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Producción de fibra de alpaca, llama, vicuña y guanaco en Sudamérica

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Resumen

Más de un millón de pequeños productores de los Andes centrales de Sudamérica tienen alpacas (*Vicugna pacos*) y llamas (*Lama glama*) como principal medio de subsistencia. Los animales proveen carne, leche, fibra, energía de transporte y guano y, además, son un elemento importante de la identidad cultural de sus pueblos. Con 3,9 millones de llamas y 3,3 millones de alpacas la producción total de fibras de camélidos en la región supera los 5 millones de kg anuales. Cerca del 30% de la producción de fibra se transforma y es usada a nivel de predio o comunidad. Alrededor del 80% de la alpaca comercializada es de color blanco y el 12% tiene diámetros de fibra menores de 23 micrones. Las fibras de llama son de menor valor y más variables en colores y diámetros que las fibras de alpaca. Ambas especies tienen dos razas, cada una con características de calidad de fibra y adaptación específica. También existen en Sudamérica dos especies de camélidos silvestres, el guanaco (*Lama guanicoe*) y la vicuña (*Vicugna vicugna*). Ambas tienen vellones de valiosa fibra *down*. Poblaciones específicas de estos camélidos califican para ser capturadas, esquiladas y liberadas generando un ingreso adicional a las comunidades en que viven. El aumento de la producción de fibras y demás productos de los camélidos sudamericanos, a la vez de preservar un recurso genético animal crítico y los valores culturales asociados y mejorar la calidad de vida de muchos pequeños productores, debe ser parte de una estrategia global de inversión sostenida en investigación y desarrollo apropiados.

Palabras clave: *alpaca, llama, vicuña, guanaco*

Summary

More than one million smallholders in the Andean region of central South America exploit alpacas (*Vicugna pacos*) and lamas (*Lama glama*) as their main means of subsistence. Alpacas and lamas provide meat, milk, fibre, power and guano; in addition it is an important element of the cultural identity of their producers. With 3.9 million lamas and 3.3 million alpacas the total annual fibre production in the region exceeds 5 million kg. Nearly 30% of the fibre production is transformed on-farm or at the community level. About 80% of the marketed alpaca fibre is white and 12% is finer than 23 microns. Lama fibres have less value and are more variable in colours and fibre diameter than alpaca fibres. Both species of camelids have two breeds, each one with specific adaptation and fibre quality characteristics. Two wild species of camelids exist in South America: the guanaco (*Lama guanicoe*) and the vicuna (*Vicugna vicugna*). Both have fleeces with precious down fibres. Specific populations of these camelids are qualified to be captured, sheared and released, providing an additional income to the communities in which they live. Due to support to improve the production of fibre and other products of South American camelids, while preserving a valuable animal genetic resource, the cultural values of the associated production systems, and improving the livelihoods of resource-poor smallholders should be part of a global strategy involving a sustained investment in appropriate R&D.

Keywords: *alpaca, llama, vicuña, guanaco*

Résumé

Plus d'un million de petits exploitants de la région des Andes centrales en Amérique du Sud utilisent les alpagas (*Vicugna pacos*) et les lamas (*Lama glama*) en tant que moyen principal de subsistance. Les alpagas et les lamas fournissent de la viande, du lait, des fibres, de l'énergie et du guano; de surcroît, ils représentent un élément important de l'identité culturelle de leurs producteurs. Avec 3,9 millions de lamas et 3,3 millions d'alpagas, la production annuelle totale de fibres de la région dépasse 5 millions de kilogrammes. Presque 30% de la production de fibres est traitée au niveau de l'exploitation ou de la communauté. Environ 80% de la fibre d'alpaga commercialisée est blanche et 12% mesure moins que 23 microns. Les fibres de lama ont moins de valeur et sont plus variables, pour ce qui est des couleurs et du diamètre, que les fibres d'alpaga. Les deux espèces de camélidés ont deux races dont chacune présente des caractéristiques spécifiques d'adaptation et de qualité des fibres. En Amérique du Sud, on trouve deux espèces sauvages de camélidés: le guanaco (*Lama guanicoe*) et la vigogne (*Vicugna vicugna*) qui ont des toisons avec des fibres précieuses de duvet. Certaines populations spécifiques de ces camélidés sont qualifiées pour la capture, la tonte et la remise en liberté, ce qui fournit un revenu supplémentaire aux communautés où elles vivent. Le soutien pour améliorer la production de fibres et d'autres produits des camélidés de l'Amérique du Sud, tout en préservant une ressource zoogénétique précieuse, les valeurs culturelles des systèmes de production y associés et en améliorant les moyens d'existence des petits exploitants pauvres en ressources, devrait faire partie d'une stratégie globale impliquant un investissement soutenu en R&D appropriés.

Mots-clés: *alpaga, lama, vigogne, guanaco*

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Introducción

Los camélidos modernos derivan de especies prehistóricas originadas en Norteamérica que desaparecieron de esa región hacen más de 11 millones de años. Antes de su desaparición algunos camélidos ancestrales migraron hacia el sur del continente para evolucionar en los camélidos sudamericanos actuales que incluyen dos especies domésticas: llama (*Lama glama*) y alpaca (*Vicugna pacos*) y dos especies silvestres: guanaco (*Lama guanicoe*) y vicuña (*Vicugna vicugna*). Estudios de ADN mitocondrial sugieren que la vicuña y el guanaco fueron los antecesores de las alpacas y las llamas, respectivamente, en un proceso de domesticación que se inició en los Andes Centrales de Sudamérica hace 6000 años (Kadwell *et al.*, 2001, Gentry *et al.*, 2004, Marin *et al.*, 2007). El uso textil de las fibras se inicia con la Cultura Huaca Prieta de hace 2500 años (Wheeler, 2004, Wheeler *et al.*, 1995), tiene un desarrollo evidente en la Cultura Paracas y posteriormente alcanza niveles de excelencia en la Cultura Mochica (Wing, 1977). En la actualidad los productos de los camélidos domésticos constituyen el principal medio de sustento para muchos productores de escasos recursos en los países andinos centrales de Sudamérica incluyendo Ecuador, Perú, Bolivia, Argentina y Chile. El aprovechamiento de las fibras producidas por los camélidos silvestres es todavía limitado pero potencialmente importante.

Distribución de los camélidos sudamericanos

Las alpacas, llamas y vicuñas habitan la zona alto-andina, por encima de 3000 msnm, del Perú, Bolivia, Argentina y Chile. Estos ambientes incluyen mesetas (altiplano) y laderas cordilleranas con alta incidencia de heladas y precaria disponibilidad de agua. Los guanacos habitan predominantemente zonas más bajas y desérticas, como la Patagonia argentina y chilena. Las alpacas y llamas también fueron llevadas a otros países, donde son criadas en condiciones más favorables que las de su ambiente de origen, para servir como mascotas o producir fibra; por ejemplo en los Estados Unidos (120.000 ejemplares), Australia (100.000 ejemplares), Canadá, Nueva Zelanda y países europeos (Lupton *et al.*, 2006).

La Tabla 1 resume la información sobre población y distribución de los camélidos sudamericanos. Los datos disponibles, que posiblemente son subestimados, contabilizan aproximadamente 4 millones de llamas y 3,5 millones de alpacas. Perú es el país con el mayor número de camélidos, aproximadamente 5 millones de animales, además de ser el país que más alpacas y vicuñas alberga. Bolivia tiene la mayoría de las llamas y Argentina la mayoría de los guanacos.

Importancia de los camélidos sudamericanos

Los camélidos sudamericanos domésticos, a veces en asociación con ovinos, constituyen el principal medio de utilización productiva de extensas áreas de pastos naturales en las zonas alto-andinas donde no es posible la agricultura y la crianza exitosa de otras especies de animales domésticos. Los camélidos convierten con eficiencia la vegetación nativa de estos ambientes en carne y fibras de alta calidad, además sus pieles y cueros tienen múltiples usos industriales y artesanales. El estiércol es otro subproducto valioso que se usa como combustible para la cocción de los alimentos y fertilizante para los cultivos. La llama cumple además una importante función de transporte (Iñiguez y Alem, 1996).

De Los Ríos (2006) estima que al menos un millón y medio de personas se dedican a la crianza de camélidos en la región alto-andina del Perú. Las áreas productoras de camélidos en el Perú incluyen las provincias con mayor pobreza y marginalización. En Bolivia, y con base en las estimaciones del INE Bolivia (2009) y UNEPCA (1999) es posible estimar que la producción de llamas beneficia a 37.000–50.000 familias de productores de escasos recursos. Sin embargo, esta producción aun no representa una vía directa para reducir la pobreza y la marginalización de sus productores, no obstante la demanda incrementada por los productos de esta especie. Lo anterior refleja un contexto de producción complejo,

Tabla 1. Población de camélidos en Sudamérica.

Camélido	Perú	Bolivia	Argentina	Chile
Alpaca	3.041.598(1)	269.285(2)	pocos	28.551(6)
Llama	1.462.730(1)	2.237.170(2)	161.402(3)	50.132(6)
Vicuña	147.000(1)	12.047(8)	131.220(4)	27.921(7)
Guanaco	pocos	pocos	636.477(4,5)	27.150(7)

Referencias:
(1)http://www.minag.gob.pe/pecuaria/
(2)INE Bolivia (2009), Censo 2007.
(3)INDEC (2002), Censo 2002.
(4)CNVG (2007), Censo 2006.
(5)Amaya *et al.* (2001), Censo 2000.
(6)INE Chile (2009), Censo 2007.
(7)Parraguez *et al.* (2004).
(8)UNEPCA (1999).

Tabla 2. Productores de fibras de camélidos en Sudamérica.

Fibra	Perú	Bolivia	Argentina	Chile
Alpaca	789.775[(1)]	13.603[(4)]	s/d	916[(5)]
Llama	297.414[(1)]	37.000–50.000[(4)]	2.803[(2)]	1.388[(5)]
Vicuña*	250[(3)]	s/d	22[(3)]	s/d
Guanaco*	s/d	s/d	15[(3)]	s/d

Para camélidos silvestres la cifra representa unidades de manejo es decir: productores de criaderos de vicuña en cautividad y comunidades involucradas en *chakus*.
Referencias:
[(1)]INIA (2006), Censo 2001.
[(2)]INDEC (2002), Censo 2002.
[(3)]Estimaciones propias, 2009.
[(4)]Estimaciones propias en base a INE Bolivia (2009), Censo 2007 y UNEPCA (1999).
[(5)]INE Chile (2009), Censo 2007.
s/d sin datos.

afectado por la limitada disponibilidad y el uso no conservativo de los recursos naturales que determinan baja productividad de los rebaños, pequeñas escalas de producción y una débil integración de las cadenas productivas con las del mercado (UNEPCA, 1997). Las poblaciones alto-andinas de Argentina y Chile no escapan a las características observadas en Perú y Bolivia, aunque por la menor cantidad de animales y productores el impacto de su producción en las economías nacionales es también menor.

Los camélidos silvestres en los países andinos se encuentran protegidos por diversas leyes y normas nacionales e internacionales por lo que su aprovechamiento comercial es limitado, puntual y sujeto a un estricto control legal. En general los camélidos silvestres son propiedad del Estado. Por ello no es posible contabilizar un número de “productores” de estos camélidos silvestres sino más bien unidades de aprovechamiento o de manejo. A estos se suman algunos pocos criaderos de vicuñas y guanacos en cautividad donde los animales sí son propiedad de productores individuales. La Tabla 2 resume estadísticas publicadas sobre el número de productores de camélidos en Sudamérica.

En la Tabla 3 se consignan cantidades de cada fibra producidas en los principales países productores. Se observa que la alpaca es la especie productora de fibra por excelencia. Aun con una población menor a la de llamas, la producción de fibra de alpaca es considerablemente mayor a la de llama. De todos modos la importancia económica de cada especie de camélidos reside en el conjunto de productos y servicios que le presta al productor. En ese sentido las llamas aportan incluso más que las alpacas. Otro aspecto a tener en cuenta aparte de la cantidad producida es el valor agregado que alcanza la fibra a nivel del productor, comunidad, industria o país. En ese aspecto las fibras de camélidos suelen alcanzar valores altos en los productos finales pero la participación del productor en ese valor suele ser pequeña.

Alpacas

Se asume que la especialización para la producción de fibra de las alpacas deriva de un proceso de selección practicado desde épocas precolombinas (Wang *et al.*, 2003). Existen dos razas de alpacas, la Huacaya y la Suri (Figura 1). La alpaca Huacaya se caracteriza por tener un vellón compacto, esponjoso y similar al vellón del ovino Corriedale que le confiere una apariencia más voluminosa, con fibras finas suaves y onduladas. La alpaca Suri presenta fibras de gran longitud organizadas en rizos colgantes, de un modo similar a los rizos del ovino Lincoln, lo cual confiere al animal una apariencia angulosa (Hoffman y Fowler, 1995; Antonini *et al.*, 2004 y FAO, 2005). La alpaca Huacaya representa 85% de la población de alpacas en el Perú.

