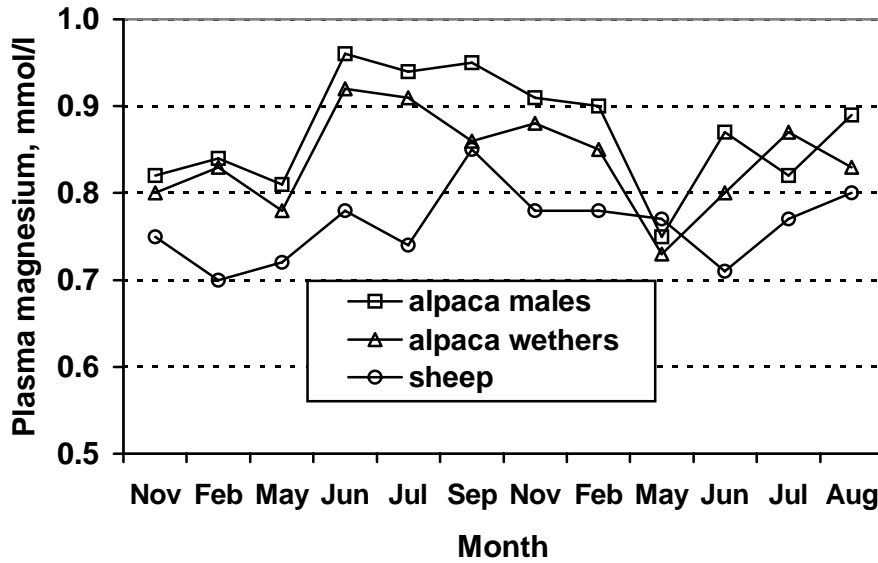


Figure 32. Mean plasma magnesium concentrations in alpacas and sheep from November 1995 to August 1997.

Mean plasma urea concentrations in alpaca males and alpaca wethers were similar ($P > 0.05$) but the mean concentration of 8.6 mmol/L in alpacas was greater than the mean concentration of 6.6 mmol/L in sheep ($P < 0.001$). For the different sampling times, the mean plasma urea concentrations were greater ($P < 0.001$) in alpacas than for sheep in the first year of the study but these differences were not so marked in the second year. Urea is a major end product of protein utilisation in body tissues and of ammonia absorbed from the intestinal tract. Plasma urea concentrations have been used as an indicator of dietary protein content. The seasonal changes in urea concentrations observed in both species (Figure 33) appeared to reflect changes in the protein content of the pasture (Table 25)

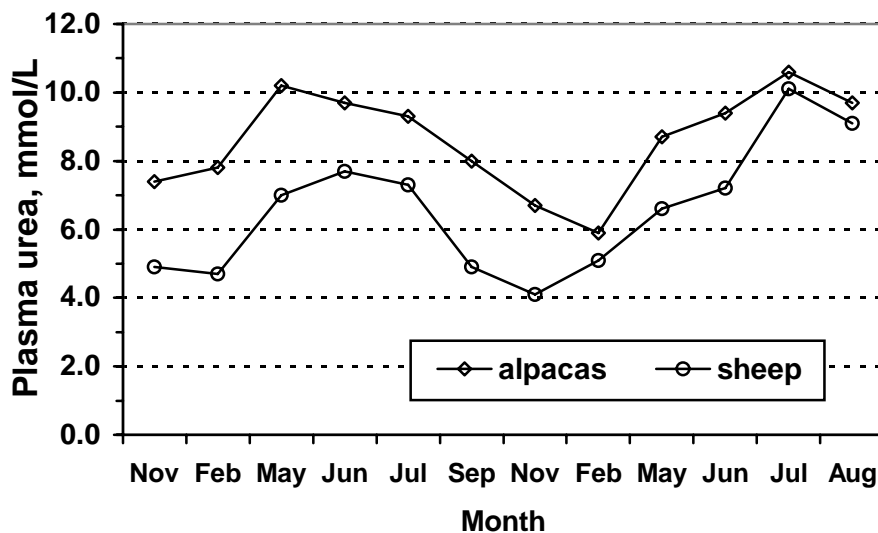


Figure 33. Mean plasma urea concentrations in alpacas and sheep from November 1995 to August 1997.

4.3.4. Trace elements and vitamins B₁₂, E and A

Mean plasma copper concentrations in alpaca males and wethers were similar ($P > 0.05$) but the mean concentration in alpacas of 9.2 $\mu\text{mol/L}$ was less than the mean concentration of 15.8 $\mu\text{mol/L}$ in sheep ($P < 0.001$). The mean values in sheep were greater than in the alpacas at all sampling times (Figure 34).

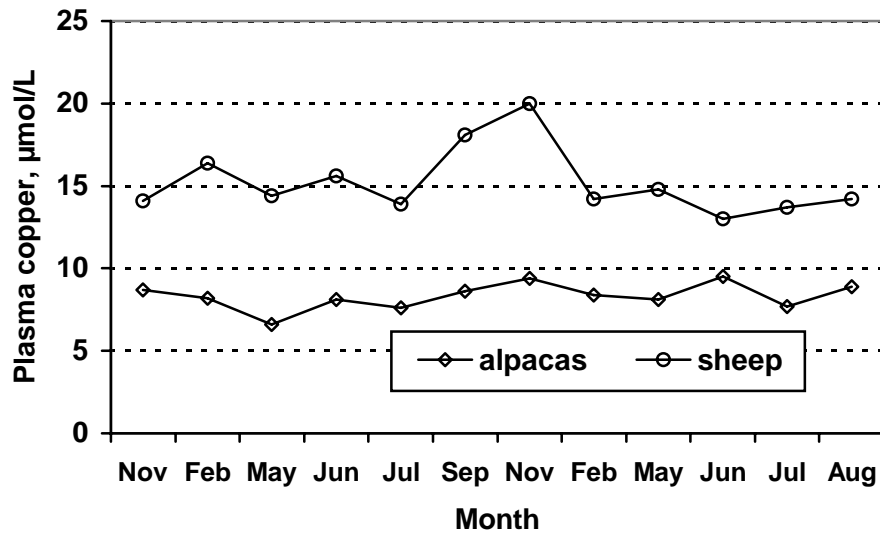


Figure 34. Mean plasma concentrations of copper in alpacas and sheep from November 1995 to August 1997

Mean zinc concentrations in alpaca males and wethers were similar ($P > 0.05$) but the mean value in alpacas of 5.8 $\mu\text{mol/L}$ was less than the mean value of 13.5 for sheep ($P < 0.001$). At all sampling times, the mean concentration in sheep was greater than in alpacas ($P < 0.001$) (Figure 35).

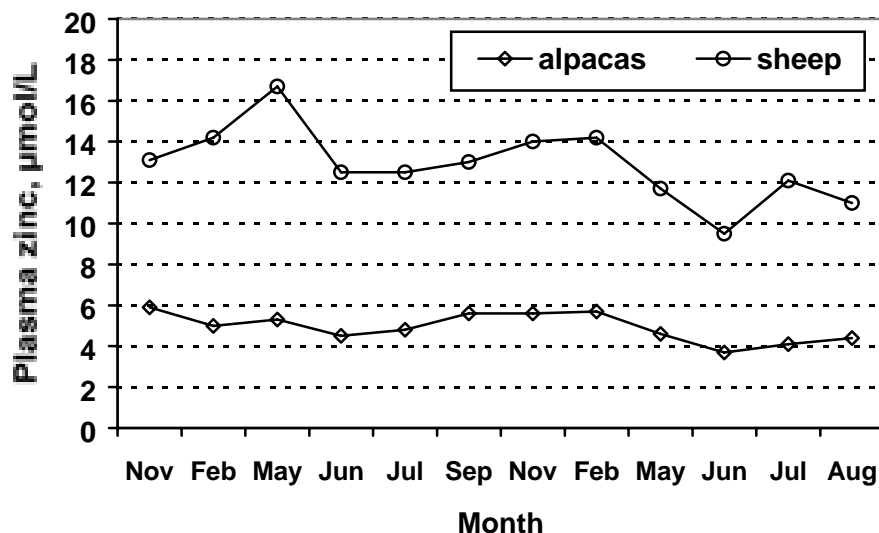


Figure 35. Mean plasma zinc concentrations in alpacas and sheep from November 1995 to August 1997.

Mean plasma vitamin B₁₂ concentrations were greater ($P < 0.01$) in alpaca males than in alpaca wethers (286 v 171 pmol/L) but both values were markedly less ($P < 0.001$) than the mean

concentration of 1300 pmol/L in sheep. At each sampling time, the mean concentration in sheep was greater than the mean concentration in alpaca wethers ($P < 0.001$) and alpaca males ($P < 0.01$) except in June, 1996 (Figure 36) when the mean concentrations in the alpaca males and sheep were similar ($P > 0.05$).

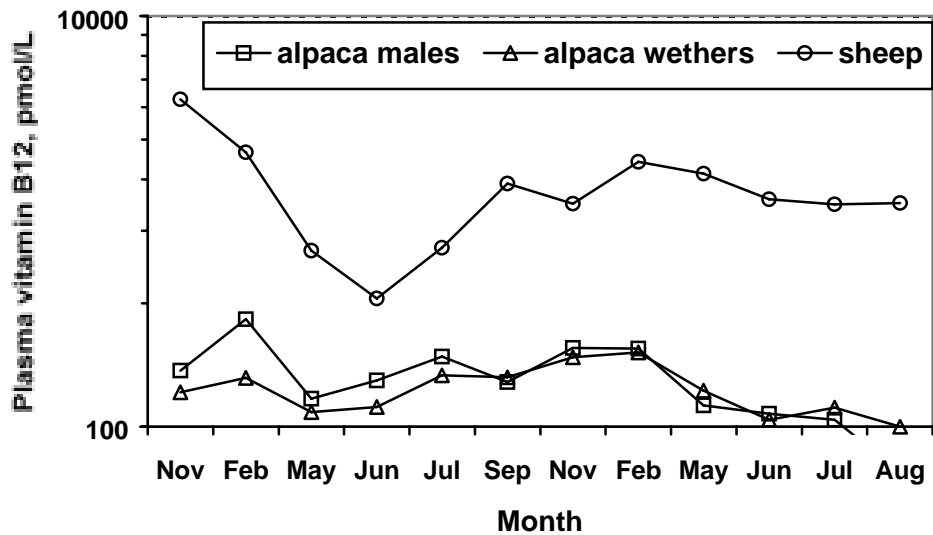


Figure 36. Mean plasma vitamin B₁₂ concentrations (logarithms) in alpaca males and wethers and wethers and sheep from November 1995 to August 1997.

Mean plasma vitamin E concentrations in alpaca males and wethers were similar ($P > 0.05$) and the mean value for alpacas (1.8 mg/L) was less ($P < 0.05$) than the mean value for sheep (2.0 mg/L). The mean concentrations for the two species were similar ($P > 0.05$) at all sampling occasions (Figure 37) except in June and August 1997 when means differed ($P < 0.001$).

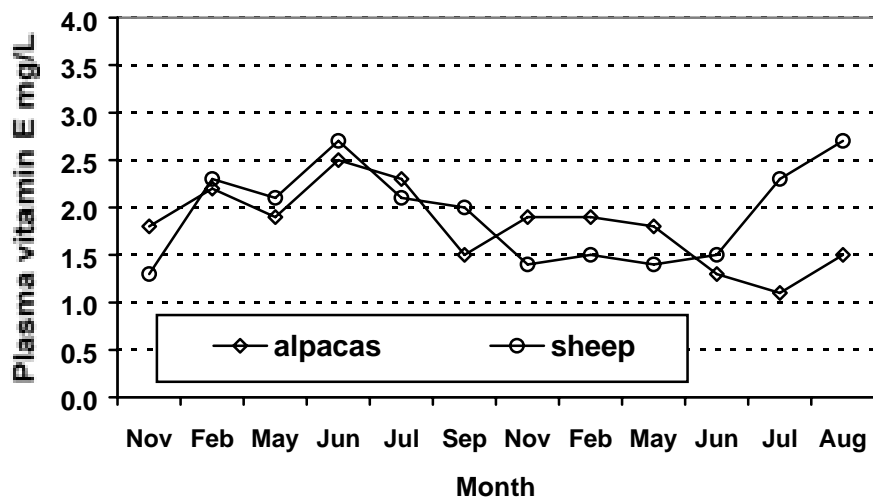


Figure 37. Mean plasma vitamin E concentrations in alpacas and sheep from November 1995 to August 1997

Mean blood selenium concentration was greater ($P < 0.001$) in alpaca wethers than in alpaca males (2.42 v 1.99 $\mu\text{mol/L}$) and these values were less ($P < 0.001$) than the mean concentration

of 3.89 $\mu\text{mol/L}$ in sheep. On all sampling occasions, apart from the initial sample, mean values for sheep were greater ($P < 0.001$) than for the alpacas (Figure 38).

The mean plasma selenium concentrations in alpaca males and wethers were similar ($P > 0.05$) but the mean value for alpacas was greater ($P < 0.001$) than the mean value for sheep (2.43 v 1.69 $\mu\text{mol/L}$). At each sampling time, mean concentrations were greater ($P < 0.01$) in alpacas than in sheep (Figure 38).

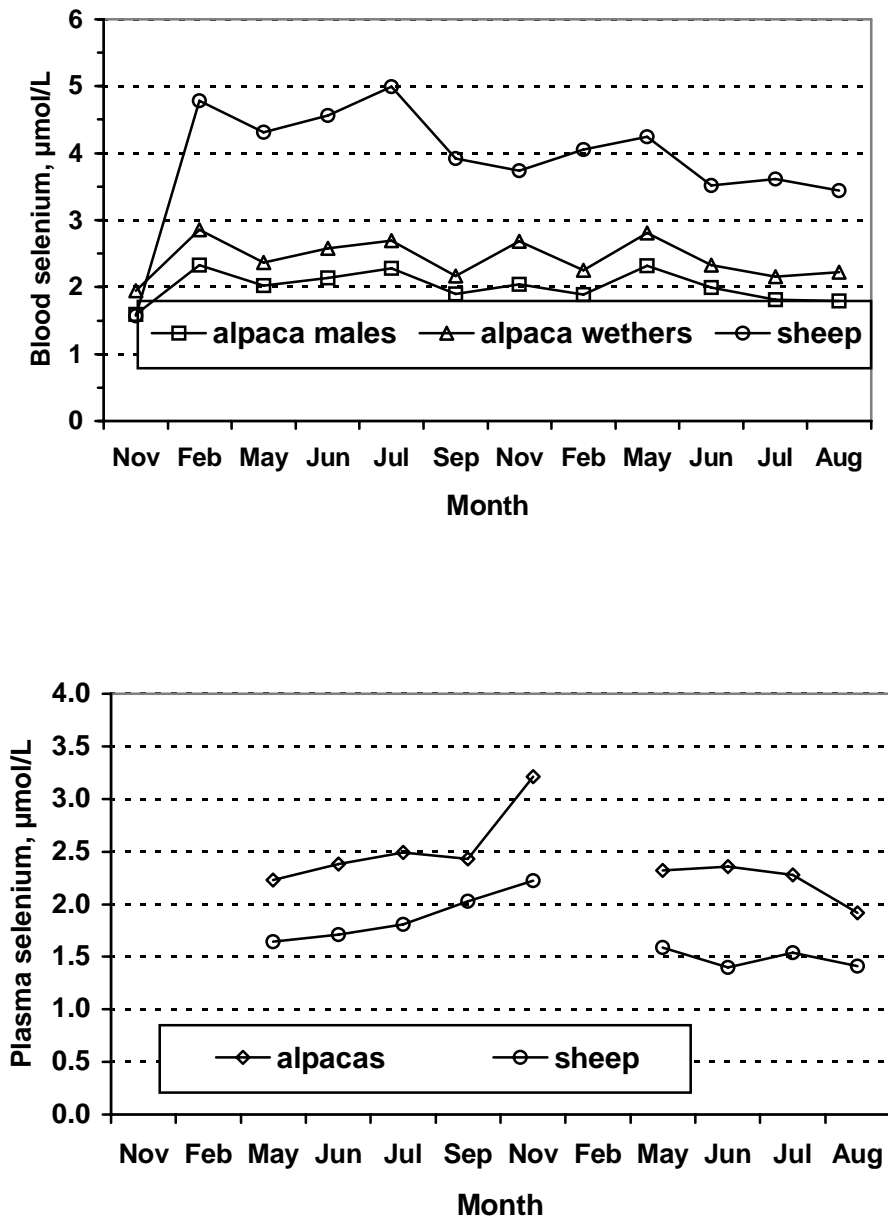


Figure 38. Mean selenium concentrations in blood (upper figure) and plasma (lower figure) in alpacas and sheep from November 1995 to August 1997.

The mean selenium concentrations ($\mu\text{mol/L}$) with their standard deviations in blood and plasma of sheep and alpaca males and wethers were as follows:

Sheep (73 obs) blood selenium = 4.02 ± 0.66 ; plasma selenium = 1.70 ± 0.34

Alpaca males (38 obs) blood selenium = 2.04 ± 0.22 ; plasma selenium = 2.34 ± 0.55
 Alpaca wethers (41 obs) blood selenium = 2.47 ± 0.51 ; plasma selenium = 2.47 ± 0.38

Statistical analysis (paired 't' test) showed that selenium concentration in blood was greater ($P < 0.001$), less ($P < 0.01$) and the same ($P > 0.05$) as the plasma selenium concentrations in sheep, alpaca males and alpaca wethers respectively. These findings indicate that the selenium concentration was markedly higher in blood cells of sheep than in alpacas.

Mean plasma vitamin A concentration was greater ($P < 0.05$) in alpaca males than in alpaca wethers (698 v 777 $\mu\text{g/L}$) and these values were greater ($P < 0.001$) than the mean concentration of 389 $\mu\text{g/L}$ in sheep. At all sampling times, the mean values for the alpacas were greater ($P < 0.001$) than for sheep, apart from the initial mean values ($P > 0.05$) (Figure 39).

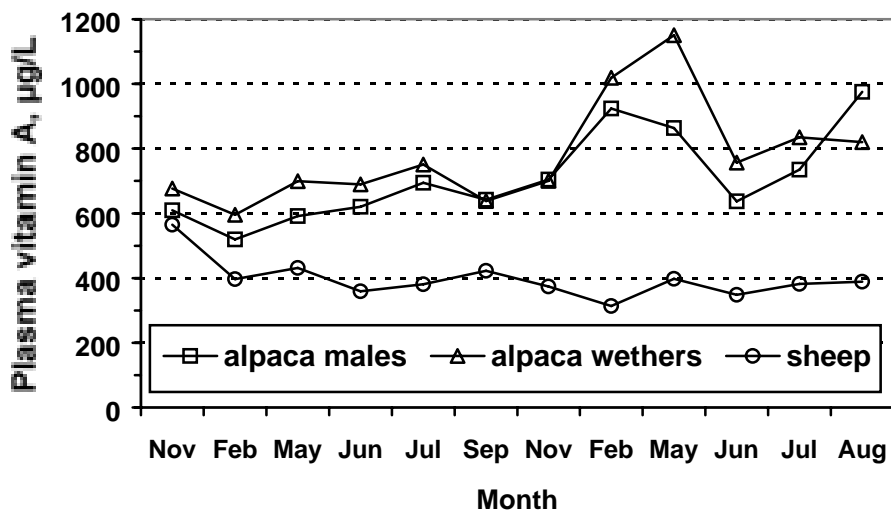


Figure 39. Mean plasma vitamin A concentrations in alpaca males and wethers and in sheep

4.3.5. Conclusions

This investigation identified a number of inter-species differences in blood constituents. Compared to sheep, alpacas had significantly greater plasma concentrations of albumin, urea and selenium and significantly lower concentrations of blood selenium and plasma calcium, copper, zinc and vitamin B₁₂. Further, plasma phosphorus and vitamin D concentrations were more responsive to changes in seasonal conditions in alpacas than in sheep. Small but significant differences were also noted between alpaca males and alpaca wethers for plasma concentrations of albumin, magnesium and vitamin B₁₂ and blood selenium concentration.

Studies with sheep and alpacas on improved pasture indicate species differences in grazing behaviour, sheep were found to have a greater preference for ryegrass (Sharp *et al* 1995) and legumes (San Martin and Bryant 1989) than alpacas. Selective grazing may have accounted for some of the differences in the blood constituents observed between the two species in the present study although in the second year, increased grazing pressure would have reduced the opportunity for selective grazing.

The findings show that marked differences in the concentration of a number of blood constituents exist between the two species when retained on the same pasture. For these constituents, reference ranges indicating adequacy in sheep may not be appropriate for alpacas.

5. INTERNAL PARASITISM IN ALPACAS IN SOUTHERN AUSTRALIA

I. H. Carmichael

5.1. INTRODUCTION

Most of the Australian alpaca foundation stock comprises animals of South American (Chilean and Peruvian) origin, imported either directly into Australia or arriving indirectly via New Zealand. A very small proportion has been derived from the established "on shore" New Zealand population. Regardless of their source, all animals in every consignment were subjected to quarantine plus prescribed testing and treatment with broad spectrum worm remedies (drenching) at each of several stages of the export/import process. The quarantine regulations dictate that each animal arriving in Australia received at least two, but in most cases three treatments with highly effective worm remedies (drenches) during a 100-180 day importation period. Often they were given extra treatments "just to be sure". In addition, they were held for a considerable portion of that time under conditions which would have greatly reduced the likelihood of parasite transmission leading to reinfection. Furthermore, the continued good health of this valuable bloodstock caused sufficient concern upon arrival in Australia that regular broad spectrum drenching became a routine procedure on most farms. By far the most commonly used drench has been ivermectin in injectable formulation, which belongs to a relatively recently developed, highly potent group of compounds, the macrocyclic lactones (the ML drenches).

Intercontinental movement of large consignments of alpacas to a vastly different environment, combined with a highly intensive treatment regimen for worms was bound to have strongly influenced the levels and types of parasites they harboured, particularly in the case of helminth (worm) parasites whose distribution and abundance are largely determined by the interactions of climate and animal management practises. Apart from some work in New Zealand (Hill *et al.*, 1993) there was no information available concerning internal parasites in alpacas farmed in a temperate, winter-rainfall climate, either as a completely new venture or on land concurrently or previously utilised for ruminant livestock production. The overall aim of the parasitology component of the research project, therefore, was to determine whether internal parasitism posed an immediate or potential threat to alpaca health and productivity in the southern Australian environment.

5.1.1. Objectives

Review of risks

An initial objective in the study of internal parasites in the alpaca in southern Australia was to review the situation in the original South American environment, identify the important worm species and management issues involved there, compare these where appropriate to local conditions, and broadly evaluate current and potential risks for the Australian industry.

Levels of parasites and the influence of the environment and management practices

The second, more comprehensive endeavour was to study the seasonality, abundance and impact of internal parasites and measures adopted to control them in several alpaca herds in the winter rainfall zone of southern Australia and provide recommendations to the industry based on the research findings.

Alpacas farmed with other livestock

A third, opportunistic study examined the parasite levels in alpacas and sheep communally grazing the same pasture over a period of 2 years.

5.2. REVIEW OF INTERNAL PARASITES OF THE ALPACA

5.2.1. Parasites of the alpaca in South America

There are very few original published records of the gastro-intestinal worms of the alpaca in South America. A list of those recorded from the alpaca in Peru and the current status of these parasites in Australia is given in Table 26. The author could find no references listing parasites recovered from the alpaca in other South American countries.

Table 26. Gastrointestinal parasites of the alpaca in Peru§

<i>Graphinema aucheniae</i> †	<i>Haemonchus contortus</i> *
<i>Lamanema chavezii</i> †	<i>Trichuris ovis</i> *
<i>Spiculopteragia peruvianus</i> †	<i>Capillaria</i> sp.
<i>Nematodirus lamae</i> †	<i>Camelostrongylus mentulatus</i> *
<i>N. filicollis</i> *	<i>Dictyocaulus filaria</i> *
<i>N.spathiger</i> *	<i>Moniezia expansa</i> *
<i>Cooperia oncophora</i> *	<i>M. benedeni</i> *
<i>C. mcmasteri</i> *	<i>Thysanitiesia giardi</i> *
<i>Trichostrongylus axei</i> *	<i>Fasciola hepatica</i> *
<i>T. colubriformis</i> *	<i>Ostertagia ostertagi</i> *
<i>Oesophagostomum venulosum</i> *	<i>O. circumcincta</i> *

§ Sources : Chafez *et al.*, 1967; Guerrero & Alva, 1986; Hill *et al.* (1993) recovered *Oesophagostomum venulosum* from an alpaca at autopsy in New Zealand.

† Specific parasites of lamoids.

* Species present in either cattle and/or sheep or goats in southern Australia.

The naturally occurring worm parasites of the alpaca in South America fall broadly into 3 categories:

(i) Lamoid-specific parasites : [*Lamanema chavezii*, *Nematodirus lamae*, (small intestine); *Graphinema aucheniae*, *Spiculopteragia peruvianus* (stomach)]

None of the lamoid-specific helminths has yet been recovered from alpacas in Australia.

(ii) **Parasites normally associated with sheep or goats** : *Nematodirus spathiger*, *N. fillicollis*, *Trichostrongylus colubriformis*, *Ostertagia circumcincta*, *Oesophagostomum venulosum*, *Haemonchus contortus*, *Camelostrongylus mentulatus*, *Dictyocaulus filaria*.

(iii) **Parasites normally associated with cattle** : *Cooperia oncophora*, *C. mcmasteri*, *Trichostrongylus axei*, *Ostertagia ostertagi*, *Fasciola hepatica* - the latter parasite frequently causes serious disease or death in sheep whereas cattle are more resilient to its effects.

All but 2 (*Capillaria* and *Thysanitiesia*) of the 18 sheep, goat and cattle parasites recorded from alpacas in South America are common in ruminants in Australia.

5.2.2. Parasites recovered from the alpaca in Australia

There are very few confirmed internal parasite identifications from alpacas in Australia . This is not unexpected because post mortem material from such a valuable animal does not regularly become available. Notwithstanding this, the limited data available have not yet been collated, probably because it was perceived to serve no useful purpose. The available records to date¹ are as follows :

<i>Cooperia oncophora</i>	Vic.
<i>Cooperia punctata</i> •	NSW
<i>Haemonchus contortus</i>	Vic.;
<i>Nematodirus abnormalis</i> •	SA;
<i>Nematodirus fillicollis</i>	SA;
<i>Nematodirus helvetianus</i> •	SA;
<i>Nematodirus spathiger</i>	SA; Vic;
<i>Ostertagia (Teladorsagia) circumcincta</i>	Vic.;
<i>Ostertagia ostertagi</i>	Vic.
<i>Trichostrongylus axei</i>	Vic.; NSW
<i>Trichostrongylus colubriformis</i>	SA; Vic
<i>Trichostrongylus rugatus</i> •	SA;
<i>Trichostrongylus vitrinus</i> •	Vic.;

- New host record

There are currently no identifications to species level of internal parasites from alpacas in WA or Tasmania.

5.2.3. Naturally acquired worm burdens in alpacas

There are no records of total worm burdens of healthy alpacas in Australia but burdens as high as 14500 (11200 *Trichostrongylus axei*) and 23500 (approximately 14700 *Nematodirus*

¹ Information provided from the following institutions and individuals : South Australian Research and Development Institute (I. Carmichael & M. O'Callaghan); University of Melbourne (I. Beveridge); Victorian Institute of Animal Science (P. Presidente); NSW Agriculture (J. Lloyd & G Fraser); Western Australian Department of Agriculture (G. Mitchell); Tasmanian Department of Agriculture (R. Mason).

spathiger and 8800 *T.axei*) worms have been recorded in 2 clinically affected young animals in Victoria. (P. Presidente, personal communication, 1999). Animals had been grazing paddocks contaminated by cattle and sheep respectively.