Tabla 3. Producción de fibras de camélidos en Sudamérica.

Fibra	Perú	Bolivia	Argentina	Chile
Alpaca	3.399 ton[(1)]	365 ton[(3)]	s/d	s/d
Llama	760 ton[(1)]	433 ton[(3)]	70 ton[(2)]	s/d
Vicuña	5.500 kg[(2)]	s/d	377 kg[(2)]	s/d
Guanaco	s/d	s/d	1.500 kg[(2)]	s/d

Referencias:
[(1)]INIA (2006), Censo 2002.
[(2)]Estimaciones propias, 2009.
[(3)]PRORECA (2003.)
s/d sin datos.

Figura 1. *Alpaca de raza Suri en Puno, Perú.*

Sistemas de producción de alpaca

Los sistemas de cría de la alpaca en el Perú son en su mayoría comunitarios, con productores de escasos recursos. Estos sistemas son extensivos, con base en la explotación de campos nativos de pastoreo y rebaños mixtos que generalmente incluyen ovinos y que pueden también incluir llamas. Los sistemas de manejo son tradicionales con limitada adopción de tecnologías conducentes a una mejora de la productividad, por tanto los rendimientos por animal y rebaño aun son bajos (Quispe, 2005 y Gobierno Regional de Huancavelica, 2006).

Las esquilas se realizan con tijeras manuales, mecánicas o con otros implementos más rudimentarios. La esquila en el Perú se la realiza en noviembre, cuando la oferta forrajera incrementa con un concomitante incremento en la condición alimenticia del rebaño. A partir de mayo la oferta forrajera declina rápidamente con el consiguiente deterioro de la alimentación de los rebaños. Estos cambios en el nivel de alimentación están correlacionados positivamente con el diámetro de las fibras, el cual es mayor en el período de abundancia forrajera y menor en el periodo de baja disponibilidad (Quispe *et al.*, 2008b).

Características de la fibra de alpaca

La industria textil refiere a las fibras de alpaca como fibras especiales y los artículos confeccionados con ellas, están clasificados como artículos de lujo (Wang *et al.*, 2003). Como todas las fibras especiales, las fibras de alpaca son flexibles y suaves al tacto, poco inflamables, de bajo afieltramiento y poco alergénicas. Además, los tejidos de estas fibras son proclives a la confección de vestidos con excelentes pliegues, apariencia, caída y lustrosidad, que en su conjunto confieren la apariencia de ser nuevos no obstante el tiempo que puedan haber sido usados. En este contexto los tejidos elaborados con alpaca son comparables a los elaborados con lana ovina pero con un diámetro promedio 3 a 4 micras menor (Inka-Alpaca, 2009). Contrastando con los vellones de ovinos, los rendimientos en limpio de los vellones de alpaca son altos (87% a 95%), lo cual permite un procesamiento industrial menos oneroso. El procesamiento de tejidos varía desde tweeds gruesos a gabardinas finas, las cuales no se rompen, deshilachan, manchan o producen estática.

Las fibras de alpaca y vicuña comparten características de suavidad (Xing *et al.*, 2004) y exhiben alta resistencia a la tracción (con valores mayores a 40 N/ktex), una condición importante en el proceso industrial (Xungai *et al.*, 2003). La capacidad de estas fibras de absorber humedad ambiental es baja (máximo 10 a 15%) y por ello no afecta su aspecto. También estas fibras permiten mantener la temperatura corporal debido a contener "bolsillos" microscópicos de aire en la medula que posibilitan que los artículos confeccionados con alpaca puedan ser usados en un amplio rango de climas (Schmid *et al.*, 2006).

Se considera que la calidad de los vellones de alpaca del Perú se ha deteriorado en lugar de haber mejorado, principalmente en lo referente a finura (De Los Ríos, 2006) y peso de vellón. Así por ejemplo los vellones producidos en los sistemas comunitarios de cría tradicional son de bajo peso y mala calidad. En estas condiciones de cría, la producción promedio bianual por animal es de 2,1 kg, mientras que en condiciones medianamente tecnificadas es posible una producción anual de 2,3 kg (Jáuregui y Bonilla, 1991; Nieto y Alejos, 1999). Muchos de los vellones son canosos, pintados y canosos-pintados, y en muchos vellones se encuentra gran heterogeneidad en la estructura, pues muchas fibras que lo conforman son de tipo medulada de forma continua o discontinua, lo cual desmerece la calidad del vellón.

No obstante esta consideración, es también posible encontrar rebaños con buena calidad de fibra. En estudios independientes en la región de Huancavelica, Perú, Quispe *et al.* (2008a) y Montes *et al.* (2008) obtuvieron diámetros de fibra entre $21{,}6 \pm 0{,}1$ μm y $22{,}7 \pm 0{,}2$ μm. En Huancavelica Quispe *et al.* (2008) registraron un peso promedio anual de vellón sucio de $2{,}3 \pm 0{,}04$ kg, mayor al reportado por Jáuregui y Bonilla (1991), Castellaro *et al.* (1998), Wuliji *et al.* (2000), León-Velarde y Guerrero (2001) y Brenes *et al.* (2001); similar a lo encontrado por Condorena (1985), Bryant *et al.* (1989), Nieto y Alejos (1999) y De Los Ríos (2006), aunque los diámetros de fibra resultaron ser menores a los diámetros reportados por Ponzoni *et al.* (1999), Ponzoni (2000), McGregor (2002) y McGregor (2006) en otros países. Estas diferencias pueden deberse a diferencias en el nivel de alimentación (Bryant *et al.*, 1989; McGregor, 2002) ó a otros factores.

El peso de vellón y la finura dependen también del sexo y de la edad del animal. Los machos producen más fibra que las hembras y el peso de vellón aumenta con la edad (Castellaro *et al.*, 1998; Wuliji *et al.*, 2000; McGregor, 2006; Lupton *et al.*, 2006 y Quispe *et al.*, 2008a). El diámetro de las fibras aumenta hasta aproximadamente los 4 años de vida para luego declinar (Wuliji *et al.*, 2000; Lupton *et al.*, 2006; McGregor y Butler, 2004 y Quispe *et al.*, 2008a). Las hembras producen vellones con menor proporción de fibras meduladas y menor diámetro promedio de fibras que los machos (Lupton *et al.*, 2006; Quispe *et al.*, 2008 y Montes *et al.*, 2008). Es posible que estas diferencias en finura se deban a que simplemente las hembras en su ciclo productivo-reproductivo deben enfrentar mayores demandas nutricionales que los machos. Los porcentajes de fibras meduladas encontrados por Quispe *et al.* (2008a) son menores a los reportados en otros estudios (Ponzoni *et al.*, 1999; Wuliji *et al.*, 2000; Marti *et al.*, 2000; Wang *et al.*, 2003 y Wang *et al.*, 2005).

Comercialización y transformación de la fibra de alpaca

A los fines de la comercialización, las fibras de alpaca producidas en el Perú son clasificadas según la Norma Técnica Peruana (2004) Nro 231.301, en función a finura y longitud promedio mínima en seis calidades: i) Alpaca Baby (23 µm y 65 mm), ii) Alpaca Fleece (23,1 a 26,5 µm y 70 mm), iii) Alpaca Medium Fleece (26,6 a 29 µm y 70 mm), iv) Alpaca Huarizo (29,1 a 31,5 µm y 70 mm), v) Alpaca Gruesa (>31,5 µm y 70 mm) y vi) Alpaca corta (fibras cortas entre 20 y 50 mm). Los nombres de estas calidades no reflejan necesariamente edades de los animales u otras características fenotípicas. La calidad Alpaca Baby, por ejemplo, se refiere a productos (tops, hilados, telas, etc.) que tienen en promedio fibras menores a 23 µm; sin embargo la fibra utilizada para lograr esta calidad puede provenir de animales menores a un año ó de animales adultos con fibra extra fina.

De Los Ríos (2006) al clasificar el tipo de fibra producido en el Perú indica que el 20% de la producción deriva de Alpaca Huarizo (fibra gruesa, >29 µm), 46% de Alpaca Medium Fleece (fibra semifina, 26,6 a 29 µm), 22% de Alpaca Fleece (fibra fina, 23,1 a 26,5 µm) y 12% de Alpaca Baby (fibra extra fina, <23,1 µm).

Existen al menos 23 tonalidades de colores de fibra de alpaca clasificadas por la industria textil que van desde el blanco puro a tonalidades cremas, marrones, plata, grises y negra (FAO, 2005; Oria *et al.*, 2009). La fibra blanca de alpaca se produce principalmente con fines comerciales ya que es fácil de teñir. Se estima que aproximadamente 86% de las alpacas del Perú son blancas (Brenes *et al.*, 2001).

Llama

Las observaciones pioneras en evaluar la variabilidad entre poblaciones de llamas para caracteres de producción en la Estación Experimental de Patacamaya (La Paz, Bolivia) en la década de los años 1970, evidenciaron notorias diferencias en tamaño corporal entre poblaciones de animales de zonas alto-andinas diferentes. Estas observaciones fueron posteriormente corroboradas por estudios específicos. En un estudio para evaluar la variación poblacional para la producción de carne, Loayza e Iñiguez (1995) identificaron regiones con condiciones excepcionales para este tipo de producción.

Así como en el caso de las alpacas se han descrito también dos tipos de llamas: Q'aras y T'amphullis (Figura 2), notoriamente diferenciadas las primeras por su menor rendimiento en vellón y menor calidad de fibra (Cardozo, 1954; Iñiguez *et al.*, 1997; Stemmer *et al.*, 2005). Existen dos poblaciones excepcionales de llamas no conectadas con alta frecuencia de animales T'amphullis: la primera población ubicada en el Altiplano sur en Sur Lípez-Potosí, ocupando altitudes entre 3800 y 4200 msnm (Iñiguez *et al.*, 1997) con una proporción de 47% de llamas T'amphullis y la segunda población, en la región cordillerana de la Provincia Ayopaya - Cochabamba, en alturas mayores a 4500 msnm, con una frecuencia aun mayor: 89,7% (Delgado, 2003; Wurzinger *et al.*, 2005; Stemmer *et al.*, 2005). En estas dos poblaciones la frecuencia de animales Q'aras fluctúa entre 8 y10%. En contraste, en la mayoría de las zonas de producción la distribución es totalmente opuesta con una proporción de llamas Q'aras que fluctúa entre 65 y 83% (Iñiguez *et al.*, 1997). Otras investigaciones (Morales, 1997) demostraron que existe más de un solo tipo intermedio entre animales Q'aras y T'amphullis (por ejemplo los tipos Pulla, Saxsalli y T'aju). No se conoce el mecanismo genético de esta variación.

La coloración de las llamas observa una mayor variación que en las alpacas. Varios estudios han tratado de explicar el control genético del color en las llamas (Lauvergne *et al.*, 2006). El conocimiento de este control puede tener una significación futura en relación con la producción de fibra. Estudios recientes están siendo conducidos en relación con la variación genética en animales del tipo Tiutiri (llamas de color blanco con manchas negras en la cabeza, pecho y cola) y su asociación con sistemas

Figura 2. *Llamas de raza T'amphulli en Junín, Perú.*

productivos orientados a producir animales Q'aras para carne (Tito Rodríguez y Volga Iñiguez. Proyecto de Valoración Genética y Productiva de Llamas en Ecotipos con Potencial de Producción de Carne, Universidad Mayor de San Andrés, La Paz, Bolivia, 2009, comunicación personal). Existen contados trabajos que estimaron la variación cuantitativa en relación con caracteres de producción, particularmente enfocados a caracteres de crecimiento (Wurzinger *et al.*, 2005) y de calidad de fibra (Stemmer *et al.*, 2005). La magnitud de las estimaciones de heredabilidad para esos caracteres, 0,36 para peso corporal y 0,33 para diámetro medio de fibras, denota un potencial para lograr progresos a través de la selección.