Guerrero *et al.* (1986b) gave details of total worm burdens in ten, 10- months old naturally infected crias which served as controls in two drench efficacy studies in Peru. Geometric mean worm burdens in these animals were as follows: *Lamanema chavezii* (1672); *L. chavezii* fourth larval stage [L4] (292); *T. axei* (152); *Ostertagia* spp. (213); *Ostertagia* spp. L4 (91); *N. lamae* (781); *N. spathiger* (544); *Spiculopteragia peruvianus* (40).

Chavez *et al.* (1967) documented the following mean worm burdens in 199 Peruvian alpacas of mixed ages: *L. chavezii* (1772); *N. lamae* (1055); *Cooperia* spp. (386); *Graphinema aucheniae* (385); *N. spathiger* (132); *Ostertagia* spp. (97); *Trichuris* spp. (90) *Trichostrongylus* spp. (74); *S. peruvianus* (67); *Capillaria* spp. (29); *N. filicollis* (18); *Camelostrongylus mentulatus* (4); *Oesophagostomum venulosum* (1); *Haemonchus* spp. (1).

The practical significance of these parasite levels is difficult to interpret because it is not known what condition the animals were in at the time of sampling.

Although it was only described as recently as 1963 *Lamanema chavezii* is the most prevalent and probably also the most important parasite of alpacas in South America; the larvae cause severe hepatic necrosis during a migratory phase through the liver of young alpacas, and adult worms located in the small intestine are responsible for varying levels of anaemia. The other three lamoid-specific parasites produce signs similar to their "scourworm" counterparts in sheep, namely loss of condition or poor growth rate, diarrhoea, anorexia (inappetence) and occasionally death. Brittleness of the fibre is also reported (Guerrero & Leguia, 1987), however the author can find no documented studies which support this claim.

It is important to remember that because all internal parasites undergo a phase of their development outside the animal the environment is the major determinant of the distribution and abundance of internal parasites. The levels of parasites and worm species described from Peru relate to animals in a very harsh climate at an altitude of around 4000m and probably bear little or no resemblance to what might be expected to be found under Australian conditions. It may well be that the four major lamoid-specific parasites, even if introduced, could be adversely influenced by the Australian environment and assume little or no importance.

An interesting observation is that the Peruvian alpacas only carried low burdens of sheep and cattle parasites of the types present in southern Australia (see parasites marked with an asterisk in Table 26), which suggests two possibilities: either those parasites are not well adapted to the Peruvian highland environment, or alpacas are not highly suited as hosts for some species of parasites they are likely to be exposed to in Australia. Notwithstanding this, there is evidence as described earlier, that alpacas are not always unaffected by infections with cattle and sheep parasites, so there is no justification for complacency, particularly where ruminants are a part of the farming venture.

5.2.4. Pathogenicity of the temperate worm species which alpacas may acquire and potential dangers in the southern Australian environment

In most animals with naturally acquired worm burdens, single species infections are uncommon and the adverse effects are usually due to the additive influence of several different worm species. The final outcome is modified by "host factors" such as age, nutritional status, physiological stress, acquired immunity etc., and "parasite factors" such as the absolute numbers of worms of each species and their inherent disease producing capacity.

The alpaca is clearly catholic in its helminth associations. It readily harbours a wide range of worms which naturally infect other herbivores. Providing that nutrition and general management are adequate, however, it is unreasonable to assume that parasites which are normally associated with cattle and sheep will adversely influence its health and productivity. Theoretically, all of the sheep or cattle parasites to which alpacas are exposed in southern Australia could be potentially detrimental to their health. In practice, this is unlikely. Some of the parasites are known to be more benign than others in their natural hosts and it may well be that the majority are of relatively low pathogenicity in the alpaca.

Increases in productivity (including both bodyweight and fibre production) in response to treatment with ivermectin have been demonstrated in Peruvian alpacas (Guerrero *et al.*, 1986a; Windsor *et al.*, 1992). Interpretation of this work is, however, difficult from an Australian perspective. Apart from the fact that the alpacas in these experiments probably had predominantly "alpaca worm" burdens, numerous animals were concurrently affected by mange and lice, which were also responsive to treatment with ivermectin. These findings do not give indications as to whether productivity gains can generally be expected to arise from routine treatment of alpacas under Australian conditions.

The Scourworms

The "scourworms" of sheep and cattle, namely *Trichostrongylus* spp., *Ostertagia* spp. *Nematodirus* spp. and *Cooperia oncophora* are capable of causing clinical disease or even death in their ruminant hosts, particularly in young animals exposed to heavy challenge, and are all readily acquired by grazing alpacas. Under hygienic management conditions, where alpacas do not graze with or following other livestock which may heavily contaminate the pasture, crias and tuis tolerate scourworm infections reasonably well and burdens generally stabilise at low levels as animals mature. Nevertheless, poor management practises leading to heavy exposure, concurrent disease, or environmental stresses can be expected to offset the level of natural tolerance of the alpaca to scourworms resulting in clinical disease, particularly in young animals. (See 5.3.6.).

Certain parasites considered to be of marginal importance in South American alpacas and not yet locally recognised as important pathogens, deserve attention because of their potential to cause serious problems in alpacas in Australia.

Lungworms of cattle, sheep and deer

Until recent years *Dictyocaulus filaria* (sheep lungworm) was not considered to be a major parasite of the alpaca in South America, but outbreaks of parasitic bronchitis and deaths are now well documented there. In southern Australia this parasite is not widespread, but sudden outbreaks can occur in sheep, usually on specific farms on which there is a history of its previous occurrence. Although there are no current records of *D. filaria* in alpacas in Australia it should be considered in the differential diagnosis of respiratory conditions, particularly on properties concurrently farming sheep and having a longer cool moist season.

Given that numerous cattle parasites readily establish in alpacas, another lungworm species, *D. filaria*, which is primarily a parasite of cattle and deer in Australia, has the potential to be dangerous even though the alpaca is not currently a recognised host. Until more information is available on the suitability of the alpaca as a host for cattle lungworm it would be prudent to maintain an awareness of the possibility of lungworm infection in alpacas which share grazing with deer or cattle, particularly on farms where lungworm has previously been found.

Liver fluke (*Fasciola hepatica*)

In the Peruvian Andes *Fasciola hepatica* has a low prevalence (8%) and discontinuous distribution because climatic conditions are generally unsuitable for the snail vector and the development and transmission of the parasite. At lower altitudes, however, when pastures previously occupied by sheep and cattle are grazed by alpacas, acute infections with high mortality rates can occur.

Apparently the small liver size of alpacas, their lack of an immune response to *Fasciola* and their habit of taking food directly from the soil surface makes them particularly vulnerable to this parasite (Guerrero & Leguia, 1987; Leguia, 1991). Because of this, great care should be taken if alpacas are introduced into areas known or suspected to be infected with *Fasciola*. The greatest danger is on farms with flood irrigation or permanent streams. There are many such areas throughout south-eastern Australia, and along the coast of NSW. Liver fluke is not present in Western Australia.

Acute fasciolosis is manifested by rapid debilitation, inappetence, prostration and death within 2-4 days. The signs of chronic fasciolosis include anaemia, inappetence, progressive emaciation, diarrhoea alternating with constipation, abdominal pain and death within 3-4 months.

Barber's Pole Worm (*Haemonchus contortus*)

Barber's Pole worm is a voracious blood sucker with a high egg laying capacity which enables it to rapidly contaminate a suitable environment. The clinical signs of anaemia and weakness in sheep can be of rapid onset and may be overlooked because there is no accompanying diarrhoea. Animals with light infections are unthrifty and severe infections can lead to death.

It is indeed surprising that a parasite such as *Haemonchus* manages to survive, albeit at a very low prevalence, in the Andean environment - one would expect much greater levels of this parasite in a warmer climate at lower altitude. Over time in its natural environment the alpaca would have had limited exposure to this parasite and may be relatively susceptible to it.

Until such time as more information is available concerning the interaction of the alpaca with *Haemonchus*, Australian alpaca owners should be mindful of the dangers it could present to their animals. This applies not only in areas where it is a perennial serious threat to the wool sheep industry and farmers are constantly reminded of its presence (eg. northern and coastal New South Wales), but also in southern Australia where it has a wide but discontinuous distribution and sudden sporadic outbreaks can cause catastrophic losses in sheep flocks on certain farms.

5.2.5. Summary and conclusions

- The naturally occurring worm parasites of the alpaca in South America fall broadly into three categories: lamoid-specific parasites, those normally associated with sheep or goats and those normally associated with cattle.
- The lamoid-specific worms are clearly recognised as being serious pathogens in the alpaca in its natural environment but none of them has yet been recovered from alpacas in Australia.
- Most of the ruminant parasites recorded from alpacas in South America are common in ruminants in Australia and many of these plus some additional related species have been recovered from alpacas in Australia.
- Many of the sheep and cattle parasites are unlikely to endanger to the health of alpacas in Australia because they are relatively benign, even in their usual hosts.
- The Scourworms [*Trichostrongylus* spp. (Black Scourworm), *Ostertagia* spp. (Brown Stomachworm), *Cooperia oncophora* (Cattle Scourworm) and *Nematodirus* spp.] have the potential to cause disease across a wide range of farming conditions but are only likely to do so in the presence of concurrent disease or under conditions of severe stress to individuals or the herd, or heavy environmental contamination.
- Worms with the potential to be a serious or sporadic problem on specific farms or in certain regions are *Fasciola hepatica* (Liver fluke), *Dictyocaulus* spp. (Lungworm) and *Haemonchus contortus* (Barber's Pole Worm). In most cases the farm owner will be aware of the presence of these parasites on the farm or in the locality because of a previous history of worm problems with sheep or cattle.

5.3. INTERNAL PARASITISM OF ALPACAS IN SOUTHERN AUSTRALIA AND THE INFLUENCE OF MANAGEMENT PRACTICES

5.3.1. Introduction and Objectives

At the time that the RIRDC – sponsored research project commenced no information was available concerning the levels of parasites in Australian alpacas. In addition, the value of routine parasitological diagnostic techniques had not been evaluated, either as research tools or as aids for monitoring herd or individual animal health. Moreover, the role that routine farming practices and specific management strategies might play in influencing the levels of parasites in a herd had not been examined. The major objective of the parasitology component of the research project was to study the seasonality, abundance and impact of internal parasites and their control in relation to management in representative herds in southern Australia and derive practical recommendations for industry.

5.3.2. Materials and Methods

Study sites

The 5 farms which comprised the study sites for the project have been described elsewhere in the report to RIRDC. However, in terms of the parasitological observations and conclusions, the previous and concurrent livestock enterprises on the farms, the farm environment, and climate are important. Details are summarised in Table 27.

Farm management and alpaca behaviour

Information was obtained on alpaca behaviour, farm management, the structure of the industry and routine husbandry procedures in both Australia and South America through personal local observations, discussions with owners, and reference to local and overseas literature and anecdotes. An attempt has been made to relate this information, where relevant, to the parasitological findings, compare the local situation with overseas examples and ascribe levels of practical significance to various behavioural or husbandry factors where appropriate.

Some interpretations are based on extrapolations in relation to factors known to influence parasite levels in ruminant farming systems, or from subjective impressions of the role that local management practices might play. Others relate to well documented behavioural characteristics of alpacas which are certain to influence the levels of parasites to which they will be exposed.

Table 27. Details of the southern Australian farms on which the parasitological studies were conducted

Property location	Langhorne Creek, SA	Penola, SA	Creswick, Victoria	Camperdown, Victoria	Trentham, Victoria
Annual rainfall (mm)	395	635	660	735	1050
Alpaca numbers ¹	55 ¹	50 ¹	235 ¹	135 ¹	50 ¹
Birthing period	Late summer to early autumn	Early autumn	Non seasonal (avoid winter if possible)	Non seasonal (avoid winter if possible)	Non seasonal (peaks in Feb.-March and June-July)
Area (ha) and number of paddocks	12 (10)	10 (7)	24 (9)	32 (9)	12 (6)
Grazing management	Set stocked	Rotational	Rotational	Set stocked	Rotational
Other livestock	sheep, goats	cattle	cattle, goats	cattle	none
Previous livestock history	Goats	Cattle for past 10 years	Sheep	Cattle and alpacas grazed separately for previous 2 years	Free of livestock for 2 years

¹. Throughout the study herd size fluctuated differently between sites because of variations in the levels of trade in animals and additions through births.

Samples

Between November 1994 and January 1997 individual fresh rectal faecal samples were collected from alpacas on the five study sites from 9 to 11 occasions.

A cross sectional sample from at least 20 alpacas representative of the whole herd was attempted on each visit and, where possible, the same animals sampled each time. This objective was not consistently achieved because some animals were unavailable when giving birth or being mated, and sometimes there were difficulties in certain animals being identified or presented at the time of the visit. There was also considerable trade in animals to and from some properties, resulting in fluctuations in herd size and composition between visits. In addition, faeces could not always be recovered from the rectum of every animal which was presented.

Laboratory Techniques

The samples were transported refrigerated to the laboratory where faecal egg counts at a level of detection of 2 nematode eggs per gram of faeces (epg) were done.

A flotation technique was employed to increase the sensitivity of egg detection in samples in which eggs were not initially detected. Animals detected positive for eggs at this level were classed as having a count of 1 epg for calculation of mean values.

Eggs were differentiated into various types based on size and morphology, as follows:

"*Trich/Ost*"- including the genera *Trichostrongylus*, *Ostertagia*, and *Cooperia* – (see scourworms). (*Haemonchus* which has a similar egg was not found in this study so the *Trich/Ost* count represented only Scourworms).

"*Nem*"- various *Nematodirus* species. Strictly speaking, *Nematodirus* spp. are Scourworms. They have been dealt with as a separate group in this study for 2 reasons. First, their epidemiology is different to other scourworms; second, they appear to have an affinity for alpacas and may be capable of causing disease in their own right.

"*Chab/Oes*"- the large intestinal parasites *Chabertia* and *Oesophagostomum*.

Other parasite eggs counted were *Trichuris* (Whipworm) and *Capillaria*.

The presence of *Moniezia* (tapeworm) eggs and coccidia were recorded on a subjective qualitative scale.

The success of the study was frustrated early by the preoccupation of some owners with regular treatment of animals with ivermectin. The initial examinations suggested that these treatments were unjustified in terms of parasite control, although in terms of the owners' peace of mind they provided reassurance that their animals' health was adequately attended to. Once the early laboratory results were available it became evident that repeated treatments were unnecessary for the continued wellbeing of their animals, and inadvisable in terms of selection for drench resistance. Furthermore, in the first 6 months some of the parasitological results were invalidated because of these treatments. Thereafter, however, farmers largely complied with a request to forgo drenching unless advised to do so.

Collation and interpretation of data

The following age classes were recognised for the purposes of data identification:

Crias	0-6 months old.
Weaners	6-12 months old.
Tuis	1-2 years old.
Adults	older than 2 years.

Throughout the course of the study numerous crias, weaners and tuis matured into successive age classes and were repeatedly sampled as they aged. The proportion of such animals varied greatly between farms. Where possible they were replaced in their original age class by similar animals from the next generation.

Data from animals which had been treated for worms (drenched) within 60 days before collection of faeces were discarded.

Formal statistical analysis of the data was considered inappropriate for several reasons:

There were few comprehensive data sets with consistent consecutive records for individual animals.

Generally there were too few animals of each age class on individual farms to allow meaningful comparisons between the classes.

Different classes of animals were sometimes herded in different paddocks or subjected to different management practices. Differences between parasite burdens may have reflected environmental influences on transmission rather than host factors.

There were large variations in management practices between farms, including previous or concurrent livestock ventures, which may have influenced not only the initial composition and levels of infection but subsequent exposure.

There were frequent new arrivals on some farms which would have acquired their internal parasites in their previous environment rather than the new one.

In view of these limitations the data are not comparative between locations but should be viewed as a broad reflection of the equilibrium established between the internal parasites of domestic ruminants and alpacas under regular management practices currently operating in the local industry. As such, they reflect a “normal pattern” within a highly variable system. In some of the areas of interaction which were examined trends were identified subjectively, in others they were clearly apparent.

The data were derived from clinically normal healthy alpacas and are assumed to be representative of the findings one would expect in a winter rainfall farming venture with reasonable management standards. It is not presumed that they might represent findings on farms where exposure may be extremely high (e.g., close integration with other domestic livestock, overcrowding etc.) or where the susceptibility of groups or individuals to internal parasites may be increased due to stresses such as concurrent disease and inadequate nutrition and shelter, or immunological deficiencies.

Table 28 summarises the numbers of animals in the study and samples collected.

Table 28. Summary of the parasitological study data base

Location	No. of collections ()*	Animals sampled ()*	No. of tests ()*# [‡]
Langhorne Creek, SA	10 (1)	76 (7)	286 (46)
Penola, SA	11 (0)	96 (0)	275 (0)
Creswick, Victoria	11 (1)	99 (15)	271 (55)
Camperdown, Victoria	9 (3)	58 (20)	149 (60)
Trentham, Victoria	11 (0)	53 (0)	210 (0)
Total	51 (5)	382 (42)	1191 (161)
Final data set	46	340	1030

* Figures in parentheses indicate faecal egg count data discarded due to animals being drenched for worms within 60 days before collection of samples. Coccidia oocyst results were not affected.

Some additional data were excluded because the age or identification of the animals was uncertain or not available.

[‡] On a few occasions laboratory observations for coccidia were inadvertently omitted.

5.3.3. Results

Faecal egg counts

Nematode egg counts were done on 1191 faecal samples from 382 alpacas; 1030 counts from 340 alpacas were suitable for inclusion in the results. Individual animals were sampled from 1-11 times as presented and all faecal egg counts were included in the final results.

Scourworm (*Trich/Ost*) egg counts

(i) Mean faecal egg counts

Mean faecal egg counts for each of the age classes are summarised in Table 29.

Table 29. Mean Scourworm faecal egg counts* in alpacas of different age classes

Location	Adults	Tuis	Weaners	Crias
Langhorne Creek, SA	1.1	3.1	26.6	41.5
Penola, SA	7.4	12.0	9.3	2.0
Creswick, Victoria	1.7	2.0	5.0	1.7
Camperdown, Victoria	4.2	2.3	-	8.9
Trentham, Victoria	4.1	24.0	71.1	101.6
No. of observations	586	151	153	140
Mean	3.3	9.8	27.4	33.8

* Eggs per gram of faeces

Comments

- By reference to values conventionally applied to ruminants such as sheep or goats the faecal egg counts were low in all age classes on all properties throughout the study, despite the fact that, in general, few animals were drenched for worms.
- On one property (Camperdown) an association might be postulated between low faecal egg counts and drenching which occurred on 3 occasions in the first six months of the study [necessitating exclusion of considerable data (Table 28)]. However, overall results were not greatly different on this farm to those on one of the other farms (Penola) on which no herd drenching was practiced.
- The Creswick herd was treated with ivermectin twice in 1994 before the study commenced and again in January 1995, resulting in loss of the February 1995 data. In addition, 20 animals (9 adults, 4 tuis, 7 crias) were again treated with ivermectin in April/May 1995 thereby excluding some of data for July 1995. It is reasonable to assume

that these treatments may have negatively influenced the overall levels of infection in alpacas of all age classes on this property.

- There is a clear trend of decreasing faecal egg count with age in at least two herds (Trentham and Langhorne Creek) and this is evident in the values for all herds combined (Table 29).
- In two of the other herds (Creswick and Penola) faecal egg counts, particularly those for crias, probably reflect local management systems where exposure to worms early in life is much more limited than on the other farms. For example, in the Penola herd all 10 crias born in the first quarter of the year and sampled in the second quarter had acquired moderate burdens of *Nematodirus*, confirming that they had been exposed to the environment, but only 3 had acquired low levels of scourworms, which suggests that environmental contamination was low. Another source of difference could be bias due to the time of sampling. On the same farm a further 6 crias, born in the last quarter and sampled in the first quarter of the next year, were all negative, both for scourworms and *Nematodirus*. In addition, some crias sampled as young as 40-50 days old had received only limited, or possibly no exposure.
- Apart from highlighting the development of resistance with increasing age the mean values for faecal egg counts do not provide much useful interpretative data for practical application.

(ii) Range of faecal egg counts

The distribution of faecal egg count values for each of the age classes of alpacas is summarised in Table 30.

Table 30. Distribution of Scourworm faecal egg counts in alpacas of different age classes

Egg count - epg	Range of faecal egg counts							
	0	1-10	11-20	21-50	51-100	101-200	201-400	>400
Adult (<i>n</i> = 586)	336	194	26	28	1 ^a	1 ^a	-	0
Tui (<i>n</i> = 151)	73	46	10	16	3	3	-	-
Weaner (<i>n</i> = 153)	60	43	17	18	10	2	1	2
Cria (<i>n</i> = 140)	69	36	7	9	7	6	3	3
Percentage	52.2%	31.0%	5.8%	6.9%	2.0%	1.2%	0.4%	0.5%

^a These counts were at consecutive examinations of the same animal

Eggs were not detected in 52.2% of samples.

Up to half of the positive samples may have been missed using conventional laboratory faecal egg counting methods which are generally reported at a level of detection of 25 epg.

Eggs were found in 42.7%, 51.7%, 60.8% and 50.7% of samples from adults, tuis, weaners and crias respectively. The difference in the infection rate between crias and weaners may be

ascribed to the likelihood that many crias, especially those tested in summer, had less opportunity than weaners to acquire infection before faeces were collected.

Only 11.9% of counts from animals older than 1 year (adults and tuis) exceeded 10 epg, compared with 29.0% for animals less than 1 year old (weaners and crias).

Counts greater than 100 epg comprised only 2.1% of the total.

All counts greater than 200 epg were from crias or weaners.

(iii) Peak levels of faecal egg counts

The highest individual counts and the months in which they were recorded are given in Table 31.

Table 31. Peak individual faecal egg counts in alpacas of different age classes

Faecal egg count* and time of year				
Location	Adults	Tuis	Weaners	Crias
Langhorne Creek, SA	24 – Feb.	30 – Aug.	292 - Feb. 112 – Dec. 162 – Dec. .	258 ¹ – July 214 ¹ – July 200 – June 144 - Feb.
Penola, SA	104 ² - July 34 – Feb. 34 – Feb. 34 – Aug.	92 – Nov. 58 – July 52 – Nov. 50 - July	54 – July 48 – Feb. 48 – Nov.	32 – Nov.
Creswick, Victoria	44 – Nov. 32 – Nov.	24 – June	28 – July	14 - June
Camperdown, Victoria	24 – Nov.	18 – Nov.	-	92 - July
Trentham, Victoria	42 – Feb. 38 – Nov. 36 – Nov.	152 – Nov. 116 ³ – Nov. 42 – June	1300 ⁴ – July 522- July 100 – Dec. 96 – Dec. 74 – Feb.	1114 ⁵ – Aug. 476 ⁵ – July 440 ⁵ – Aug. 58 – Aug.

* Eggs per gram of faeces

¹ Counts of 132 and 108 one month earlier

² This animal had consistently higher counts than other adults at all locations

³ Count of 110 three months earlier

⁴ Count of 286 one month earlier

⁵ Counts of 192, 70 and 192 epg one month earlier

All of the peak faecal egg counts were in clinically normal animals which showed no obvious ill effects from their worm burdens.

The highest counts were clearly in crias and weaners and in these age classes were mostly found from June to August.

Although there was no marked seasonality in the peak counts in animals older than 1 year, more than half of them occurred in late spring or summer suggesting that burdens may accumulate slowly over spring or that stress factors may influence counts in older animals at that time of the year.

Only 4 animals (1 adult, 2 crias and 1 weaner) with the highest egg counts were drenched. All other animals with elevated counts in which observations were able to be continued returned to low or zero egg counts within 1-3 months.

***Nematodirus* faecal egg counts**

(i) Mean *Nematodirus* egg counts

Mean *Nematodirus* faecal egg counts for each of the age classes are summarised in Table 32.

Table 32. Mean *Nematodirus* faecal egg counts* in alpacas of different age classes

Location	Adults	Tuis	Weaners	Crias
Langhorne Creek, SA	0.1	1.5	11.8	6.3
Penola, SA	1.9	7.2	14.2	24.5
Creswick, Victoria	0.8	1.3	4.0	6.8
Camperdown, Victoria	0.9	0.1	-	12.3
Trentham, Victoria	0.3	1.8	8.1	8.5
No. of observations	586	151	153	140
Mean	0.8	3.2	10.8	11.4

* Eggs per gram of faeces

Comments

- Similarly to the other Scourworm counts the *Nematodirus* egg values were generally low in all age classes on all properties throughout the study when compared with those conventionally applied to ruminants such as sheep or goats (see later – individual peak counts).
- Again, there is a clear trend of decreasing faecal egg count with age in the overall and individual location values. This confirms the development of resistance with increasing age.
- There are differences in counts in young animals between locations which are at variance with the trends in Scourworm egg counts. For example the Langhorne Creek and Trentham locations both had very much higher Scourworm egg counts than those at Penola, but the reverse applies for *Nematodirus* counts. The Scourworm counts at Creswick were markedly lower (on average one thirtieth) than those at Trentham but there is little difference between *Nematodirus* counts at the two locations.
- No specific factor can be identified to account for these differences. They may simply reflect local management systems creating greater exposure to one or other of the parasite

groups. For example, *Nematodirus* eggs, unlike Scourworm larvae, can survive for extended periods in the environment or on fodder. Agistment, even on rested “clean” paddocks, confinement on certain paddocks at critical times, or feed harvested from contaminated paddocks at home or on other properties could all influence the pattern on an individual farm.

- Cattle were a concurrent venture on the Penola property, which had very low Scourworm counts but the highest (albeit low) *Nematodirus* counts. One of the 2 properties with higher Scourworm, but lower *Nematodirus* counts than Penola ran goats and sheep concurrently (Langhorne Creek), the other had no additional livestock. Whether, on balance, alpacas are more likely to acquire *Nematodirus* species from cattle than from other livestock is a matter for speculation. Fully integrated systems with either cattle or small ruminants both have inherent dangers of more practical significance, including the age, numbers and parasite status of the ruminant animals and the management (parasite control) system established.

(ii) Range of *Nematodirus* faecal egg counts

The distribution of 293 *Nematodirus* faecal egg count values for combined weaner and cria age classes is summarised in Table 33.

Table 33. Distribution of *Nematodirus* faecal egg counts in alpacas less than one year old

Range of <i>Nematodirus</i> faecal egg counts							
Location	0	1-10	11-20	21-50	51-100	101-200	>200
Langhorne Creek, SA (n = 72)	47	12	6	5	1	0	1
Penola, SA (n = 89)	36	24	9	7	11	2	0
Creswick, Victoria (n = 51)	27	15	4	5	0	0	0
Camperdown, Victoria (n = 14)	3	6	4	0	1	0	0
Trentham, Victoria (n = 67)	29	27	2	6	2	1	0
Percentage	48.5%	28.8%	8.5%	7.8%	5.1%	1.0%	0.3%

Eggs were not detected in 48.5% of samples.

Counts greater than 10 epg comprised 22.7% of the total compared with 29.0% for Scourworm counts in the same group of animals.