La existencia de poblaciones como las de Sur Lípez y Ayopaya es una ventaja incuestionable para el posible mejoramiento de la producción de fibra. Se ha evidenciado que los productores de estas zonas consideran la calidad del vellón como criterio de selección de sus reproductores (UNEPCA, 1997; Maria Wurzinger, Universidad de BOKU, Viena, Austria, 2009, comunicación personal). Existen procesos inducidos por el desarrollo que no han considerado la potencialidad de las llamas de Sur Lípez y/o Ayopaya, más allá de promover el descerdado de las fibras. Este desconocimiento ha dado lugar en la zona de Ayopaya a una introducción masiva de alpacas por el simple hecho de que la zona cuenta con inmensos bofedales (semi-pantanales cubiertos con agua y vegetación durante la mayor parte del año) donde pastoreaban llamas con alta calidad genética. En un periodo no mayor a 15 años la explosión poblacional de las alpacas ha sido notable en esa región a expensas de una notoria depresión en la población de llamas, lo cual debe estar conectado con la erosión de un excelente material genético para la producción de fibra (Carlos Coello, productor de llamas, comunidad de Calientes, Ayopaya, Cochabamba, Bolivia, 2009, comunicación personal).

Sistemas de producción de llama

Las llamas se manejan y producen en sistemas de producción pequeños y por productores de escasos recursos económicos y naturales, confrontando la secuela de marginalización de los sistemas de subsistencia. Los sistemas explotan la pradera nativa comunitariamente aunque con cargas animales que sobrepasan su capacidad productiva sin que tal desequilibrio haya sido revertido ni atendido adecuadamente por políticas a nivel nacional, regional y de comunidad. Lo anterior ha conllevado a la progresiva declinación de la productividad y degradación de las praderas (Alzérreca, 1992; Stemmer *et al.*, 2005).

En sistemas donde la producción de llama es un componente central, el pastoreo sigue una rotación estacional, más notoria en zonas de producción extensiva. En muchos de estos sistemas los bofedales, tienen gran significación por producir forraje durante el periodo seco (Lara y Lenis Cazas, 1996). En general los techos de producción anual de materia seca forrajera de las praderas son bajos: 200–600 kg/ha en serranías y planicies y 600–2450 kg/ha en bofedales (Alzérreca, 1988; Alzérreca *et al.*, 2001). Además, estas praderas son frágiles y altamente susceptibles de erosión (Lara y Lenis Cazas, 1996; UNEPCA, 1997).

Existen arreglos comunitarios que en muchos casos determinan aspectos importantes en el manejo de los rebaños. Por ejemplo, en algunos sistemas los machos se incluyen en rebaños separados de las hembras para ser pastoreados por la comunidad en lugares alejados, y luego reunidos durante la época de monta que coincide con las lluvias de enero y marzo (Rodríguez y Quispe, 2007). Independientemente de estos arreglos, los rebaños mixtos incluyen hembras de producción y de reemplazo, y crías y animales de un año sin separación de sexos. Cuando los machos alcanzan entre 12 y 18 meses de edad pueden ser destinados a la producción de carne o seleccionados como futuros reproductores (Wurzinger *et al.*, 2008; Rodríguez y Quispe, 2007). En otros sistemas extensivos los rebaños mixtos incluyen machos reproductores que permanecen con las hembras durante todo el año (Iñiguez *et al.*, 1997; Wurzinger *et al.*, 2008; Rodríguez y Quispe, 2007).

Las prácticas de cría aplican procedimientos ancestrales, excepto en regiones donde se introdujeron nuevas tecnologías para el beneficiado de la esquila y/o la elaboración de carne salada y seca (charque). En este contexto el notable conocimiento local no ha sido suficientemente reconocido e integrado en la investigación (Maria Wurzinger, Universidad de BOKU, Viena, Austria, 2009, comunicación personal; Rodríguez y Quispe, 2007). El conocimiento local también es aplicado a los aspectos de salud animal.

Invariablemente los sistemas de producción de llama integran un rebaño típico de ovinos criollos (UNEPCA, 1997). Este arreglo posiblemente confiere flexibilidad y menor vulnerabilidad al sistema con mayor oferta de proteína animal para la familia. Lo importante es que cualquiera sea la complementariedad o la competencia por forraje entre estas especies, la inclusión de un componente ovino para reducir riesgos productivos ha exacerbado el sobrepastoreo. El tamaño de rebaño promedio varía con las zonas de producción fluctuando entre 40–60 llamas en zonas con mayor concentración de personas en las comunidades, p.e. en Ayopaya (Delgado, 2003), hasta 120–180 llamas en zonas con menor concentración y más extensivas, p.e en Sur Lípez o en el altiplano central occidental (Iñiguez *et al.*, 1997; Huaygua y Rodríguez, 2001). En contraste, el tamaño del rebaño ovino es muy similar en todas las zonas fluctuando entre 40–70 animales (UNEPCA, 1997; Stemmer *et al.*, 2005).

La infraestructura productiva es precaria, contándose sólo con corrales rudimentarios de piedra u otro material local, vecinos a la vivienda de los productores o en lugares específicos donde los animales pernoctan protegidos de predadores y del frio (Iñiguez *et al.*, 1997; Wurzinger *et al.*, 2008).

Los sistemas productivos no tienen una naturaleza comercial pero progresivamente parecen orientarse hacia las demandas del mercado. Por ejemplo en la región de Ayopaya en las alturas de la ciudad de Cochabamba, un centro con alta demanda de charque, los productores intensificaron sus sistemas productivos, transportando machos jóvenes a zonas más bajas del valle (2500 msnm), hacia terrenos propios o fruto de una transacción, donde serán engordados con mejores pastos y residuos de cosecha, para finalmente ser sacrificados y su carne procesada en charque (con un atractivo valor de venta) (Carlos Coello, productor de llamas, Comunidad Calientes, Ayopaya, Cochabamba, 2009, comunicación personal). Tal estrategia permite penetrar el nicho de mercado mencionado con un valor añadido. Aparentemente esta carne está valorizada porque el mercado empieza a pagar una diferenciación. Es posible que con una integración vinculante de zonas de cría con zonas con mayor acceso a fuentes de forrajes y subproductos, se pueda captar la demanda de esta producción valorada con mayor eficiencia y beneficio para el productor.

Las acciones actuales de investigación y de asistencia técnica prácticamente son inexistentes desde que fueron discontinuadas en el pasado. Esta condición de mínima oferta tecnológica sumada a la productividad disminuida de las praderas determina bajos índices reproductivos, por ejemplo una fertilidad estimada entre 45–55% (Rodríguez y Cardozo, 1989; Stemmer *et al.*, 2005) y un intervalo entre partos no menor a dos años (Nürnberg, 2005). Igualmente, la mortalidad de crías puede ser muy elevada y alcanzar niveles entre 30-50% en años con sequías y fríos severos (Nürnberg, 2005; Stemmer *et al.*, 2005).

Comparativamente con otras zonas del país, la acción del desarrollo en la producción de camélidos también ha sido pobre. No obstante de ello, los contados proyectos de desarrollo impulsaron la acción asociativa de productores y promovieron un notable cambio en la comercialización de la carne de llama. Estos proyectos también influenciaron en la comercialización de la fibra de llama, en particular en Sur Lípez, la cual, hasta principios de la década de 1980, no era comercializada masivamente. Es posible entonces concluir que los sistemas de producción han tenido un tipo de integración al mercado pero aun permanecen subvalorados además de deprimidos y desasistidos.

Las llamas bolivianas también tienen influencia sobre las poblaciones de llamas del noroeste argentino, a pesar de las restricciones sanitarias al comercio internacional entre ambos países. En particular las llamas de Sur Lipez son apreciadas por la calidad de su fibra fina.

Características de la fibra de llama

Aunque el color de fibra preferido por la industria textil es el blanco, los vellones y fibras de llama son de diferentes colores (25% blancos, 48% de colores enteros y 27% de colores mezclados). Un problema mayor de la fibra de llama deriva de su elevada medulación (proporción de cerda) (PRORECA, 2003).

La llama produce diferentes tipos de fibras. Los estudios sobre diferenciación se remontan al clásico trabajo de Tellería (1973) quién evidenció contrastes en calidad de fibras en animales contemporáneos de diferentes zonas del Altiplano Central, particularmente involucrando animales Q'aras. Martinez *et al.* (1997) describieron por primera vez las fracciones de fibras sin medulación (20,2%), con medulación fragmentada (36,7%), medulación continua (39,4%) y kemp (3,7%), y evaluaron sus diámetros, siendo la fibra fina no medulada (25,5 µm) y la fibra gruesa (40,7 µm). Si el vellón de llama es clasificado (en función a diferentes partes del cuerpo) y descerdado (remoción de los pelos gruesos), se obtiene una buena proporción de fibras finas.

En Argentina se suelen clasificar los vellones de llamas con marcada diferencia en porcentajes de fibras meduladas en vellones de estructura simple con una sola "capa" de fibras homogéneas, ó vellones de dos "capas": una de fibras finas y cortas y otra de fibras largas meduladas y gruesas. En Argentina la población de llamas de una capa es del 47%, mucho mayor al de Bolivia. Ese tipo de vellones son preferidos porque evitan la necesidad de separar la fibra fina de la gruesa, un procedimiento tedioso o costoso.

La producción promedio de llamas Q'aras es de 1,1 kg por animal/año en condiciones experimentales y posiblemente no mayor a 800 g por animal en condiciones de rebaños de productores (Rodríguez. y Cardozo, 1989; Martinez *et al.*, 1997). El vellón de estos animales contiene una elevada proporción de fibras meduladas, 79,8%, incluyendo medulación fragmentada, medulación continua y kemp, y un porcentaje de medulación de 43% (incluyendo medula continua y kemp) que determina mayor diámetro promedio de fibra (31,6 µm) (Martinez *et al.*, 1997). Comparativamente las llamas T'amphullis producen un vellón de mayor peso (1,5–1,8 kg/animal/año) (PRORECA, 2003; Stemmer *et al.*, 2005), con menor medulación: 38.9% en el caso de Sur Lípez y 22,4% en el caso de Ayopaya, y menor diámetro promedio de fibras: 21,2 µm, en el caso de Sur Lípez y 22,2 µm en el caso de Ayopaya. Aun no se han establecido planes sostenibles de selección genética en esa dirección que permitiría en el mediano plazo producir animales con fibras con mínima medulación y mayor valor.

Poblaciones de llamas de Cieneguillas (Jujuy, Argentina) se destacan por su tamaño y fibra fina. En general la fibra de llama argentina es fina. El 48% con diámetro menor a 21 μm y solo el 16% con fibra mayor a 25 μm (Frank *et al.*, 2006). En la provincia argentina de Catamarca a su vez se sospecha la influencia de alpacas procedentes de Chile, los vellones también son bastante finos (17–36 μm) y se observa una alta proporción de animales de colores marrón (Francisco Rigalt, 2009, comunicación personal).

Comercialización y transformación de la fibra de llama

En Tabla 3 se observa que la producción de fibra de llama en Perú se estima en 760 ton, en Bolivia en 433 ton y en Argentina en 70 ton anuales. Estas cantidades no suelen llegar al mercado ya que una proporción importante se destina al autoconsumo y transformación. Por ejemplo en Bolivia se estima que un 70% de la fibra de llama producida se destina al mercado y 30% al autoconsumo. En Argentina se estima que sólo un tercio de la fibra de llama es comercializada en bruto y el resto transformada o utilizada por el propio productor.

En muchos casos los productores no esquilan sus animales anualmente porque consideran que el largo de fibra es insuficiente o porque no hay una comercialización organizada. Por tanto, es común ver animales con vellones de dos años o mayores. Los trabajos de Rodríguez (1977) señalan que la producción anual de fibra alcanza el largo suficiente como para ser integrada en el proceso comercial.

En general la esquila suele ser manual con tijeras especiales aunque todavía existen lugares donde se usan elementos más primitivos para esquilar, y también existen esquilas mecánicas. La fibra obtenida se comercializa en las ferias comunales y regionales donde suele ser comprada por acopiadores especializados. La fibra ofertada contiene impurezas y mezcla de colores, razón por la cual los acopiadores deben realizar trabajos de purificación y clasificado por color antes de ofertar su producto a la industria textil (PRORECA, 2003).

Tanto en Bolivia como en Argentina algunos productores y comunidades realizan el trabajo de purificación y clasificado para apropiarse del valor agregado. En particular hacen el descerdado (separación de las fibras gruesas o cerdas) de las fibras. Sin embargo si no se hacen los esfuerzos concomitantes, confiriéndole a la fibra ofertada una identidad propia en su comercialización ese valor no suele ser reconocido.

En centros de reclasificado y enfardado de fibra de acopios en el norte argentino se separan 9 colores (o mezcla de colores) y 4 rangos de finura (superfino <21 μm, fina 21-25,9 μm, gruesa 26-34,9 μm y "bordel" 35 μm o más). El pago de premios por fibra clasificada y más fina es incipiente (Hugo Lamas, 2009, comunicación personal).