There were only 4 counts (1.5%) greater than 100 epg.

(iii) Peak levels of *Nematodirus* faecal egg counts

The highest individual *Nematodirus* egg counts and notes relating to the outcomes are listed in Table 34. Some lower values are included in the weaner and cria categories to illustrate the usual progression of *Nematodirus* infections in young animals.

Table 34. Peak⁺ individual *Nematodirus* faecal egg counts in alpacas of different age classes

Peak <i>Nematodirus</i> faecal egg count* values			
Adults	Tuis	Weaners	Crias
36 [∞]	146 [∞]	292 [#]	124 [•]
30 [♠]	98 [•]	98 ^{∞♦}	124 [∞]
28 [•]	34 [•]	94 [•]	122 [•]
26 [•]	16 [•]	74 [∞]	92 [•]
24 [•]	16 [•]	72 [∞]	80 [∞]
22 [•]		54 [•]	66 [∞]
		50 [♠]	56 [•]
		48 [•]	54 [•]
		44 [•]	44 [•]
		40 [•]	36 [•]

⁺ Some lower values for weaners and crias are included.

* Eggs per gram of faeces.

[∞] No further observations

♠ Egg count remained similar over the next 6 months.

• Egg count decreased to zero or a low level within the next few months.

Count remained elevated (94 egg) after 3 months. No observations thereafter.

♦ Had an egg count of 76 egg as a cria with no ill effects.

The highest *Nematodirus* faecal egg count in an adult alpaca was 36 egg, but no further observations were made on this animal. The next highest (30) remained at a similar level over the following 6 months. In all other adult alpacas in which continued observations were made the egg count declined within a few months to zero or very low levels and did not become elevated again. Elevated *Nematodirus* faecal egg counts in adult alpacas are therefore unusual and probably signify an increased susceptibility to infection in individuals. *Nematodirus* species are not recognised as important pathogens of adult ruminants and are unlikely to be so in adult alpacas. The importance of adult alpacas carrying *Nematodirus* infections lies mainly in their potential to contaminate the environment by producing large volumes of faeces. Even low faecal egg counts can produce significant contamination which accumulates over time because *Nematodirus* eggs are able to survive on pastures for long periods, including the dry summer months. Short or even medium term resting of pastures will not eliminate *Nematodirus* from them and they may serve as reservoirs of infection for crias and weaners, which are more susceptible.

With 2 exceptions, peak counts in the other age classes did not rise much over 100 epg. In one of these (weaner) the count fell from 292 epg to 94 epg after 3 months but no further observations were made; the other (tui – 146 epg) was not sampled again.

In 7 of the other 9 cases where the count was 50 epg or greater and examinations were later repeated, levels fell without intervention to zero or very low within a few months.

The data indicate that in the majority of animals under 1 year old *Nematodirus* infections will spontaneously resolve without treatment. Infections appear to persist in some individuals, however, and they may be at risk.

Comments

- The records of parasites recovered from alpacas in Australia (see 5.2.2.) together with the present data confirm that *Nematodirus* from both sheep and cattle establish readily in young alpacas. Most animals older than one year develop a strong resistance to the parasite.
- *Nematodirus* eggs in the faeces of adult alpacas, sheep or cattle can accumulate on pastures because they are resilient to dry conditions. When moisture becomes available they may mature and become infective *en masse*. Therefore, constant grazing of the same area by young stock, concurrent grazing with ruminants, or grazing of pastures subsequent to cattle or sheep can be dangerous. We know that alpacas readily acquire all of the *Nematodirus* species that are carried by ruminants – in combined farming ventures worm control programs in the ruminants are equally important not only for their health, but are essential to reduce contamination which can become available to the alpacas.
- Adult alpacas probably contribute much less to serious pasture contamination than ruminants because they usually have low faecal egg counts, whereas *Nematodirus* egg output from sheep can often be very high. In addition, cattle produce large volumes of faeces and animals with even low faecal egg counts can rapidly and heavily contaminate a small area. It may be relevant [see mean *Nematodirus* faecal egg counts] that the highest levels of *Nematodirus* were on a property which also farmed cattle.
- No association of *Nematodirus* infections with clinical disease or failure to thrive was observed in this study. However, Dr P. Presidente (personal communication, 1999) is concerned that *Nematodirus* has the potential to be pathogenic in alpacas, especially in their first year. Apart from a clinical case where he recovered large numbers of *N. spathiger* from a cria which had been grazing a sheep paddock at Mt Moriac, Victoria (see 5.2.3.), he has observed that many female *Nematodirus* recovered from alpacas are not fully matured and may not be producing eggs to their full capacity. This suggests that in some cases faecal egg counts may underestimate the level of infection that the alpaca is carrying.

Large intestinal worms – *Oesophagostomum/Chabertia*

The large intestinal worms (LI), of which *Oesophagostomum venulosum* is by far the most common in ruminants in southern Australia, are of little economic importance. Most if not all of the eggs found in the faeces of alpacas in this study are probably from *O. venulosum* which is benign, but which has closely related species (Nodule Worms) capable of causing serious disease in sheep and cattle in summer rainfall areas.

At 3 of the locations combined (Langhorne Creek, Creswick and Camperdown) a total of only 7 adults, 7 tuis, 3 weaners and 1 cria had positive LI egg counts. The highest counts were 176 and 46 epg for adults and 46 and 36 epg for tuis. No further relevant observations were made on these animals.

At the remaining 2 locations (Penola and Trentham) numerous animals had positive faecal egg counts. The highest counts in animals over 1 year old were 56 epg in an adult and 400 epg and 58 epg in tuis. The count in the adult animal remained similar 3 months later but no further observations were made in the tuis. The highest LI egg counts in animals less than 1 year old were:

Crias 302, 392*, 56*
 Weaners 466*, 240*, 70*, 62, 52*, 50*.

Those marked with an asterisk returned to low values or zero within 3 months. No further observations were made in the other 2 animals.

Mean LI faecal egg counts according to age class on the Penola and Trentham farms were 0.5 epg (adults), 6.1 epg (tuis), 21.8 epg (weaners) and 13.7 epg (crias). A single count from one tui contributed 80% of the total eggs counted for this class; if this count is excluded the mean count for tuis is 1.0 epg. The lower egg counts in crias than weaners are not surprising. It takes 7-8 weeks from the time of exposure to LI worms for the parasites to mature in the animal and begin to pass eggs in the faeces; developing infections would have been missed.

The range of faecal egg counts of large intestinal worms in crias and weaners on 2 farms (Penola, SA and Trentham, Victoria) is summarised in Table 35.

Table 35. Distribution of faecal egg counts of the large intestinal worms (*Chabertia/Oesophagostomum*) in alpacas less than one year old

Range of faecal egg counts* of large intestinal worms							
Age class	0	1-10	11-20	21-50	51-100	101-200	>200
Crias (<i>n</i> = 61)	47	9	1	1	1	0	2
Weaners (<i>n</i> = 95)	58	26	3	3	3	0	2
Percentage	67.2%	22.4%	2.6%	2.6%	2.6%	0%	2.6%

* Eggs per gram of faeces

Eggs were not detected in 67.2% of samples. Counts greater than 50 epg comprised only 5.2% of the total.

Comments

- The trends in the egg counts relating to large intestinal worms are similar to those for both the Scourworms and *Nematodirus* in that overall there is a decrease with increase in age.
- Most animals that acquire LI worm infections carry them for only a short time, spontaneously cure and remain refractory thereafter.
- The species of LI worms found in the winter rainfall area of southern Australia are unlikely to assume any clinical importance in alpacas farmed there.

Whipworm – (*Trichuris* spp.)

Overall 43 animals (12.6%) representing all study locations were positive. The mean egg count in infected animals was 12.6 epg. The highest counts meriting documentation in each of the age classes were: adult (10 epg, 8 epg); tui (8 epg, 8 epg); weaner (176 epg, 92 epg); cria (48 epg, 40 epg, 36 epg). No ill effects were seen in any of the animals.

Comment

- In large numbers *Trichuris* can cause chronic, life threatening diarrhoea in camels in Australia which does not always respond to ivermectin treatment. In addition, the *Trichuris* egg has tremendous potential for survival in the environment. It should not, therefore, be discounted as a possible pathogen in alpacas on certain properties, given sufficient time for build up of high levels of contamination in overcrowded areas.

Capillaria

Eggs belonging to parasites from this genus (related to the whipworm) were found in the faeces of 5 alpacas. The relevance of this is uncertain because there are many species of *Capillaria* parasitising birds and the eggs passed in the faeces of the alpacas could have been acquired from the environment whilst grazing.

Capillaria spp. have been reported from the alpaca in South America (Table 26).

Tapeworm – (*Moniezia* spp.)

Tapeworm eggs of similar dimensions and shape to those of *Moniezia expansa* were found in samples from 3 (0.9%) animals, all of which were older than 1 year.

This parasite is probably of no importance to alpacas in Australia, although owners may become alarmed when they see segments on the surface of freshly passed faeces.

Coccidia – (*Eimeria* spp.)

Altogether 962 faecal samples from 374 alpacas were examined for coccidia (*Eimeria* spp.) – these are protozoan parasites of the small intestine. Some individuals were examined several times, others only once or twice.

The percentage of positive samples on the five properties ranged from 57.4% - 82.2% (mean 69.3%).

Infection rates in individual adults, tuis, weaners and crias were 36.0%, 45.9%, 66.9% and 67.0% respectively. Some animals were confirmed to be positive only after several examinations, indicating that the true prevalence of coccidia infection in alpacas in Australia is most probably higher than that shown in this survey.

All 4 species of coccidia present in South American alpacas (*Eimeria lamae*, *E. punoensis*, *E. alpaca* and *E. macusaniensis*) were found, although *E. macusaniensis* was only detected on one occasion in 2 crias from the same property.

On subjective evaluation oocyst levels in crias and weaners were generally higher than those in older animals. Nevertheless, counts which were classed as moderate to high (++ and +++ classifications) were found in all age groups – 3 adults, 2 tuis, 3 weaners, and 2 crias (2.7% of animals). This clearly shows that older, clinically normal animals can heavily contaminate an environment for crias and weaners. The faeces from a weaner 0.55 years old (+++ classification) had 24750 oocysts of *E. lamae* per gram.

Comments

- Coccidia are very specific to their host, which means that alpacas are not going to become infected from other domestic animals.
- Coccidial infections appear to be important only in very young alpacas. Rosadio & Ameghino (1994) reported a Peruvian outbreak under rangeland conditions which involved crias from 25-35 days old with a history of diarrhoea and sudden death. The carcasses were thin and dehydrated. The small intestines were reddened throughout and distended by gas. *Eimeria macusaniensis* was confirmed as the cause of this outbreak.
- Leguia (1991) reports that coccidiosis is mainly a problem of animals reared in confinement. Outbreaks of subacute and acute disease occur frequently in Peru in animals born late in the breeding season (presumably when contamination has reached high levels), or after weaning (presumably when crias are severely stressed). *Eimeria lamae* in association with *E. macusaniensis* is mainly responsible and these two together are highly pathogenic, since the first species destroys the intestinal epithelium, while the second damages the crypt glands and inhibits healing. The intestinal lining is completely stripped and vulnerable to secondary bacterial or viral infection with up to 50% mortalities in newborn animals.
- Although local outbreaks have not yet been recorded and there is evidence that the majority, if not all, animals are exposed to coccidia early in life without adverse effects, this is a disease which we need to be acutely aware of in Australia. No matter how convenient a paddock may be to the sheds or the farmhouse there are potential grave dangers in constantly maintaining the same area for animals to give birth. Coccidia are

remarkably resistant in the environment and tend to become infective *en masse* when conditions are suitable. Special provision of uncontaminated areas where hembras can give birth and crias can be held in the first 2 months of their life is certainly the most important means of control under our conditions.

Recommendation

To limit extreme exposure of crias to coccidia, clean, uncontaminated areas should be provided for hembras to give birth and, where possible, crias and weaners should be raised apart from older age classes.

5.3.4. Other Observations

The development of resistance to parasites with increasing age

The faecal egg count data from this study provide clear evidence of a process of development of resistance to worms by alpacas as they grow older. This holds true for all the major types of internal parasites, including the Scourworms (Tables 29 , 30 & 31), *Nematodirus* (Tables 32 & 34) and the large intestinal worms. The evidence suggest that this generally takes place sometime during their second year although large variations between individuals in the emergence and robustness of this immunity would be expected. In cases involving overriding challenge with worms, concurrent disease [eg. bacterial, viral and protozoon infections, including coccidiosis], injury, or other stress age resistance to parasites may either not develop, or be swamped.

In the current study repeated observations on individual animals, especially those in the younger age groups were very limited. Nevertheless it was possible to record the successive Scourworm faecal egg counts of 5 tuis over a period of 12 months which provide some insight into the timing of the emergence of resistance to worms. The information is given in Table 36.

Table 36. Consecutive faecal egg counts in tuis illustrating the development of age resistance to worms

Faecal egg counts of Scourworms –(eggs per gram of faeces) ⁺					
Animal no.	August 1995	November 1995	February 1996	June 1996	July 1996
1	8 (1.11 yr)*	1	16	0	2
2	34	154	2 (1.60 yr)*	6	0
3	2 (1.46 yr)*	2	2	2	0
4	110	116	6 (1.89 yr)*	6	0
5	36	0 (1.55 yr)*	0	0	0

⁺ Faecal egg counts in bold type

- Figures in parentheses indicate the age of the animal at the time of that particular collection

Animals 1 and 3 had very low faecal egg counts by the age of 12 –18 months which were maintained for the following year.

Animals 2, 4 and 5 showed the development of immunity at around the age of 18, 22 and 18 months respectively. In all cases the animals appeared to be reasonably refractory to further infections for at least the following 6 months.

This information supports that presented in Table 31 which shows that in most cases elevated faecal egg counts in tuis will return to low values in a few months as age immunity develops.

The persistence of age resistance to internal parasites in adult alpacas

Repeated faecal egg counts in untreated adults over long periods were possible on some farms with stable populations. The results are summarised in Table 37.

Table 37. Faecal egg counts* in untreated adult alpacas on four properties over time.

Herd	No. of adult animals	Untreated period (months)	No. of observations	Range of mean egg counts for all observations	Mean egg count overall
1 (SA)	12	19-24	6-10	0-3.5	0.7
2 (SA)	11	15-30	5-10	1.9-11.8	4.8
3 (Vic.)	5	13-17	6-7	0-1.3	0.5
4 (Vic.)	10	11-24	5-9	0.3-4.7	2.5

Altogether 48 adult alpacas were untreated for worms for periods ranging from 11-30 months. Each animal had from 5-10 faecal egg counts done over this time. The highest individual

faecal egg counts recorded were from 20-26 epg and the highest mean value for any group on any occasion was 11.8 epg.

These observations clearly confirm that faecal egg counts of adult alpacas under reasonable farm management systems in southern Australia should normally be expected to be below 50 epg. Regular drenching of alpacas over 2 years of age is therefore not necessary.

Development of Scourworm infections in crias over winter

It is well documented that peak numbers of infective nematode larvae of ruminants are usually present on pasture in southern Australia over winter and spring. By means of sampling at reasonably frequent intervals the influence that this might have on transmission to autumn born crias was examined on one farm. Results are summarised in Table 38.

None of the animals showed any clinical signs of parasitism.

Three crias developed infections which reached levels during July and August which were believed to justify intervention, and they were drenched. The faeces of one of these which was examined 5 months later was free of nematode eggs.

The egg count of 1 cria peaked at 440 epg in August and thereafter remained at near 100 epg over the next 5 months. It was not treated.

The remaining 3 crias, despite occupying the same environment, did not develop appreciable faecal egg counts and were also never treated.

These findings illustrate the variation in faecal egg counts to be found in crias within the same farming system and the need to consider them individually, not as a group. Most crias which develop moderate egg counts will naturally overcome the infection, but some individuals may need to be treated on the basis of their faecal egg counts.

Table 38. Faecal Scourworm egg counts in 6 crias over the period of greatest availability of worm larvae on pasture

Faecal egg count – eggs per gram of faeces						
Animal no.	Age in years (July)	June	July	August	December	January
1	0.37	0	92	1114*	-	0
2	0.30	70	476*	0	-	-
3	0.28	72	192	440	100	86
4	0.46	28	30	14	-	36
5	0.50	286	1300*	0	-	-
6	0.30	-	-	30	96	0

* Individuals treated.

It is likely that autumn born crias are more at risk to internal parasites than those born at other times of the year because of the greater levels of worm larvae on the pasture at the time that

they first begin to graze. This may not necessarily be disadvantageous however, because it ensures that their immune mechanisms are stimulated very early in life. On the other hand, animals born in spring or over the summer months may only receive their first appreciable exposure to worms after the break of the season the following year. This is perhaps why some of the weaners and tuis in the present study were found to have moderate faecal egg counts. This makes it important to consider all animals under one year of age as potentially susceptible and ensure that regular cleaning of the environment is to the benefit of this age class as a whole.

Undesirable drenching practices

Indiscriminate drenching of alpacas is addressed in some detail later in this report . Two examples are given here of practices which the writer has experienced which are not only wasteful of time and effort, but which can contribute eventually to the emergence of strains of worms resistant to the remedies that farmers depend upon to control worms in all livestock, including alpacas.

Case 1

A producer selected and drenched 11 crias and 5 adult alpacas on the basis that their appearance suggested that a drench was necessary. Egg counts had been done on these animals 4 weeks previously. Only 1 cria and 1 adult had positive faecal egg counts at that examination. The average faecal egg counts for the crias and adult respectively were 0.8 and 0.1 epg respectively. There was no need to drench any of the animals.

This illustrates the difficulty in “eyeballing” animals to determine whether they need to be drenched.

Cases 2 & 3

A producer had animals faecally tested in November. Mean counts for adults, tuis, weaners and crias were 3.9, 0.7, 4.5 and 6.0 epg respectively. Despite this result the animals were treated in January.

Another producer treated his flock in December only 4 weeks after mean faecal counts of 9.3, 10.7, and 6.7 had been confirmed in adults, tuis and crias respectively. Alpacas in the same herd were again treated in May after counts in February had shown 0.2, 0, and 0.3 epg in the same classes of animals. The animals were once again treated in June after an interval of only 3 weeks.

All of the above treatments were unnecessary and can ultimately do much more harm than good.

Comments

- Windsor *et al.* (1992) cite other Peruvian authors as saying that even one nematode egg in an alpaca is too many. I disagree with this contention. There is clear evidence both from the present study and that of Hill *et al.* (1993) in New Zealand that alpacas develop a

strong age immunity to internal parasites in our environment and there is very good reason to encourage this by allowing some level of early exposure.

- Infections with the large intestinal parasites appear to be overcome quite early in life in most cases, but Scourworm infections are able to persist well into the first year, with quite a strong immunity present by the time animals have reached two years old. Clear differences were seen in the New Zealand work between 6- and 18-months old animals, but there were no differences between 18- and 36-months old animals. This is supported by the post-mortem records of Chavez *et al.* (1967) which show a dramatic 75% reduction of worm burdens from 1-2 to 2-3 years of age.

5.3.5. Clinical disease

In this study we did not find any cases of clinical disease due to worms. Furthermore, based on other laboratory submissions we have not yet confirmed worm infections to be the primary cause of clinical disease in alpacas. However, there have been cases where there is evidence that internal parasites may have compounded other conditions responsible for ill thrift and wasting such as lumpy jaw and other chronic infectious conditions.

It has been mentioned earlier (see 5.2.3.) that Dr P Presidente (personal communication, 1999) has records of 2 alpacas in Victoria which died from worm infections. Both of these animals had been grazing paddocks either together with or after ruminant livestock. This signals the potential danger of this practice and it should be followed only if alpaca owners are prepared to regularly monitor their animals.

Enquiries further afield have also revealed 2 documented cases where worm infections have caused or contributed to alpaca deaths in the Berrima – Mittagong area of NSW.² The cause of illness and death in a third case is not so convincing. Although these cases are outside the scope of the current report they are recorded here because of their relevance to the overall concept of internal parasitism in the Australian herd. The 2 animals had a history of voluminous green diarrhoea terminating in death. In both of them the main post mortem finding was severe gastritis (C3 stomach). Large numbers of worms were seen in histological sections of the stomach; there was no damage in the small intestine. The findings are highly suggestive of infection with *Trichostrongylus axei*.

The third animal had a marked chronic active liver cirrhosis and mild parasitic gastritis. It had been agisted on a property with identified worm problems but the post mortem findings did not confirm that it suffered from a serious parasitic infection.

The conclusion to be drawn from these findings are clear. Alpacas in the Australian environment are not refractory to worm infections. In the above cases the role played by inefficient or exhausted immune systems cannot be evaluated, but it may be that parasite problems, when they arise, will do so in individuals rather than groups or whole herds. This means that close observation and monitoring of individuals should remain a priority in overall herd management.

² The assistance of Janie Hicks of Coolaroo Alpaca Stud, Mittagong in gathering this information, and of Veterinary Pathology Services and W. R. Beresford and Associates, Veterinary Surgeons for access to their records is gratefully acknowledged.

5.3.6. Animal and management factors influencing internal parasitism in alpacas in southern Australia

Age of animal :

Under field conditions in Peru animals less than 2 years of age are usually more affected, both clinically and subclinically, than older animals. Animals over 6 years of age have also been observed to have worm burdens of a similar magnitude to those in young animals. This may be ascribed to the fact that there, unlike in Australia, they are often kept under the poorest conditions as a group and rarely treated (Chavez *et al.*,1967).

In this study egg counts in crias and weaners usually stabilised at low or moderate levels, and in most cases declined without treatment as the animals grew older. Egg counts in around 10% of animals younger than 1 year progressed to elevated levels. Higher levels were generally found in those born in autumn and winter because this is the time of the year most suitable for the survival and accumulation of the infective stages of worms in the southern Australian environment

Crias and weaners had greater faecal egg counts than tuis and adults for all worm categories, confirming a very clear age resistance to internal parasites. Once age resistance has become established it appears to persist if general management and husbandry are adequate. An awareness is important of conditions which could interfere with this immunity such as other disease, overcrowding and nutritional and social stresses.

The study suggests that crias and weaners certainly need to be monitored for internal parasites more frequently than other animals in the herd; however they do not necessarily need to be drenched frequently.

Class of animal

Hembras (adult females), although not specifically identified in the study, are probably also highly susceptible to worm infections, by virtue of the fact that they have an 11.5 month gestation and are mated again almost immediately after giving birth. This results in subjecting them to three successive stresses, namely birth, lactation and mating.

Herd concentration

In Peru, the practice of herding the animals together for giving birth increases exposure to parasites for both the cria and hembra as does concentration of animals for other routine procedures such as shearing (Leguia, 1991).

The author has observed that the practice of concentrating animals persists as a general management procedure under Australian farming conditions. This is presumably because

- alpaca owners don't like the animals too far from sight for aesthetic and security reasons,

- the alpaca is a friendly and gregarious animal and lends itself to concentration in small areas close to the household or stockyards,
- careful attention is essential to supervise individual matings.

There are dangers in this practice, particularly for crias. Once a holding paddock becomes heavily contaminated with worms it can remain so for many months. A small change in climatic conditions could see such an area changing almost overnight from a safe to an extremely dangerous area in terms of Scourworm, *Nematodirus* or coccidia infection.

Grazing behaviour

In Australia the systems under which alpacas are farmed are quite different to those in their natural South American habitat. We tend to graze alpacas like sheep, yet it is well recorded that they have distinct differences in grazing behaviour from sheep. If set stocked they tend to graze small areas to a very low pasture height and continue grazing the regrowth, leaving large areas of the paddock lank and ungrazed (San Martin, 1991, cited by Hill *et al.*, 1993). Leguia (1991) reports that they graze rather than browse and take food directly from the ground. These habits can lead to abnormal exposure to internal parasites, especially where alpacas are set stocked on small paddocks or rotated regularly in limited areas with insufficient time between grazing intervals for infective worm larvae to die. Under such conditions the beneficial effects of the toilet habits of alpacas (see below) can not only be negated, but the latrines can provide massive concentrations of infective worm larvae which the animals may not be able to avoid.

Defecation behaviour (alpaca latrines)

Alpacas defecate and urinate in discrete common latrines and avoid grazing these areas (Guerrero & Alva, 1986). Given sufficient grazing area and the removal of interference through competitive grazing with other herbivores they substantially limit their own exposure to worms. As mentioned above, enforced grazing practices which override this natural mechanism of control may have adverse outcomes.

Effect of worms on production

The alpaca is clearly catholic in its worm associations, but the influences of sheep and cattle worms on its health and productivity have not yet been examined. Increases in productivity (including both bodyweight and fibre production) in response to treatment with ivermectin have been demonstrated in Peruvian alpacas (Guerrero *et al.*, 1986a; Windsor *et al.*, 1992). Interpretation of this work is, however, difficult from an Australian perspective. Apart from the fact that, unlike their Australian counterparts, the alpacas probably carried predominantly "alpaca worms", many were concurrently affected by mange and lice which were also responsive to the treatment. On the basis of currently available information it is not possible to predict whether productivity gains can be expected from treatment of alpacas under Australian conditions.

It is preferable to consider drenches as a tool to be used when necessary to assist good management practices and genetics to optimise production. I believe that productivity gains will not be convincingly demonstrated unless management is poor.

Recommendations

- Do not overcrowd animals in small yards or paddocks
- Avoid sharing or rotating grazing with other animal species, particularly calves and lambs. If this is unavoidable the alternative animal species should all be cleared of worms with a broad spectrum drench before being introduced to the paddocks.
- Try to avoid grazing crias and weaners with large numbers of older animals.
- Provide shelter against both cold, wet weather and extreme sunshine and ensure that animals have adequate nutrition.
- Remove faeces from pasture latrines at least monthly either manually or by vacuuming. Faeces should be composted for at least 10 weeks in summer or for 20 weeks if collected from autumn to spring. Faeces from pasture latrines should never be distributed on the pasture as fertiliser without first being composted.
- Rotational grazing of pastures every few weeks as practiced on many alpaca farms is unlikely to have an appreciable impact on parasite transmission, except possibly over summer.

5.3.7. The diagnostic significance and interpretation of faecal egg counts in alpacas :

Faecal egg counts in South American alpacas

Faecal egg counts in Peruvian alpacas rise to what we would consider in Australia to be alarming levels, without causing farmers undue concern. For example, Windsor *et al.* (1992) mention that "nematode infections were always very low" in alpacas they examined in the dry western side of the Peruvian Andes .."the maximum count being 1100 strongyle eggs per gram". Their judgement on the level of infection was based, with the best of intentions, on a text with values referable to sheep. This study has confirmed that faecal egg counts in alpacas in Australia should be considered quite apart from those in other grazing animals.

Subjective interpretation

Interpretation of the results of faecal egg counts of alpacas is extremely subjective. There is no magic figure of faecal egg count which denotes a dangerous situation with respect to worm infection in an animal or herd and no sliding scale of egg count which demands intervention or forgives inaction at some chosen point.

Clinical condition and history

Consideration of faecal egg counts requires a knowledge of the clinical condition of the animals, their age, nutritional status and possible stress levels, husbandry practices, and drenching history. Without this information the results of faecal egg counts in alpacas are impossible to interpret.

Numbers of animals

Counts from only one or two animals in a herd rarely provide useful information. Selecting only those that are "doing poorly" or "looking wormy" is an unsatisfactory procedure for determining the parasite profile in a herd because many other unrelated factors may have contributed to the relatively poorer condition of the animals which are sampled.