En la actualidad existen plantas descerdadoras de fibra de llama que pueden procesar fibra de animales Q'aras en tanto tengan la longitud deseada y particularmente la fibra de animales de la zona de Sur Lípez-Potosí. La industria textil exporta fibra descerdada o transforma la fibra en prendas u otros artículos (PRORECA, 2003).

Guanaco

Del total de guanacos consignado en Tabla 1, el 80% se encuentra en la Patagonia argentina y chilena. En el pasado los indígenas de la Patagonia cazaban guanacos para alimentarse, usaban su cuero para vestimenta y construcción de viviendas y aprovechaban su fibra para tejidos y decoraciones. Con la llegada de los colonizadores y la introducción masiva de ovinos el hábitat del guanaco se modificó, aumentó la competencia por el forraje (un guanaco consume el equivalente a 1,5 ovinos) y aumentó la caza indiscriminada. Así en los años 1970 las exportaciones anuales de pieles de guanaco en la Argentina llegaron a 63.000 piezas. Como consecuencia se redujo fuertemente la población de guanacos a lo que en 1992 la Convención para el Comercio Internacional de Especies Amenazadas de la Flora y Fauna Silvestre (CITES) lo incluye en su Apéndice II, el cual recomienda suspender la comercialización internacional de productos de guanacos de la Argentina y de esa manera promovió el desarrollo de tecnologías y normas para un manejo racional y controlado de la especie (Cancino, 2008).

Sistemas de aprovechamiento de guanacos

Actualmente las actividades de exportación y tránsito de productos y subproductos del guanaco están restringidas a fibras obtenidas de animales vivos siguiendo reglas estrictas y monitoreo durante la captura y esquila. La caza está prohibida salvo extracciones controladas en casos excepcionales. La captura de guanacos para su esquila es difícil ya que los animales saltan los alambrados habituales para ovinos, pueden resultar peligrosos cuando son arrinconados y escapan a gran velocidad. Técnicas especiales se han desarrollado para su captura, esquila y liberación para evitar temor y lesiones innecesarias. Se identifican tres sistemas de aprovechamiento de guanacos (Amaya y von Thüngen, 2001): extracción controlada, cría en semi-cautividad y cría en cautividad.

La extracción controlada se basa en la caza de una proporción de animales de una población específica. La determinación de la cuota de extracción requiere conocer la dinámica poblacional y por ello se ve limitada a poblaciones estudiadas para tal efecto. A través de la extracción controlada sería posible obtener volúmenes importantes de fibra, pero la información censal y biológica necesaria para su implementación es costosa. Además esta opción es poco atractiva para el consumidor moderno de productos de la fauna, quien se resiste a utilizar fibras de animales cazados. Las experiencias documentadas de producción de fibra por extracción son muy escasas.

Figura 3. *Guanacos en semicautiverio, Patagonia, Argentina.*

La cría en semi-cautividad se basa en el arreo, captura, esquila y suelta de guanacos mantenidos en condiciones semi-controladas (Figura 3). Esta opción implica la construcción de mangas o embudos permanentes o temporarios en los cuales controlar los guanacos. Se han desarrollado técnicas apropiadas a situaciones específicas con éxitos variados en cuanto a la proporción de animales capturados del total de la población controlada (De Lamo, 1995). Esta opción es la más atractiva habiendo promovido en la Patagonia varios emprendimientos comerciales (Chechile, 2006, Arreche y Abad, 2006).

La cría en cautividad exige el confinamiento de los animales a un territorio determinado y por ende una fuerte inversión inicial en infraestructura. Existen experiencias con este sistema de cría en Argentina (Sarasqueta, 2001) y Chile (Bas y González, 2000). Los criaderos suelen requerir mucha atención veterinaria y monitoreo nutricional, además de un delicado manejo reproductivo por lo que su rentabilidad dependerá de la eficiencia productiva de la población cautiva y de los costos en cada caso en particular.

Características de la fibra de guanaco

En un sistema de semi-cautividad, raramente se logra capturar al mismo grupo de guanacos de un año a otro por lo que se esquilarán animales con diferentes periodos de crecimiento de fibra. En general se evita esquilar al mismo animal todos los años para así asegurar un largo de mecha de al menos 30 mm, valor requerido para su peinado industrial aunque la producción total con dos esquilas es mayor (Cancino *et al.*, 2008). Los pesos de vellón en animales adultos alcanzan 300–700 g. Los vellones son esquilados con tijera ó máquina de esquilar y contienen dos tipos de fibras: las valiosas, finas y cortas (*down*) y las gruesas y largas (cerda). La proporción de fibras finas suele ser de 35 a 50%. Algunos productores separan manualmente parte de las fibras gruesas antes de ofrecer el vellón para venta. En ese caso el rendimiento de fibras finas asciende a 65–95% según el trabajo de separación realizado (Sacchero *et al.*, 2006).

Aunque la fibra de guanacos no tiene la finura de la fibra de vicuña, en otros aspectos es bastante similar, incluyendo las variaciones de color marrón y la presencia de fibras muertas y cerda junto a las fibras valiosas. El promedio de diámetros de fibra varía entre animales y entre grupos etarios. La eliminación de la cerda en adultos reduce el diámetro de las fibras remanentes en 1–2 µm. A su vez animales jóvenes suelen tener fibras con diámetros hasta 3 µm menos que animales adultos (Cancino, 2008). El coeficiente de variación (CV) de diámetros entre animales es de aproximadamente 10%, similar a lo observado en ovinos laneros. En un muestreo de 6 poblaciones de guanacos en el norte de la Patagonia se obtuvo un rango de promedios de diámetros de fibra de 14,5 a 17,8 µm. En otro relevamiento de tres poblaciones se observaron diámetros de $14{,}6 \pm 0{,}7$ a $16{,}5 \pm 1{,}7$ µm y largos de mecha entre $14{,}4 \pm 3{,}3$ a $38{,}1 \pm 9{,}1$ mm (von Thüngen *et al.*, 2005). Se observa que la fibra de guanaco patagónico tiene buena finura pero el largo de mecha está en el límite de lo aceptable.

Vicuña

La inclusión de la vicuña en el Apéndice I de CITES en 1973 implicó la prohibición del comercio internacional de sus productos y subproductos, y promovió el desarrollo de políticas y normas de protección de la especie, tal que luego de un período de casi extinción la población de vicuñas se recuperó sustancialmente en todos los países andinos. En la Tabla 1 observamos que Perú y Argentina tienen ahora las mayores poblaciones.

La vicuña es la especie más pequeña de los camélidos sudamericanos. Exhibe un cuerpo grácil, alcanzando un peso entre 35 y 50 kg y una alzada de hasta 1 m. Es de color canela en el dorso y blanco en la parte ventral, que la confunde con el pajonal donde vive, y tiene un cuello largo, que le permite detectar a sus enemigos a la distancia. Sus orejas son similares a las de la alpaca. Vive en la puna encima de los 3000 msnm, concentrándose desde los 9°30′S en Ancash, Perú hasta los 29°S en la III Región de Atacama, Chile, y el norte de la provincia de San Juan, Argentina (CNVG, 2007). En Chile y Argentina también se encuentran en altitudes menores.

La vicuña tiene adaptaciones fisiológicas a esos ambientes fríos y altos. Por ejemplo para la protección contra el frío tiene una fibra tupida y muy fina, con alta capacidad de retención de la temperatura; en el pecho posee un mechón de pelos largos que le sirve para cubrir las patas delanteras al dormir echada en el suelo. Las vicuñas concentran las pariciones en los días soleados y durante las primeras horas de la mañana (en 80%), lo que favorece el secado de las crías, que nacen durante la época de lluvias – entre febrero y marzo, con una mayor incidencia en horas de la tarde – pues como ocurre con los otros camélidos, la vicuña no puede lamer sus crías y éstas deben secarse al aire). Por otro lado, y para contrarrestar los efectos de la baja presión parcial de oxigeno debida a la altitud, su sangre posee una alta concentración de glóbulos rojos, cerca de 14 millones/mm^3, permitiendo una mayor superficie de captación y transporte de oxígeno.

Existen dos subespecies de vicuña: *Vicugna vicugna mensalis* y *Vicugna vicugna vicugna*. La primera es de un color más oscuro, tiene un pronunciado mechón de pelos largos y blancos en el pecho, es algo más grande y se encuentra hacia el norte del paralelo 20°S (Wheeler *et al.*, 1995; Brenes *et al.*, 2001). La segunda es de pelaje más claro, no presenta el mechón de pelos de pecho, es más pequeña y se distribuye hacia el sur de ese paralelo.

Sistemas de aprovechamiento de vicuñas

Con la recuperación de las poblaciones de vicuña y con políticas de control y conservación adecuadas CITES reubicó algunas poblaciones de vicuñas en el Apéndice II. Poblaciones con ese status pueden ser aprovechadas comercialmente cuando cumplen con sistemas de aprovechamiento aprobados. En todo caso la fibra debe ser obtenida de animales vivos. Existen básicamente tres sistemas de aprovechamiento de vicuñas:

- Crianza en cautiverio, implementado bajo las normas propuestas por el Instituto Nacional de Tecnología Agropecuaria (INTA) de Argentina, por las cuales grupos de 10–20 vicuñas son provistos a productores individuales por el criadero de INTA (criadero de más de 1500 vicuñas) y confinados a espacios alambrados de su ambiente habitual y sujetos a un manejo mínimo. En este caso los animales quedan a cargo del productor y la fibra es propiedad del productor (Amendolara, 2002). Los criaderos particulares poseen un total de 600 vicuñas (Mónica Duba, 2008, comunicación personal).
- Aprovechamiento en silvestría, implementada en Perú, Bolivia y Argentina, basado en Bolivia en el Reglamento Nacional para la Conservación y Manejo de la Vicuña, que otorga a las comunidades campesinas el derecho exclusivo a la custodia, aprovechamiento y beneficios de las vicuñas ubicadas en sus áreas de jurisdicción comunal, manteniendo el Estado el derecho al almacenamiento y venta de la fibra. En Argentina se realizan encierres periódicos de diferentes poblaciones de vicuñas con dos variantes de captura: mediante módulo fijo y módulo móvil. En el modulo fijo al menos parte de las instalaciones de embudo y manga son fijas en cambio en el modulo móvil se instalan en forma temporaria y función de la población de vicuña a capturar.
- Crianza en semi-cautiverio, o sistemas de cercos cuyos principales promotores son Perú y Chile, y que consiste en el mantenimiento de las vicuñas en grandes ambientes de pasturas de más de 500 ha limitadas con cercos de alambre y/o piedras. Este tipo de crianza tiene muchas ventajas: seguridad de su mantenimiento frente a depredadores y cazadores, fácil monitoreo, fácil captura, y mejor aprovechamiento de la fibra. La captura se realiza mediante una práctica utilizada desde la época del imperio incaico conocida como *chaku*. El *chaku* consiste en el arreo y captura de las vicuñas utilizando un cerco de humanos y/o vehículos que va cerrándose paulatinamente en un gran "embudo", donde los animales quedan atrapados (Figura 4). Esta práctica puede no resultar eficiente y puede ser estresante para los animales, sin embargo es práctica y revalora acciones comunitarias ancestrales. Los factores estresantes para la vicuña (p.e. captura, manipulación, insensibilizado, inmovilización, temperaturas extremas, ruidos, olores nuevos y esquila) pueden incrementar los riesgos de muerte por shock tales como miopatía de captura e inmunosupresión o pueden afectar la salud de los animales.

Figura 4. *Captura de vicuñas "chaku" en Huancavelica, Perú.*

Los gobiernos de Perú y Chile han implementado la estrategia de ceder vicuñas, en modalidad "de uso", a las comunidades campesinas, que se encargan de su cuidado y del aprovechamiento de su fibra. En Perú desde 1992, las comunidades inicialmente tuvieron derecho sólo al uso y posteriormente tuvieron derechos sobre la propiedad. En 1995 el Gobierno promulgó la Ley 26.496 mediante la cual se otorgó el uso (usufructo) de la vicuña a las comunidades campesinas en cuyas tierras se encontraban estos animales, responsabilizándolas también de su manejo y conservación. En diciembre 2006, Perú informó en la XV Reunión Ordinaria de la Comisión Técnico-Administradora del Convenio la Vicuña realizada en San Salvador de Jujuy, Argentina, la existencia de 28.000 ejemplares en 250 cerramientos.

El crecimiento de la fibra no es rápido, es por eso que durante el Incario los *chakus* se realizaban a intervalos trianuales. En la actualidad en muchos lugares la captura y esquila se realizan cada año, lo cual tiene como objetivo una mejor vigilancia, esquilándose sólo aquellos animales con fibras de al menos 2 cm de largo, obteniéndose tasas de esquila que van disminuyendo año a año, por ejemplo desde 65% en 1995 a 40% en 2006. Estos datos permiten recomendar que los *chakus* deberían realizarse cada dos años, pudiendo obtenerse producciones de hasta 250 g/animal. Considerando que las vicuñas viven en promedio ocho años en su hábitat natural, entonces la producción de fibra en su vida es de aproximadamente 1 kg. En Catamarca, Argentina, datos del control oficial de la Secretaría de Ambiente indican que sobre 207 vicuñas capturadas en Laguna Colorada (3740 msnm) en el año 2005, el peso de vellón promedio resultó 461 g, y que a solo 32 km de distancia en Laguna Blanca (3223 msnm) 339 vicuñas dieron un promedio de 262 g (Rigalt *et al.*, 2006).

Características de la fibra de vicuña

La subespecie mejor estudiada es la *Vicugna vicugna mensalis*, la cual tiene una longitud media de mecha a nivel del manto de 32,8 mm en animales adultos con un rango entre 29,2 a 41,7 mm y alcanza largos de mecha a nivel del pecho de 18 a 20 cm. El diámetro medio de la fibra exceptuando las zonas del cuello y extremidades es uniforme, variando entre 11,9 µm a 14,7 µm con una media de 12,5 ± 1,5 µm (Solari, 1981), no existiendo diferencias significativas entre sexos y edades (Hoffman *et al.*, 1983). La densidad folicular promedio es de 78,7 folículos por mm^2, con una frecuencia de pelos de 2%. La resistencia a la tracción varía entre 40 y 64 N/ktex, por lo cual la fibra es considerada como "muy resistente", observándose que fibras de vicuñas que pastorean sobre pasto de buena calidad tienen mayor resistencia frente aquellas que pastorean pastos de mala calidad.

Para la subespecie *Vicugna vicugna vicugna* existe un extenso trabajo de caracterización de la producción de fibras en condiciones del criadero de INTA, Argentina realizado por Rebuffi (1999). En machos de criadero se observó un rango de diámetros de 11,9 a 22,0 µm con un promedio de 13,6 µm (desvío estándar, DS 4,0). En muestras de la misma población Sacchero y Mueller (2005) obtuvieron promedios de diámetro de fibras de 13,8 µm (DS 3,0) para muestras descerdadas y 14,1 µm (DS 4,5) en muestras no descerdadas. Para vicuñas adultas de ambos sexos capturadas en Laguna Blanca, Catamarca, Argentina, Rigalt *et al.* (2008) obtuvieron en 61 muestras un promedio de diámetro de fibras de 12,6 µm (DS 4,4) y un largo de mecha en laboratorio de 37,7 mm y de 31,0 mm medido con regla a campo.

Comercialización y transformación de la fibra de guanaco y vicuña

Las fibras finas *down* de la vicuña son extremadamente valiosas y especiales no sólo por sus características textiles sino también por su escasez y por su asociación con ambientes y culturas exóticas. El hilo y las prendas hechas de fibra de guanaco y vicuña tienen un alto precio de mercado pero requieren materia prima con adecuado largo de mecha y requiere la separación de la cerda y pelos muertos de las fibras *down* valiosas. En Argentina se han utilizado descerdadoras mecánicas para purificar la fibra de guanaco, en vicuña el descerdado se realiza a mano.

Se ha mencionado que las fibras de los camélidos silvestres se obtienen y comercializan bajo estrictas normas de producción y fiscalización a los fines de evitar la caza furtiva y asegurar la conservación de las especies. El problema que se presenta, es que la fibra de vicuña ilegal (de animales muertos o cazados) se obtiene a precios muy inferiores a la fibra legal, en una relación de 1:5. A pesar de los esfuerzos para controlar ese comercio la caza continua en algunos lugares debido a la presión de la demanda por fibra. Sólo en la provincia de Catamarca, Argentina, existen unas 500 artesanas que demandan aproximadamente 500 kg de esta fibra para su subsistencia en la confección de hilados y prendas artesanales. Se estima que la producción legal de fibra de vicuña en Argentina durante 2008 fue de 377 kg, gran parte destinada a la exportación sin agregado de valor.

Otras dificultades en la comercialización de la fibra de vicuña como así también de guanaco se vinculan con la falta de una oferta en cantidad previsible y con las grandes fluctuaciones en el precio obtenido. Ambas son dificultades habituales para los productores de fibras especiales. Con cantidades pequeñas de fibra disponible y demanda volátil, relacionada con modas y tendencias, es difícil planificar una producción sostenible que garantice un ingreso al productor o a la comunidad. De todos modos hay un potencial que puede ser aprovechado esporádicamente.

El futuro de la producción de fibras de camélidos sudamericanos

Los camélidos sudamericanos son un recurso genético nativo de alto valor socioeconómico en la zona alto-andina. Sin embargo la condición actual de los sistemas productivos asociados con esta especie no permite se los identifique como elementos motores para una mejora substantiva de los medios de vida de sus productores, ni la reactivación económica de las zonas deprimidas donde estos animales son producidos. Para modificar esta situación se requiere una enorme tarea que seguramente requerirá de un marco en el que interactúen la investigación, la extensión y el desarrollo, además de políticas innovadoras que garanticen la integración de las cadenas productivas con el mercado, sin que se ignore o excluya a cualquiera de estos componentes como ha ocurrido en el pasado. Los grandes desafíos estarán en el área del fortalecimiento institucional de las comunidades hacia un manejo sostenible de los recursos naturales, valoración de la producción y manejo innovador de las potencialidades de los criadores y la versatilidad y variabilidad genética que ofrecen los camélidos sudamericanos. En este contexto la cooperación regional de países productores puede conferir mayor coherencia y acelerar los procesos de transformación necesarios. El aumento de la producción de fibras y demás productos de los camélidos sudamericanos, a la vez de preservar un recurso genético animal crítico y los valores culturales asociados y mejorar la calidad de vida de muchos pequeños productores, debe ser parte de una estrategia global de inversión sostenida en investigación y desarrollo apropiados.

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Cashmere-producing goats in Central Asia and Afghanistan

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Summary

Indigenous goats of Central Asia and Afghanistan produce cashmere, the warm undercoat grown annually to protect them from cold winters. Cashmere is appreciated in luxury markets, but there are no efforts to conserve these goats. Commercial assessments of their fibre quality have recently been undertaken. Poorer villagers in the most climatically difficult remote desert and high altitude regions are particularly dependent on raising goats. Villagers in Kazakhstan, Kyrgyzstan and Tajikistan started selling raw cashmere mainly to Chinese traders in the 1990s. Afghan producers have been selling cashmere for a longer time. In comparison with China and Mongolia, Central Asian and Afghan producers sell their cashmere unsorted and at relatively low prices. Traders do not offer producers differentiated prices according to quality, but world commercial prices are highly sensitive to quality. Producers thus lose potential value. Summaries are given of tests on the quality of cashmere from samples of 1 592 goats in 67 districts and 221 villages from 2003 to 2008. There are cashmere goats in these sampled districts which produce the finest qualities of cashmere typical of Chinese and Mongolian cashmere. There is impetus to increase the production, commercial value and income for producers from cashmere produced by Central Asian goats.

Keywords: *Afghanistan, cashmere, goats, Kazakhstan, Kyrgyzstan, Tajikistan*

Résumé

Les chèvres indigènes de l'Asie centrale et de l'Afghanistan produisent du cachemire, le sous poil chaud qui pousse chaque année pour les protéger du froid de l'hiver. Le cachemire est apprécié dans les marchés de luxe, mais aucun effort n'est consacré pour la conservation des chèvres. On a entrepris récemment des évaluations sur la qualité de leur fibre d'un point de vue commercial. Les villageois plus démunis qui résident dans les régions reculées du désert et des montagnes les plus difficiles du point de vue climatique dépendent de façon particulière de l'élevage des chèvres. Dans les années 90, les habitants des villages du Kazakhstan, du Kirghizistan et du Tadjikistan ont commencé à vendre du cachemire brut surtout aux commerçants chinois tandis que les producteurs afghans vendent du cachemire depuis plus longtemps. Par rapport à la Chine et à la Mongolie, les producteurs de l'Asie centrale et de l'Afghanistan vendent le cachemire en vrac et à des prix relativement faibles. Les commerçants ne proposent pas aux producteurs des prix différenciés selon la qualité. Les prix commerciaux dans le monde sont très sensibles à la qualité. Les producteurs perdent ainsi de la valeur potentielle. On présente ici un résumé des essais effectués, entre 2003 et 2008, sur la qualité du cachemire à partir des échantillons de 1 592 chèvres dans 67 districts et dans 221 villages. Dans les districts pris en examen, il y a des chèvres qui produisent les qualités les plus raffinées du cachemire typique chinois et mongol. Il existe des possibilités d'augmentation de la production, de la valeur commerciale et des revenus pour les producteurs du cachemire des chèvres de l'Asie centrale.

Mots-clés: *Afghanistan, cachemire, chèvres, Kazakhstan, Kirghizistan, Tadjikistan*

Resumen

La cabra indígena de Asia Central y Afganistán produce cachemir, el cálido manto de base que produce cada año para protegerse de los fríos inviernos. El cachemir es muy apreciado en los mercados de lujo. No se está haciendo ningún esfuerzo para conservar estas cabras. Recientemente se han llevado a cabo valoraciones acerca de la calidad de sus fibras desde una perspectiva comercial. Los aldeanos más pobres, que residen en zonas de gran altitud y en el desierto remoto, donde existen las más duras condiciones climáticas, dependen especialmente de la cría de cabras. Los aldeanos de Kazajstán, Kirguizistán y Tayikistán empezaron a vender cachemir en su estado puro principalmente a comerciantes chinos en la década de los 90. Los productores afganos han estado vendiendo cachemir durante más tiempo. En comparación con China y Mongolia, los productores afganos y centroasiáticos venden su cachemir sin clasificar y a precios relativamente bajos. Los comerciantes no ofrecen a los productores precios diferenciados según la calidad. Los precios comerciales a nivel mundial son altamente sensibles a la calidad. Por lo tanto, los productores pierden un valor potencial. Se facilitan resúmenes de las pruebas realizadas para determinar la calidad del cachemir a partir de muestras obtenidas de 1592 cabras en 67 zonas y 221 aldeas entre 2003-2008. Existen cabras de Cachemir en dichas zonas que producen esta fibra de la más alta calidad, típico del cachemire chino y mongol. Queda margen para aumentar la producción, el valor comercial, y los ingresos para los productores, gracias al cachemir producido por las cabras centroasiáticas.

Palabras clave: *Afganistán, cachemira, cabras, Kazajstán, Kirguistán, Tayikistán*

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Introduction

There has been a global trend for goat populations to increase relative to large ruminants and sheep. Over the last two decades, goats have become relatively more prevalent in the low-income countries of the less developed world. Goat populations increased by 70% from 1980 to 2000, compared to 31% for sheep and 35% for cattle (Boyazoglu *et al.*, 2005).

Cashmere is the seasonally grown and shed undercoat of the goat (*Capra hircus*), that is produced by domestic (as well as wild) goats in cold winter climates. It is a fine warm fibre underneath the rough outer protective (guard) hair of the goat. Cashmere-producing goats are not a special breed, although the quality and amount of cashmere can be increased through breeding. The inner and central Asia regions are considered to be the origin of the world's domesticated cashmere-producing goats (Millar, 1986).

World annual production of greasy (raw and unprocessed) cashmere is estimated at 15 000 to 20 000 tonnes, that is equal to 6 500 tonnes after scouring and dehairing (Food and Agriculture Organization [FAO], 2009). China produces approximately 60–70% of the world's cashmere, followed by Mongolia with around 20%. Most of China's domestically produced and imported raw cashmere is shipped after intermediate processing to fabric and garment makers in Italy, Japan, Korea and the United Kingdom (Schneider Group, 2008). The Chinese and Mongolian textile industry has also increasingly produced cashmere garments for export (Lecraw, 2005).

Raw cashmere fibre comprises a mixture of an undercoat of fine cashmere fibres down and coarse outer guard hair. For the international cashmere industry, quality is primarily determined by the diameter, length and colour of the cashmere fibres (Schneider Group, 2008). Fibre diameter is measured in micrometres microns (μm). World cashmeres are judged against the industry standard of Chinese white, that accounts for about half of all cashmere produced in the world. The Chinese National Standard has set the upper limit for the mean fibre diameter (MFD) of cashmere at 16.0 μm (+0.5); the trade organisations of the United States, Europe and Japan have set higher diameter thresholds of up to 19 μm (Cashmere and Camel Hair Manufacturers Institute, 2009; Phan and Wortmann, 2000) although some processed cashmere tops have a fibre diameter of 19 to 20 μm (McGregor and Postle, 2004). In addition to fibre diameter, cashmere buyers also have tight specifications for quality based on the diameter distribution of fibres in the fleece, degree of crimp, colour and lustre. Most cashmere processors, for example, spinners, weavers and knitters, buy fibre with an upper mean diameter of 18.5 μm. For high-quality goods there is a preference for finer fibres such as cashmere with a mean of less than 16.5 μm and particularly those fibres with a mean of less than 15.5 μm.