At least ten animals, but preferably 15 (or all of the herd if it is smaller than this) need to be sampled if meaningful results are to be obtained.

Level of sensitivity

In the southern Australian environment faecal egg counts are of limited value in alpaca diagnostics if done at the level of sensitivity that is routinely used at veterinary diagnostic laboratories for faecal egg counts of sheep (25 epg). Samples processed at a level of 50 or 100 epg are completely inappropriate.

All faecal egg counts in the current study were routinely processed using a sensitive flotation technique to detect eggs at a level of 2 epg. This produced a data set which was sufficiently sensitive for comparisons to be made between and within groups and benchmark values to be identified. For practical conditions this level of precision is not necessary. Given the general crudeness of faecal egg counting techniques, however, it is strongly suggested that for meaningful results alpaca counts are done at a minimum level of sensitivity of 15 epg.

Bulk faecal egg counts

Bulk faecal egg counts, which are routinely used for evaluation of the internal parasite status of sheep flocks, provide no useful information in the case of alpacas and are a waste of money.

Differentiation of egg types

The eggs should be accurately differentiated according to their shape and size by an experienced person into at least the Scourworm, *Nematodirus* and Large intestinal worm categories. Grouping of eggs into one overall egg count does not give sufficient information on which to base meaningful interpretations.

Recommendations

- In the southern Australian environment faecal egg counts of alpacas are usually of limited value if done at the level of sensitivity that is routinely used for faecal egg counts of sheep (25 epg). Samples processed at a level of 50 or 100 epg are inappropriate. The lowest satisfactory level of detection is 15 epg.
- Bulk faecal egg counts of groups of alpacas provide no useful information.
- Counts from only one or two animals in a herd rarely provide useful information.

- Unless the eggs are accurately differentiated according to morphology by an experienced person, the results may be meaningless.

5.3.8. Critical faecal egg counts and drenching practices

The critical categories of faecal egg counts of alpacas are those referring to Scourworms and *Nematodirus*. These are the parasites which are most likely to exert an adverse influence on the health of animals. Other counts are of little consequence.

Under southern Australian conditions, for animals in reasonable condition with adequate nutrition the following epg values are a guide to general categories of the levels of infection.

Crias and weaners

These are the most susceptible class of animal and nearly always have the highest counts. Counts of <100, 100-250 and 250-400 Scourworm eggs per gram can be considered to be "low", "moderate" and "elevated" respectively, >400 epg "high" and >1000 "very high". In the present study only 0.9% of egg counts from crias and weaners exceeded 200 epg and only 5 out of 293 counts exceeded 400 epg. Only 2 animals were drenched.

In general, I would recommend drenching only when the level exceeds 350 epg unless there is some unusual stress factor present or a concurrent moderate or high burden of another parasite such as *Nematodirus* with an egg count of 50 - 100 epg or greater.

Nematodirus needs to be considered separately. Infections in most animals spontaneously resolve (see Table 34). We found only 4 crias and weaners with counts over 100 epg. I would suggest that individual animals with counts exceeding 100 epg are drenched.

Tuis and adults

As a general rule Scourworm egg counts of <20, 20-75, 75-125 and >125 epg can be regarded as "low", "moderate," "elevated" and "high" respectively.

Most counts are zero, "low" or "moderate", the majority being below 20 epg. We found very few "high" egg counts (Table 31) and no obvious disease conditions related to internal parasites, but as discussed earlier, this provides no justification for complacency.

It is probably necessary to drench any animal with a count greater than 125 epg, because it may be at risk of developing disease. In addition it will be contributing significant contamination to the environment.

It is recommended that all tuis and adults with *Nematodirus* counts greater than 50 epg are drenched. The main justification for this lies in reducing environmental contamination. I have serious concerns about whole herd drenching as a routine practice. There are opportunities for compromise.

My suggestion is that faecal monitoring twice a year (July/August and December), will detect those animals which need to be drenched. These animals may have been more exposed than others by chance, or are more susceptible. They may unduly contaminate the environment, or potentially suffer ill effects. The *identified animals should be individually drenched* without it being necessary to treat the whole herd. In this way undue selection for drench resistance will be averted and the continued maintenance of natural immunity in the herd assured.

5.3.9. Drench resistance

In the introduction to this report it is described how and why alpacas arriving in Australia received repeated treatments with broad spectrum drenches at various steps in the import and quarantine process, and thereafter. The most commonly used product was ivermectin in injectable formulation. As mentioned earlier, the current study was initially frustrated by the preoccupation of some owners with regular treatment of animals with ivermectin, leading to invalidation of some of the parasitological results in the first 6 months. The practice of repeated treatment of animals with ivermectin by owners and some of their professional service providers became so entrenched that a new verb, "to ivomec", found its way into the popular lexicon of the industry. There appears to have been no awareness of the possible outcomes of this rampant product abuse.

Australia and New Zealand have among the highest levels of drench resistance in the world. Until recently this was limited to the white (benzimidazole) and clear (levamisole) groups of drenches. Strains of sheep Brown Stomachworm resistant to ivermectin have now developed under field conditions in Western Australia and it is unrealistic to expect that the process of resistance selection is not already well advanced in the eastern states as well. Ivermectin and moxidectin, which belong to the same drench group (the macrocyclic lactones or "ML" drenches), are extremely suitable for administration to alpacas because they are safe, highly effective and easily administered in low volume injectable formulations. Although not registered or recommended for use in camelids the ML's have become the treatment of choice for internal parasites in alpacas. Because of their value to the industry it is essential that these drenches are preserved for the future. This means that they should always be used responsibly, for a reason, and not administered regularly or haphazardly, simply because animals are not doing well. Indiscriminate use of these products could have serious outcomes.

Alpacas carry sheep worms, which we know have high levels of resistance to white and clear drenches and probably low, currently undetected, resistance to ML drenches. They also harbour cattle worms whose resistance status to date has been unimportant in Australia. There are ominous signs that this may be changing. Recently McKenna (1996) has reported that resistance of cattle parasites to white drenches, always at a low level in New Zealand, may be increasing. Most importantly, resistance of *Cooperia* spp. in cattle to the ML drench group has been confirmed in New Zealand (Vermunt *et al.*, 1995). McKenna suggests that because of the rapid growth in intensive dairy beef production in New Zealand and a proportionately greater expansion in the cattle drench market the problem of drench resistance in cattle nematodes might be expected to become more widespread in the future. Given that history shows Australia to be, at most, a short step behind New Zealand in major drench resistance problems it is not unnecessarily alarmist to suggest that the word "alpaca" could be substituted for "cattle" if excessive use of drenches goes unchecked in Australian alpacas. There is a real potential to select in alpacas for both sheep and cattle worms resistant to the ML drenches. This could seriously affect the industry.

Recommendations

- Before drenching alpacas one should be confident that it is essential for the wellbeing of the animals. In most cases a conservative approach, associated with regular monitoring of parasite levels, can avoid a large amount of unnecessary drenching without compromising the health of the animals.
- Drenching of the whole herd as a routine management practice is not recommended because of the danger of the development of resistant worms.
- Drenching based on the double summer drench concept commonly employed for worm control in sheep and sometimes recommended for cattle in southern Australia is not recommended. At most, animals should be treated once, in December, and a second drench only given to individual animals in February upon confirmation by faeces examination that it is required. Drenches given at other times of the year should be in response to a requirement identified by faecal sampling, and should therefore rarely include animals older than 1 year.
- The necessity to give a second drench in February is strong evidence that parasite control has failed under the management system operating on the farm and it should be urgently reviewed and amended.
- Recently developed pour-on formulations of the ML drenches were not intended for, or tested on camelids, and should not be used on them.

5.4. THE PARASITE INTERACTIONS BETWEEN COMMUNALLY GRAZED SHEEP AND ADULT ALPACAS

5.4.1. Introduction

From September 1995 to September 1997 the opportunity was taken to examine the levels and composition of parasite infections in mature alpacas and sheep grazing sympatrically in a winter rainfall environment in southern Australia. This work involved direct collaboration between the Victorian Institute of Animal Science and Primary Industries, South Australia.

5.4.2. Materials and Methods

Location, animals and management

Animals were grazed at Attwood, 18 km north-northwest of Melbourne (37°40`S, 144°53`E, altitude 135 m ASL.). Twelve adult Huacaya alpaca (mean \pm SD; age 5.2 \pm 2.7 years, range 2 to 11 years; live weight 72.0 \pm 9.5 kg) were donated by members of the Australian Alpaca Association. Ten Merino sheep (age 3 years; live weight 54.0 \pm 3.9 kg) were purchased commercially. These animals were introduced together in September 1995 and grazed a 3.2 ha improved pasture (estimated carrying capacity 12 DSE/ha) at a stocking rate of 8 DSE/ha.

No treatments for internal parasites were given to either group in the period leading up to or during the trial.

The animals were excluded from 25% of the area by the erection of an electric fence in early October 1996, increasing grazing pressure to 10 DSE/ha. To further increase grazing pressure, ten six month old Merino lambs were introduced to the pasture in late March 1997, increasing grazing pressure to an estimated 15 DSE/ha. These lambs were drenched with a broad spectrum worm remedy one week before being introduced to the area and confirmed by faecal examination to be free of internal parasites. They remained on the pasture until mid-September 1997. During the entire period no supplementary feeding was provided and no worm drenches were given to grazing animals.

Pasture and climate

The animals grazed improved annual pasture composed of the following species: Subterranean clover, Annual rye grass, Fog grass, Brome grass, Silver grass, Barley grass, Couch grass and Cape weed with a number of other grasses and weeds making a minor contribution. Rainfall for the three years was: 1995, 680 mm; 1996, 596 mm; 1997, 310 mm).

Parasitological examinations

Faecal egg counts were done on the adult sheep and alpacas 7 times between December 1995 –February 1997, and on the lambs in April 1997 to confirm that they were free of worms after drenching with ivermectin in March. Counts were done on all 3 groups a further 5 times from May – September 1997.

For each collection infective nematode larvae were harvested and identified from composite group faecal cultures. Where 50 or more larvae were recovered from a culture the results were included in the calculation of average values for that group of animals. If less than 50 larvae were recovered from a culture the results were not considered further.

5.4.3. Results

Faecal egg counts

Faecal egg counts of mature alpacas remained at very low levels throughout the entire 2 year period. The highest individual counts of Scourworm eggs were 50, 64, and 72 epg and of *Nematodirus* eggs was 20 epg. Only on 2 occasions did the mean Scourworm egg count exceed 10 epg.

The faecal egg count pattern in adult sheep was quite different. Levels remained low to very low over the first summer and autumn, began to rise in winter and peaked in late spring and summer, probably under the influence of nutritional stress. Thereafter they declined once more to very low levels and did not rise again. Several Scourworm counts exceeded 400 epg, the highest mean value was 184 epg and on 8 occasions the mean count exceeded 10 epg.

Within 8 weeks of placement on the pasture the lambs had a mean egg count of 104 epg, which continued to increase in each of the next 3 months to peak at 304 epg when the experiment was concluded. Several individual counts exceeded 600 epg. The mean *Nematodirus* faecal egg count in lambs at the second and third last observations was 19 epg but the animals had spontaneously thrown off most infections by the following month. During this period no samples from mature sheep or crias were positive for *Nematodirus* eggs.

The faecal egg counts over time are illustrated in Figure 40.

Larvae cultured from faeces

The result from one of the faecal collections was discarded because larvae from the sheep and alpaca cultures were mixed.

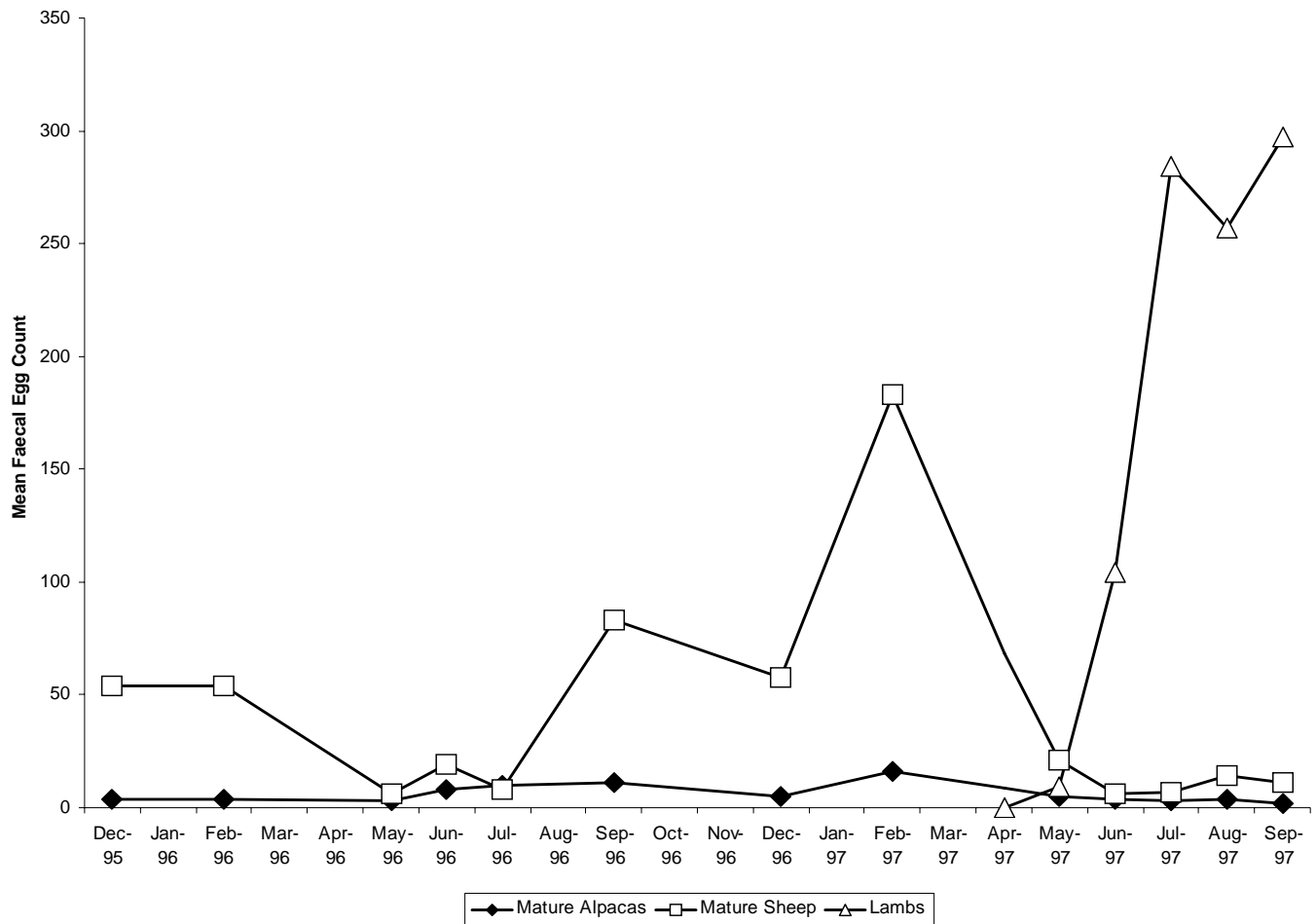


Figure 40 Scourworm faecal egg counts in mature alpacas, mature sheep and lambs grazing together

The numbers of cultures which yielded sufficient larvae for inclusion in average values were 10/11, 7/11 and 5/5 for mature sheep, mature alpacas and lambs respectively.

All animal groups in the system carried burdens of the same worms but they were not evenly distributed.

The faeces of mature sheep produced proportionately larger numbers of large intestinal worms than either alpacas or lambs. Burdens in lambs were predominantly Scourworms. *Cooperia oncophora*, which is recognised as mainly a parasite of cattle, was recovered commonly from alpacas but was rare in adult sheep and absent from lambs.

Mean values for the proportions of different larval types recovered from the faecal cultures are summarised in Table 39.

Table 39. Proportions of larval types from faecal cultures of lambs, mature sheep and mature alpacas grazing together

Percentage of larvae			
Animal or worm category	Scourworm	Large intestinal worms	<i>Cooperia oncophora</i> (calf scourworm)
Lambs	95 %	5%	0%
Mature sheep	56%	42%	2%
Mature alpacas	69%	6%	22%

5.4.4. Discussion

The uptake of sheep parasites by alpacas has been the subject of an excellent field study by Hill *et al.* (1993) in New Zealand. Worm free Romney sheep and alpacas of similar age groups (6, 18 and >36 months) were grazed for 16 weeks on pasture contaminated by lambs. Among other measurements, faecal egg counts, larval cultures and dag scores were done. For the respective age groups alpacas had lower peak worm egg counts in their faeces [384, 50 and 60 eggs per gram of faeces (epg) vs 1500, 500 and 140 epg] and faecal contamination of the perineum (dags) than the same ages of sheep. Alpaca crias had significantly higher egg counts than tuis or hembras, but counts in tuis and hembras did not differ significantly. The same nematode genera (*Ostertagia*, *Trichostrongylus*, *Cooperia*, *Haemonchus*, *Chabertia/Oesophagostomum*) were cultured in similar proportions from bulked faecal samples of both alpacas and sheep, except for *Haemonchus*, which was more common in sheep faeces.

The New Zealand trial demonstrated that alpacas do not develop as high an output of worm eggs when grazing the same pasture contaminated solely by sheep, which suggests that they become less parasitised. Under the circumstances that the trial was conducted this can be ascribed either to differences in grazing behaviour, or natural immunity. Age immunity in alpacas to helminth parasites was also confirmed in this trial.

Results in the study at Atwood were similar to those in New Zealand. Despite the presence of larvae on the pasture, as evidenced by the acquisition of moderate infections in adult sheep in 1996 and substantial infections in lambs in only a few months in 1997, adult alpacas remained largely refractory to infection. The differences cannot reasonably be dismissed on the basis of differences in grazing habits because all of the animals were forced by artificial grazing pressures (fencing and high stocking rate) to consume the pasture which was available.

There is clear evidence in 1997 of the development of a solid age immunity to worms in the group of mature sheep which maintained very low faecal egg counts despite the rapid acquisition of large burdens by their younger counterparts. The level of their immunity was presumably not sufficient to withstand challenge the previous year.

In addition, the small burdens of worms that the alpacas accrued contained different proportions of the various worm species to the sheep. *Cooperia oncophora* established strongly in alpacas but not in sheep, which suggests that young alpacas could be at risk if forced to graze with heavily infected calves. Larvae of the large intestinal worms (most

probably *O. venulosum*) comprised nearly half of those recovered from faeces from mature sheep but were scarce in those from lambs and alpacas.

5.4.5. Conclusions

- The results confirm that :
- Adult alpacas maintain a natural resistance to infection with sheep nematodes under conditions of constant challenge.
- The level of natural resistance that alpacas develop against internal parasites of sheep is probably much more robust than that developed by sheep, at least the Merino breed.
- Alpacas grazing with ruminants may acquire different levels and species of parasites to the ruminants.
- Even in the absence of cattle alpacas are able to maintain burdens of *Cooperia oncophora*.
- Sheep are unlikely to acquire significant worm burdens through grazing with adult alpacas. They are much more likely to be the source of their own infections.

6. FUTURE RESEARCH DIRECTIONS

6.1. FIBRE

It is recommended that the following areas be considered for future research:

- development of a genetic improvement program to significantly increase animal fibre production
- determine if recent imports of genetic material are more productive than the present base herd
- further develop fleece harvesting guidelines which focus on improving fibre quality by incorporating the relevant findings of these studies
- develop a program of training with the objective of reducing the contamination of saddle fleece.
- identify the causes of high sampling variance of medullated fibre measurements and determine methods to reduce their influence.
- develop testing procedures to enable the main determinates of processing performance of pooled lots to be determined.
- develop shearing strategies aimed at maximising the harvest of high quality fibre from young alpacas.
- investigate alternative methods to substantially lower the cost of alpaca fibre harvesting.
- further investigate the effects of pasture availability and pasture management on alpaca live weight change, productivity and fibre quality.

6.2. GENETICS

Further investigations, building on the knowledge and experience derived from the current project should be conducted in the following areas:

- Estimation of phenotypic and genetic parameters for production traits. The phenotypic and genetic parameters (means, variances, heritabilities, correlations) are the 'building blocks' of genetic improvement programs. Some work has already been conducted in this area as part of the present project, but much more remains to be done. Part of the work would consist of analysis of data already collected, but more information should be sought to further improve the accuracy of our parameter estimates. The work in this area would culminate with the formulation of practical genetic improvement programs for Alpaca breeders.
- Further investigations on the inheritance of the Huacaya and Suri (as well as any other worth postulating) phenotypes. This part of the work would build on what we have already done in the context of the present project, but using more and new information, and exploring when necessary additional genetic models.

- Elucidation of the inheritance of coat colour in Alpacas. This is an aspect that requires much more study before we have genetic models that enable us to confidently predict the likely outcomes of particular matings. This part would build on what has already been initiated overseas, but using much more information to enable refinement of the genetic models.

The knowledge derived from research and development in the above mentioned areas would play a very important role in ensuring the future viability of the Australian Alpaca industry.

6.3. BIOCHEMISTRY

- Measurement of blood constituents is a valuable diagnostic aid in identifying disorders likely to affect the health and productivity of animals. Abnormal blood values are identified as those that fall outside reference limits established for each constituent in healthy animals. The present study was successful in establishing typical blood concentrations for minerals, trace elements and vitamins in apparently healthy alpacas and also identified important factors such as age, season and location that are likely to influence these constituents. The present work also showed that the concentration of many of these constituents differed markedly from those concentrations normally encountered in healthy ruminants. Therefore the blood reference limits established with ruminants are inappropriate for alpacas.
- The present work provides typical blood values in healthy alpacas that can be used as a guide by veterinarians in diagnosing mineral, trace element or vitamin disorders in alpacas. However, further work is required in order to more precisely define the lower and upper limits of these blood constituents that are consistent with health and high productivity. Often these limits can be established in dietary studies to determine the mineral, trace element and vitamin needs of the animal.
- Of major significance was the indication from the present work that alpacas over wide areas of southern Australia are at risk of vitamin D deficiency in winter and spring: the young are particularly vulnerable to this disorder. There is an urgent need to clearly define the environmental conditions in southern Australia where alpacas are at risk and to assess the significance of dietary calcium and phosphorus levels in the aetiology of this disorder. The present work has established a convenient treatment regime to prevent the disorder using subcutaneous injections of vitamin D. However, the dose and frequency of providing oral supplement of vitamin D requires investigation.

6.4. PARASITOLOGY

The current study has provided a basis for planned diagnosis and control of internal parasites in alpacas in the southern Australian winter rainfall environment. There are, however, extensive areas of Australia carrying a considerable proportion of the national alpaca herd which were not covered. Importantly, this report does not provide specific relevant information for the non seasonal and summer-predominant rainfall areas of central and northern New South Wales and southern Queensland, where potentially dangerous parasites

such as Barber's Pole Worm are prevalent and the species, proportions and seasonality of worms will be different to that in southern Australia.

The recommended areas for future research are :

- A study similar in design to the present one in which the acquisition of parasite infections in the various age classes of alpacas is studied on 3-4 farms in central and northern NSW. This will complete the parasite profile for the alpaca industry in Australia and define the strategies for diagnosis and control into the future.
- A specific examination of the relationship between *Nematodirus* spp. and some of the cattle worms (*Trichostrongylus axei* and *Cooperia oncophora*) in young alpacas. All of these worms are potentially dangerous to alpacas and it is important to identify early in the life of the industry the unique role that they might play in determining the outcomes of intensive farming ventures, particularly where ruminants are also part of the system. There are suitable new sites for this study in New South Wales and Victoria.
- The establishment of an interstate network to gather and collate data relating to clinical parasitism in alpacas, including herd and treatment histories, total worm counts and post mortem findings. For comparative purposes, and to assemble an Australian data base, this should include parasite data from normal healthy animals which have died from other causes. The industry is sufficiently small and integrated for this information to be useful to all members and for profiles to be developed indicating danger times, areas and, more importantly, farming practices which lead to parasite problems in alpacas.

7. COMMUNICATIONS STRATEGY

7.1. PUBLICATIONS TO DATE

- Aylan-Parker, J. and McGregor, B.A. (1999). Optimising the sampling method for assessing alpaca fleece quality. *Small Ruminant Res. Journal* (submitted for publication).
- Carmichael, I 1996. Internal parasitism in alpacas in Southern Australia. *Camelid Medicine & surgery Proceedings 278 1 Post Graduate Foundation in veterinary Science*, University of Sydney, pp 327-339
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- McGregor, B.A. (1997). The quality of fibre grown by Australian alpacas : 1 - The commercial quality attributes and value of alpaca fibre. *Proc. International Alpaca Industry Conf. Sydney*. pp. 43-48. (Aust. Alpaca Assn.: Forest Hill, Victoria).
- McGregor, B.A., Howse, A.M., Hubbard, D. and Tuckwell, C.D. (1997). The quality of fibre grown by Australian alpacas : 2 - Survey of the quality of fibre grown by Australian alpacas. *Proc. International Alpaca Industry Conf. Sydney*. pp. 49-52. (Aust. Alpaca Assn.: Forest Hill, Victoria).

- McGregor, B. A. (1997). Fibre quality, productivity, mineral, vitamin and parasite status and genetics of fleece type in Australian alpacas. Proceedings III International Festival of Sudamerican Camelids, Arequipa pp. 31 - 32. (International Alpaca Association : Arequipa).
- McGregor, B.A. (1998). The effect of excellent nutrition and drought on the live weight, fibre growth and quality and grazing behaviour of alpacas and Merino sheep. Proc. International Alpaca Industry Conf. Perth. pp. in press. (Aust. Alpaca Assn.: Forest Hill, Victoria).
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- Tuckwell, C.D, Ponzoni, R.W., McGregor, B.A., Carmichael, I., Judson, G.J. and Keynon, R.. (1995). A brief account of South American Camelids in Australia, with a description of an alpaca research project and a summary of preliminary data. Proc. European Assn of Camelids pp. 153-62.
- Tuckwell, C.D., Ponzoni,R.W., McGregor, B.A., Carmichael, I., Judson,G.J. and Kenyon, R. (1996) An Australian Alpaca research Project – some preliminary data. Proceedings: Australian Alpaca Association Conference, Brisbane, Queensland, pp. 1-8.

7.2. FUTURE PUBLICATIONS

- RIRDC Final Project Report
- International Alpaca Industry Conference, South Australia, Adelaide, 1999

7.3. PRESENTATIONS TO DATE

- 2nd European Symposium on South American Camelids, Camerino -Italy, 1995
- 3rd international Festival on South American Camelids, Arequipa –Peru 1997
- Alpaca conference, America (Raul Ponzoni)
- International Alpaca Industry Conference, Victoria, Geelong 1995
- International Alpaca Industry Conference, Queensland, Gold Coast 1996
- Australian Veterinary Association (Camelids) Conference, Melbourne 1997
- International Alpaca Industry Conference, New South Wales ,Sydney 1997

- International Alpaca Industry Conference, Western Australia 1998
- Australian Alpaca Association (SA Division), Woodside 1998

7.4. FUTURE PRESENTATIONS

- Australian Veterinary Association (Camelids) Conference, Walwa, Victoria 1999
- Australian Alpaca Association (Eastern Victoria Division), Melbourne 1999
- International Alpaca Industry Conference, South Australia, Adelaide 1999
- International Conference on Trace Elements in Man and Animals, France 1999

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