In 2008 and 2009, prices for raw cashmere across the world were lower than in the 10 previous years (Schneider Group, 2008). This was due to several factors. The slowdown in some major economies, for example, the United States, Europe and the Far East, led to a reduced demand among consumers for luxury products such as cashmere garments. Therefore, Chinese and European factories had fewer orders for raw cashmere. Chinese banks limited their credit supplies to businesses, that had previously been on generous terms, resulting in a credit squeeze for Chinese companies purchasing raw cashmere from sources such as Central Asia.

Cashmere goats in Afghanistan

In spite of the years of war, Afghanistan is still among the major producers of raw cashmere and is third in the world after China and Mongolia. Eighty percent of goats kept in Afghanistan are estimated to be the native *watani* (local) breed, that is a cashmere-producing goat (Thieme, 1996). The Kabuli, Kandahari and Tajiki *watani* breeds are small sized black goats which represent more than 75% of the Afghan goat population (Ulfat-un-Nabi and Iqbal, 1999).

It has been estimated that the total export of Afghan cashmere, including fleeces, is well above 1 000 tonnes/year (Altai Consulting, 2005). According to an FAO Agricultural Census (2003), Afghanistan had around 7.6 million goats in 2004, but this census did not include the livestock of most nomadic Afghan pastoralists (De Weijer, 2007). According to long-term FAO data (Figure 1), the number of goats has been rising continuously since the late 1980s, with dips associated with drought, and increased by 2.5 times by 2004 and then dropped to 5.4 million by 2007 (FAOStats, 2009).

The rise in the numbers of goats relative to the other main livestock species could be due to several factors. Native goats have a better rate of survival during droughts or other forms of climatic stress; for example, this has been noted in Mongolia. In the drought-prone arid and semi-arid regions of the less developed world, pastoralists are now keeping more goats as a proportion of large ruminants (Peacock, 2005). Another reason may be that as rural Afghans endured increasing unsettled economic conditions in the past decades, they turned more to goats to alleviate poverty; goats reproduce faster than the other ruminant species, and their meat is readily marketable. Furthermore, goats are often the species of choice for families with labour constraints. Goats have a lower human labour requirement for herding because of their more diverse dietary selection and the efficiency of their digestion. This means that small children can be entrusted to oversee goats in pastures that are often nearer to home.

Most cashmere in Afghanistan is reportedly collected in the northwest provinces and exported through Herat (Altai Consulting, 2005; Kerven and Redden, 2006; De Weijer, 2007). However, the results of tests carried out

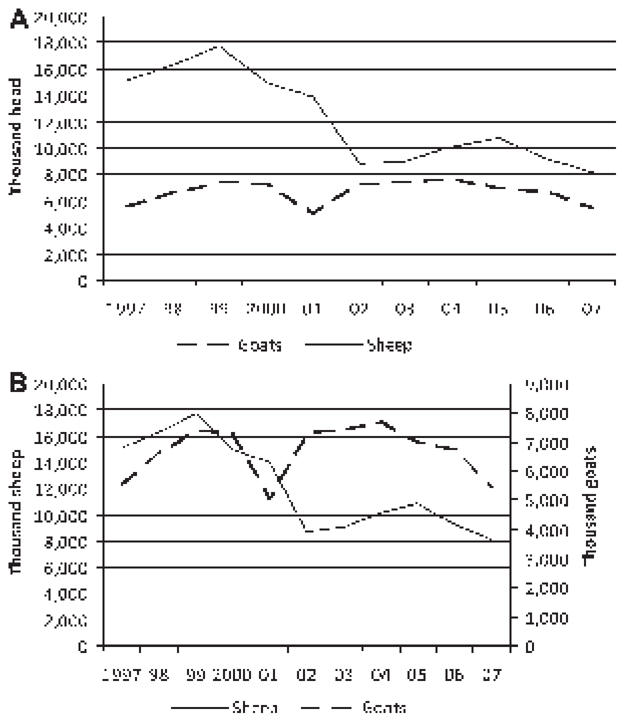

Figure 1. Goat and sheep populations in Afghanistan, 1997–2007. Part A sheep and goats on one axis and part B sheep and goats on two axes. *Source*: FAOStats (2009).

(Kerven and Redden, 2006) from other provinces across the country indicate that most other provinces had finer quality cashmere than the northwest (see Table 1).

All of the samples which were examined were fine or very fine, with 84% under 16. µm. The overall mean was 14.1 µm, with values ranging from 10.8 µm to a maximum of 19.2 µm. The means for provinces ranged from 12.8 µm (Baghlan) to 16.3 micro;m (Herat). This is high quality as defined by international markets. Very fine diameter Afghan cashmere from those provinces is valued in international markets.

The knowledge among international buyers of the quality of cashmere from goats in Afghanistan has been sparse and unrepresentative of the national herd. Afghan cashmere is often exported to Iran from Herat, the main collection centre in western Afghanistan. In 2006, about 30% was recorded as going to Iran (De Weijer, 2007). In Iran, Afghan cashmere is combined with lower-quality Iranian cashmere before further re-export. Iranian cashmere is generally of lower quality than Afghan local breeds. The MFD of three Iranian local breeds (Raeini, Nadoushan and Birjandi) ranged from 17.92 ± 1.71 to 17.09 ± 0.88 to 18.83 ± 1.99 µm (Ansari-Renani, 2007). Afghan farmers and pastoralists received from US $14 to $20/kg in 2006 and higher prices of between US $16 and $22/kg in 2007. By 2009, cashmere prices paid to producers were on average US $16/kg (Dal Grande, 2009).

Table 1. Cashmere test results from Afghanistan in 2006.

Province	No. samples	MFD (µm)	SD	Average cashmere yield (%)
All Animals	373	14.1	3.2	31
Badakhshan	110	13.1	3.1	51
Badghis	48	14.8	3.3	26
Baghlan	21	12.8	2.8	12
Faryab	28	14.2	3.3	24
Ghazni	9	15.0	3.0	21
Herat	63	16.3	3.4	29
Kabul	8	13.2	3.0	15
Kandahar	62	13.8	3.1	20
Takhar	23	12.9	2.7	14

Note: MFD, mean fibre diameter; SD, standard deviation. Cashmere yield is (cashmere weight/sample weight).
Source: Kerven and Redden (2006).

Only around 30% of the Afghan cashmere goats are currently being harvested (De Weijer, 2007). Lack of market participation by producers in regions other than the northwest might be attributable to poor links to domestic traders. There could be scope to expand cashmere production over the entire country, that would present Afghanistan with a large, mostly untapped resource and would generate increased export, household income, rural enterprise and employment opportunities.

Two types of cashmere exist in Afghanistan: the more expensive spring cashmere (*bahari*) combed from live animals during spring and the cheaper skin cashmere manually extracted from the skins of slaughtered animals. The exporters tend to blend the two types together to produce an average product for an average price. International (mostly European) buyers prefer the qualities to be kept separate, with prices dependent on quality.

There is a lack of testing and processing capacity within Afghanistan, that severely hampers commercial potential at present. Sorters employed by the Herat traders manually separate the valuable cashmere from the coarse outer hair. The sorted and manually de-haired cashmere is mostly exported to Belgium, often via Iran. Belgium has the only large-scale European facility for disinfecting raw animal fibre, that is particularly important for cashmere originating in Afghanistan because of the risk of anthrax. Chinese buyers are increasingly entering the Afghan market (Altai Consulting, 2005; Dal Grande, 2009).

Cashmere goats in Central Asia

The biological and productive traits of Central Asian goats were last thoroughly investigated during 1928–1933 by an expedition from the Academy of Sciences of the USSR (Eidrigevich, 1951). During the Soviet period, a wide-scale programme of goat cross-breeding was started in 1936 in all of the Central Asian countries (Millar, 1986; Dmitriev and Ernst, 1989). The primary breeding aim was to increase the down yield per head in order to increase the total output of down from the newly established state collective farms in the 1930s. The indigenous goats had fine down but yielded relatively low amounts (Aryngaziev, 1998a). A secondary breeding aim was to increase the down length, because native breeds produce short length down.

Goat down was processed and the products distributed internally within the Soviet Union, where there was a demand for the warm fibre because of the coldness of the winters. Up to the end of the Soviet period, there was no incentive for breeders to produce down to meet the international standards of cashmere. Instead, Soviet breeders developed their own standards for goat down quality, in accordance with their industrial requirement and domestic markets of the USSR.

The Soviet cross-bred fibre goats in Kazakhstan, Kyrgyzstan and Tajikistan produce the type of down termed 'cashgora', that often refers to the product of crossing cashmere goats with Angora goats (Phan and Wortmann, 2000). The cashgora produced by the Soviet cross-bred goats has a coarser fibre diameter as well as mohair characteristics of more shininess or lustre and less waviness or crimp, characteristics often unacceptable to cashmere manufacturers, especially those marketing high-class products. Some cashgora can have more intermediate fibres, which make adequate mechanical separation of down from guard hair difficult in the processing. World demand for cashgora is limited.

In 2000, during a field assessment of livestock product markets in Central Asia, Prof Angus Russel, who developed the Scottish cashmere goat breed at Macaulay Institute, United Kingdom, noted that the native Kazakh goat produces cashmere (Kerven *et al.*, 2002; see Figure 2). In Soviet Central Asia, national researchers and producers, who were isolated from international markets, had not appreciated the potential worth of this cashmere.

Field studies since 2000 have found that the native strains of domestic goat are still maintained in a few isolated pockets of Kazakhstan, Kyrgyzstan and Tajikistan, where the Soviet cross-breeds were never introduced or have since disappeared. Tests have been carried out on the cashmere quality of these native goats. Summaries of the test results are presented in this paper.

In late winter to early spring, villages in each district were sampled for geographical spread and distance from the main towns. Samples were collected from farmers' goat flocks, consisting of fleece containing guard hair and cashmere taken from the mid-side site by cutting the fibres from a 10-cm^2 square at skin level. Sampling was timed to coincide with the maximum cashmere growth prior to the seasonal moult.

The results indicate that many of these animals could be highly desirable as cashmere breeding stock, because some regions and some flocks have fine diameter down which, if marketed correctly, could fetch much higher prices, benefitting both producers and local industries.

Cashmere goats in Kazakhstan

The goat population of Kazakhstan was 40% of all goats in the early Soviet Union, the highest of any Soviet Republic, with an estimated 4 million goats in 1928. However, goat numbers in Kazakhstan began to decline in 1955 from 2.7 million to 0.5 million in 1968 (Aryngaziev, 1998a). This was due to a renewed state planning emphasis on sheep production in Kazakhstan from the early 1950s (Zhambakin, 1995). During the Soviet period, the main official attention to small stock was directed at breeding new sheep breeds adapted to specific ecological regions and introducing these en masse to state collective livestock farms (Matley, 1989).

With the expansion of the wool industry, the government prohibited the keeping of goats in these more favoured

Figure 2. Combing cashmere from a native cashmere goat in Kazakhstan. Photo: Carol Kerven.

wetter regions to prevent the contamination of sheep wool with coarse goat fibres. Consequently, the genetic resources of Kazakh native goats have been much better conserved in the more arid regions where goat production was not banned and goats were kept privately by state farm employees.

The passing of the Soviet Union and the subsequent emergence of a market economy has had ramifications extending to the most remote deserts of Kazakhstan, the domain of livestock producers and pastoralists (Kerven, 2003a).

In Kazakhstan, goat populations have been rising over the past two decades since independence from the USSR, from 700 000 in 1992 more than 2.5 million in 2007 (Figure 3). This is an increase of 275% in the 15-year period.

Goats are preferred by poorer farmers trying to restock because of the steep and disastrous reduction of sheep numbers from 34 million in 1992 to 10 million in 1997 (Behnke, 2003; Kerven *et al.*, 2005). The relatively sharp increase in goat populations in Kazakhstan and Kyrgyzstan started in the mid-1990s when state livestock farms were rapidly dissolved and state subsidies to the livestock sector ceased. As sheep were bartered away in the economic crisis of this period, they became scarce, expensive and thus unobtainable for the many newly poor villagers who had suddenly lost their jobs in the state organisations. Poorer households started to keep goats as an alternative to sheep. Experienced Central Asian livestock owners claim that their native goats reproduce faster than local or interbred sheep, and some goats produce twins, kid twice per year, or both. Data collected quarterly from 2001 to 2003 in a household survey of five villages in southeast Kazakhstan (DARCA, 2003) shows the higher rate of goat reproduction compared to sheep,

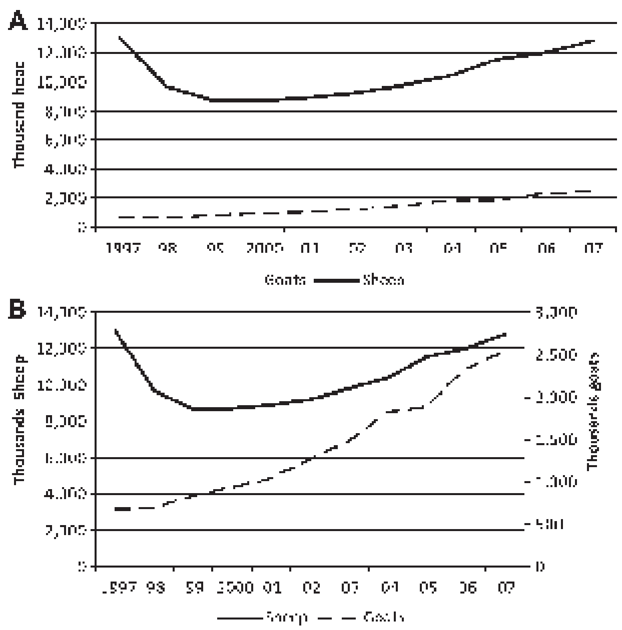

Figure 3. Goat and sheep populations in Kazakhstan, 1997–2007. Part A sheep and goats on one axis and part B sheep and goat on two axes. *Source*: FAOStats (2009).

because the annual number of offspring per doe was significantly greater at 1.29 than per ewe at 1.09 (SE = 0.031 and $p < 0.001$). As a Kazakh expression states, 'If you are really starving, you have to keep goats' (Global Livestock Collaborative Research Support Program [GL CRSP], 2006).

Soviet breeding programmes for downy and cashmere goats

A 1971 government resolution ordered the development of goat breeding and production again.

To increase down productivity in Kazakhstan, several cross-bred lines were developed using Russian, US and Asian cashmere goats with native goats. There are two main types of Russian cashmere goat – the Don and Orenburg (Porter, 1996). The Don goat from the lower Don and Volga river valleys has a high down fleece weight of 500 g to 1.5 kg for does, with a fibre diameter ranging from 16 to 25 µm, averaging around 19 µm (Millar, 1986) The fibre coarser than 19 µm would be regarded as cashgora. The Orenburg goat has finer down than the Don, with an average fibre diameter of 15 µm but lower fleece weight at 250–400 g. The Gorno Altai goat from the mountainous country between Mongolia, Russia and China was also used to improve fibre production in Kazakhstan. This is another high-fleece weight cashmere breed, producing 600–900 g of down with diameters between 16 and 17 µm. Lastly, Angora goats were imported from Texas, United States, into Kazakhstan as early as 1936. These were crossed with native breeds and with the Don, Orenburg and Gorno Altai breeds to create several new lines in Kazakhstan.

Some cross-bred lines with Angora proved unsatisfactory for the extreme climatic conditions of Kazakhstan and the other Central Asian countries (Aryngaziev, 1998a). By 1962 the Soviet Mohair breed had been developed which had some of the hardiness of native Central Asian goats as well as higher down production. However, the diameter of the down had been increased to between 17.4 and 19 µm in females (Dauletbaev and Aryngaziev, 1978, 1980) compared to the native Kazakh goat which had fibre diameters ranging from 15.9 to 16.5 µm for females (Millar, 1986; Aryngaziev, 1998b).

The Soviet Mohair breed was widely introduced into the state livestock farms in Kazakhstan and the other Central Asian Republics during the 1970s and 1980s. The descendents of these animals, referred to as 'Angorski' type, are still now commonly found in private shepherds' flocks except in the driest southern and western regions where they do not thrive (see Figure 4).

Throughout the Soviet period, the intrinsic commodity produced by native goats that were traditionally kept by Kazakh pastoralists was discounted, although the hardiness of the native goat was used as a foundation for several new

Figure 4. 'Angora' type Soviet mohair goat, 2001. Photo: Carol Kerven.

breeds to meet state production objectives (Dmitriev and Ernst, 1989). It is only since the passing of the Soviet Union that pastoralists have turned back to their native breeds, and it is fortuitous that these same breeds may provide a basis for developing national cashmere industries.

Market development of cashmere in Kazakhstan

The early 1990s, after the state agricultural production and distribution system abruptly ended, brought chaos at all levels – the shepherds on the rangelands, the markets for livestock products and the research infrastructure (Kerven, 2003a). By 2000, raw cashmere began to be purchased from farmers and pastoralists by enterprising Chinese and Turkish traders venturing into the remote regions of Kazakhstan's hinterland (Kerven *et al.*, 2005).

Farmers now generally sell the whole sheared fleece, including rough outer hair containing the cashmere down. Combing the cashmere out is preferable from a processing standpoint, as shearing fleeces reduces the length of the cashmere fibres and native Central Asian goats tend to have cashmere which is already rather short for processing. However, combing goat down is somewhat of a lost art in the Central Asian rangelands. Traders and processors then have to manually sort and extract the cashmere from the whole shorn fleeces. Local village traders do not know the difference between good and bad quality goat fibre. They seek to buy everything regardless of quality and sell to bigger traders who make more profit by sorting the cashmere before selling to industrial processors. One medium-size trader in Kazakhstan with experience of the Mongolian cashmere industry remarked about Kazakh goat farmers: 'If only they knew how much money we make by sorting their fibre'. A livestock farmer who had recently emigrated from China to a desert village in Kazakhstan commented, 'In China, this goat down is very expensive but here in Kazakhstan people don't know about down so they shear, mix together and sell everything at a low price' (GL CRSP, 2006).

Quality testing and commercial potential of Kazakh cashmere

In spring of 2006, Kazakh goat researchers collected cashmere samples in southeast, south and west Kazakhstan (GL CRSP, 2006). These regions are known to contain the greatest proportion of native goats and the least numbers of introduced Angora-type cross-breeds (Aryngaziev, 2005). The researchers took mid-side samples in each of three private farms within 20 districts in six provinces (Oblasts). The results are provided in Table 2.

Cashmere quality varies between provinces and districts and from very coarse (not normally considered true commercial quality) cashmere to very fine, highly desirable cashmere. The western provinces of Aktube and Atyray have Orenburg goats, which do not produce cashmere as defined internationally. In the provinces of South Kazakhstan and Almaty, some Angora cross-bred goats were introduced to state livestock farms in the Soviet period. However, in Kyzl Orda province, a semi-arid region in the southwest, almost no other exotic goat breeds have been introduced and a relict population of native goats remains. This province had the finest cashmere (mean = 15.4 μm) across the sample in 2006. Within the four sampled districts of Kyzl Orda, one district had a mean of 14.9 μm (10 samples).

The weights of combed cashmere per goat were assessed from 50 adult goats in farmers' flocks from the provinces of Kyzl Orda, Almaty and South Kazakhstan (GL CRSP, 2006). The average weight was 101 g, with a range from 44 to 272 g. These weights are quite low in comparison to cashmere goats bred by Chinese and Mongolian researchers. Low harvest weights mean less income from each goat and discourage farmers from harvesting their cashmere.

In Kazakhstan the results indicate that, as expected, the quality of cashmere is higher in those regions where native goats have not been bred in the past with Angora mohair types. In the drier semi-desert regions, past efforts had failed to introduce these breeds to the state farms in the 1980s (Aryngaziev, 2005). According to interviews with pastoralists in these drier regions, the new breed did not thrive in the desert conditions and could not keep up with other livestock breeds on the long migratory journeys to seasonal pastures. Farmers in some of these regions stated that they are trying to eliminate the Soviet Angoras from their private flocks (GL CRSP, 2006).

Cashmere goats for Kazakh livelihoods

Farming households which have less livestock and are located in the drier zones of Kazakhstan are more reliant on goats and on selling cashmere from these goats. A

Table 2. Cashmere fibre diameter from sample of 129 goats in southwest Kazakhstan.

Province	No. samples	Fibre diameter (μm)				
		Max.	Min.	Mean	SD Mean	CV Mean
Aktube	10	20.3	14.7	17.3	3.9	22.4
Atyray	6	17.9	14.8	16.1	3.3	20.7
West Kazakh	16	19.0	14.9	17.3	3.7	21.5
Kyzl-Orda	41	17.0	12.4	15.4	3.3	21.7
South Kazakh	47	20.6	14.0	16.7	3.5	21.2
Almaty	9	19.4	15.8	17.1	3.5	20.7
Overall		NA	NA	16.4	3.5	21.4
Female	111	20.6	13.1	16.5	3.6	21.5
Male	18	19.1	12.4	15.7	3.3	21.2

Note: SD, standard deviation; CV, coefficient of variance; NA, not available.
Source: GL CRSP (2006).

sample of 45 livestock-owning households was surveyed over eight quarterly rounds from 2001 to 2003 in six villages of southeast Kazakhstan covering higher and lower precipitation zones (DARCA, 2003; Kerven *et al.*, 2003). Larger flock owners kept mainly sheep. Household wealth is mainly defined in the semi-arid rangelands by flock size, as crop agriculture cannot be carried out because of low precipitation and lack of irrigation, and local wage employment opportunities remain very scarce.

The ratio of goats to sheep in small flocks increases with aridity. Two of the sample villages were located in the desert zone with 130 mm of annual precipitation, where the percentage of goats in all flocks rose to 49%. In the two villages within the semi-desert, that has more annual precipitation (350 mm), the percentage of goats in all flocks was 33%. However, this dropped to 19% among all flocks in the more lush pasture areas of the mountain foothills with annual precipitation of 450–650 mm, depending on altitude, where crop farming is widely practiced and proximity to the main city of Almaty provides cash employment opportunities.

In another survey of 60 households in three small villages in the semi-arid region (annual precipitation of 150 mm) of Kyzl Orda province in southwest Kazakhstan, the pattern of goat ownership according to wealth (i.e., herd size) is even clearer (GL CRSP, 2005). The ratio of goats to sheep increases in smaller flocks. Almost a quarter of the households only owned goats, predominantly among the households with smaller flocks. Smaller flock owners gained proportionally more income from goats, because they depend more upon them, according to the results of this survey. The poorest households had between 1 and 20 small stock and obtained 32% of their livestock cash income from goats, with 11% (mean = $21) of cash income from selling cashmere. Seventy percent of households had medium-sized flocks with 21–100 small stock and obtained 38% of their cash income from goats, with $63 from cashmere sales. Households with the largest flocks of more than 500 small stock gained $154 from cashmere sales.

The desert ecological regions where native goats produce good quality cashmere are among the most economically disadvantaged in Kazakhstan. According to UNDP Human Development indices, these semi-arid regions are classified as ‘low potential’, with higher proportions of people living below the poverty line and lower per capita incomes, than other climatically better-favoured regions. The desert villages receive little assistance from the state, that is due to their low population density, remoteness and little obvious capacity for generating wealth.

In the province of Kyzl Orda in southwest Kazakhstan, combed cashmere was selling at US $30 to $40/kg in spring 2006 (GL CRSP, 2006). Given the average weight of combed cashmere per local goat, the annual harvested value per goat to a farmer would be US $3.30 to $4.40. A poorer farmer owning a typical flock of only 10 goats could expect to receive US $33 to $44 for their cashmere, more than the market price for an adult goat in the district towns. By contrast, sheep in this region produce only coarse wool, that fetches only a few cents per kilogram and is often not sold at all. A farmer in the semi-arid rangelands would need 90 sheep to gain the same *annual* income as from 10 cashmere goats.

Cashmere goats in Kyrgyzstan

The goat population in Kyrgyzstan was 850 000 in 2007 (FAOStats, 2009). By comparison, the sheep population in 2007 was 3 198 000 (Figure 5). There has been an increase of almost 400% in the goat population in 10 years. However, a recent small sample assessment in 12 villages in two districts of southern Kyrgyzstan (Osh province) indicates that goat numbers are between three and five times higher than official district counts (Kerven and Toigonbaev, 2009). Local village officials and farmers in this study region acknowledge that village goat populations are routinely under-enumerated, as farmers have to pay a higher head tax per goat compared to sheep.

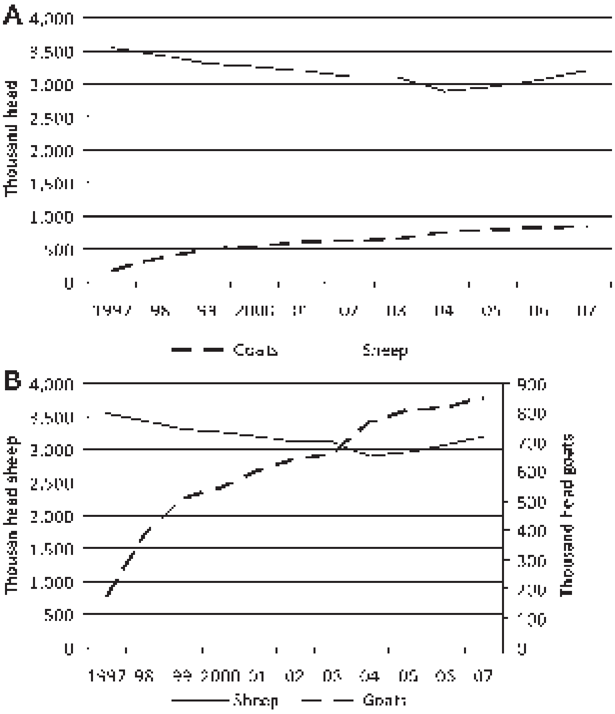

Figure 5. Goat and sheep populations in Kyrgyzstan, 1997–2007. Part A sheep and goats on one axis and part B sheep and goats on two axes. *Source*: FAOStats (2009).

The mean flock size of goats among households in these two districts of Osh province is 7.7 (Kerven and Toigonbaev, 2009). In these two districts, 54% of sampled farmers with small stock (sheep and goats) had between 1 and 10 head and 27% had between 11 and 20 head (Mountain Societies Development Support Programme [MSDSP], 2006). Forty percent to 50% of the small stock in these flocks were goats.

The local Kyrgyz cashmere goats are in danger of disappearing. As in Kazakhstan and the other central Asian countries, during the Soviet period a new breed of goat was developed and widely introduced into state collective farms in Kyrgyzstan. This was the Don–Kyrgyz down breed, from crossing the local Kyrgyz goat with the Don breed from Russia. Dmitriev and Ernst (1989) recorded that Don–Kyrgyz cross adult females had down MFD of 16.6 µm and a harvest of 360 g. Adult males had coarser down with an MFD of 18.1 µm and 550-g harvest. By contrast, native (not Don crosses) goats of southern Kyrgyzstan sampled in 2008 had an MFD of 15.7 µm and harvest of 164 g combed cashmere (McGregor *et al.*, 2009). The Don breed's fibre was and still is exported for use as dense Siberian shawls, which are still in demand in Russia.

The fibre from the introduced breeds is coarser than the local Kyrgyz goats and the Don has dark coloured fibres, which is less attractive to cashmere buyers. This breed was widely distributed to northern Kyrgyz collective farms, but it did not reach the extreme southern regions of the Pamir mountains, bordering with Tajikistan, where villages are located at altitudes between 2 000 and 3 200 m above sea level (Kerven *et al.*, 2008). There the local Kyrgyz goat has continued to flourish in village flocks, and it has only recently been evaluated as having very fine cashmere (McGregor *et al.*, 2009).

Descendents of the original Don–Kyrgyz crosses have now spread into areas of northern and central Kyrgyzstan such as Naryn province, where goats were sampled in 2008 (see Figure 6; McGregor *et al.*, 2009). However, the Don–Kyrgyz crosses were not generally successful in the far southern districts of the Pamir mountains in Osh province because of the high altitude and extreme climate.

Buyers from China and other countries started coming to Kyrgyzstan every spring in the late 1990s to buy cashmere from farmers and pastoralists. They only

Figure 6. Kyrgyz Don goat, Alay District, Osh province. Photo: Carol Kerven.

Table 3. Producer prices for cashmere in Osh, southern Kyrgyzstan, in 2004–2009.

Year	Farm gate price/kilogram (raw, greasy) (US $)	
	Sheared whole fibre (fleece)	Combed down
2004	1.9–3.5	7
2006	6.9–7.4	19. 2–22
2007	8.2–9.6	22–27.4
2008	5.47–5.5	16.4–16.5
2009	3	7

Source: Kerven and Toigonbaev (2009).

reached the remote villages of the Pamir mountains in about 2004.

At first the Chinese buyers purchased goat down from northern and central Kyrgyzstan, but the buyers did not offer producers any price incentives to sell finer diameter or white cashmere and only paid by weight sold. Although the Don goat breed was not maintained in a pure form after the state farms were dissolved in the mid-1990s, farmers in central and northern Kyrgyzstan started buying and crossing this Don type with their native cashmere goats as the Don–Kyrgyz cross produces much more down per animal, that brings a higher total sale amount per flock. The motivation of the farmers is that because traders buy down by weight rather than quality, farmers prefer to have goats which produce more quantity of down per animal. Flocks are often small and most villagers are poor, so every gram counts when selling fibre at prices fluctuating each year from US $15 to 25/kg to small-scale middlemen who buy everything regardless of quality.

Producers are not paid according to quality and they are not aware of the high international value of good quality cashmere, so the number of local cashmere goats is decreasing. This represents the loss of a genetic resource which is part of Kyrgyzstan's natural heritage and of significance to world cashmere research and commercial organisations. Very fine cashmere is rare in the world, and Kyrgyz villagers are losing an opportunity – perhaps forever if their own breeds are not preserved – to gain better prices for their cashmere. Meanwhile, the reputation of Kyrgyzstan 'cashmere' is declining, as the few European buyers who have purchased in northern and central Kyrgyzstan are increasingly offered low quality 'cashgora' from the Don-local crosses, that do not have the desired commercial characteristics of true cashmere.

Shifts in world events played out in the mountain villages of Kyrgyzstan, as the economic downturn caused a depression in demand for cashmere (Table 3).

Quality testing and commercial potential of Kyrgyz cashmere

Cashmere from Kyrgyz goats has not been assessed previously. In spring 2008, samples of fibre were taken from 1 023 goats sampled from 156 farmers' flocks in a total of 51 villages within five districts (Osh province and Naryn province). A sub-set of the samples was tested in a US fibre laboratory. Full results are given in McGregor *et al.* (2009; see Table 4).

A low standard deviation indicates cashmere with low variability in the range of fibre diameters, that results in even yarn and an even surface finish on garments. A low standard deviation increases the value of the product and is thus a desirable characteristic of the cashmere fibre. The curve degree per millimetre is a measure of fibre curvature, an objective measurement of cashmere fibre crimp (McGregor, 2007) associated with fibre diameter. Greater degrees of curvature are therefore likely to be more in demand for higher-priced garments.

Cashmere quality was different in the southern districts of Osh province compared to the central and eastern districts of Naryn province. The differences have large commercial importance (McGregor *et al.*, 2009). Cashmere from the sampled districts of Osh province had an MFD similar to premium cashmere from China whereas cashmere from Naryn province would be less preferred for traditional hosiery textiles.

The results in Table 4 indicate that Don–Kyrgyz cross-bred goats are widespread in Naryn; these are predominantly black and have coarser (higher diameter) cashmere. In the southern Osh region, although Don–Kyrgyz goats were introduced in the Soviet period, there is still a relatively large population of native Kyrgyz goats of mixed colours and many white, with a lower (finer) fibre diameter. These goats of the Pamir mountains of Osh province are therefore more commercially valuable.

Table 4. Cashmere test results from 760 goats sampled in Osh and Naryn provinces, Kyrgyzstan, in 2008.

District	No. samples	MFD (μm)	SD	CV	Curve (deg/mm)	Black (%)	White (%)	Other colours (%)
Naryn	162	16.4	3.3	20.2	56.3	79	13.8	7
Atbashy	108	16.7	3.3	19.5	56.4			
Jumgal	162	16.7	3.2	19.0	53.9			
Alay	260	15.8	3.0	18.8	60.2	40.4	28.9	30.8
Chong Alay	68	15.6	3.1	18.9	58.7			

Note: MFD, mean fibre diameter; SD, standard deviation; CV, coefficient of variance.
Source: McGregor *et al*. (2009).

Cashmere goats for Kyrgyz livelihoods

In the districts of Osh province in southern Kyrgyzstan where this survey was undertaken, villagers and local officials confirm that goats have recently become more popular, noting that goat numbers are growing faster relative to sheep (Kerven, 2004; Kerven and Toigonbaev, 2009). Villagers reported that goats reproduce faster than sheep because they often kid twice a year and produce twins and are milked by families that have few or no cows. Goat milking was increasing. In some villages, goats were at least half of the small stock in flocks. It was reported that poorer families were trying to accumulate goats, that were cheaper to purchase than sheep, in order to build up their flocks. As families became wealthier, they exchanged goats for sheep through the markets, as sheep remain the preferred small stock species for those who can afford them.

There is a clear trend in southern Kyrgyzstan's mountainous regions for poorer households, defined by flock size and annual income, to have a higher proportion of goats than sheep in their flocks (MSDSP, 2006). For households owning between 1 and 10 small stock, 53% of their flocks were composed of goats. This was 32% ($n = 314$) of sampled households. The trend of goat ownership then declined according to wealth rank and number of small stock owned. Household flocks with 11–20 small stock had 39% goats, flocks with 21–50 small stock had 39% goats, flocks with 51–70 small stock had 28% goats and the largest flocks of 70+ small stock contained the least proportion of goats at 24%.

Cashmere goats in Tajikistan

Tajikistan experienced a drop in both sheep and goat populations in the troubled period of the 1990s, with both populations now rising since 2002 as the national economy improves. The goat population has increased by 75% in the 12 years since 1997 (see Figure 7).

As in the other ex-Soviet states of Central Asia, a breeding programme was established to produce Angora-based goat breeds in the Soviet period (Karakulov, 2002). One new breed called Soviet (now Tajik) Mohair was widely introduced in the Sogd region in the northwest. Another breed called Pamiri Downy was bred from Angora, the Don (Russian Downy breed, discussed earlier) and local goat breeds and was introduced into Gorno Badakhshan (eastern Tajikistan). The mohair harvested from these goat breeds was in high demand in the USSR. There is still a market for this fibre. However, as in Kazakhstan and Kyrgyzstan, many Soviet-bred goats in Tajikistan have been inter-bred in the post-Soviet period with local Tajik goats, and the resulting fibre has much reduced quality and demand.

Starting in the late 1990s, traders from the bordering countries of China, Uzbekistan and Kyrgyzstan started to barter with isolated Tajik villagers in the mountains, who exchanged their goat skins with the traders in return for basic commodities such as soap (Kerven, 2003a). The traders later extracted the cashmere from the goat skins. As in Kyrgyzstan and Kazakhstan, there have been no government or international donor programmes to promote cashmere market development for Tajik villagers.

In 2003, samples were taken of Tajik goat down from six districts in the mountainous regions of the Rasht Valley and Gorno Badakhshan and tested in the United Kingdom (see Table 5; Kerven, 2003b). Samples from the districts of Jirgitol, Tojikabod, Rasht and Vanj were very fine, on average from 14 to 15.3 µm. However, most of the samples from two other districts of Murgab and Shugnon in Gorno Badakshan province would not meet the international fine cashmere standard, as they were above the preferred international fibre diameter because of the previous introduction of the Soviet Mohair breeds.

In another mountainous region of Zerafshan Valley, further samples were taken from goats in three districts in 2007 (Kerven and Redden, 2007). In Ayni District, the MFD was 14.3 µm (65 samples) with a standard deviation (SD) of 2.9. Penjikent District's 68 samples had a mean diameter of 15.1 µm with an SD of 3.0 (see Figure 8). Kuhistoni Mastcho District had the least fine results, with a mean diameter of 16.9 µm from 54 samples, an SD of 3.3 and a longer length than is generally preferred for cashmere. Soviet Mohair goats had been introduced to Kuhistoni Mastcho district in the Soviet period. In terms of colour, 14% of samples were white and a further 25% light coloured. White and light colours are preferred by the cashmere industry as they can be dyed a range of colours without bleaching.

Cashmere goats for Tajik livelihoods

Villages in the mountainous regions of Tajikistan have been impoverished since the breakup of the Soviet Union, with a subsequent civil war in the 1990s and into this decade. Household surveys found that, among the poorest households, goats are the dominant flock species and are more likely to be kept than sheep (Aga Khan Foundation [AKF], 2005). For those households owning between 1 and 10 head of small stock, 90% keep goats compared to 52% keeping sheep. This difference in proportions is significant ($p < 0.001$). In the case of those owning more than 10 animals the McNemar test is insignificant ($p = 0.125$), so there is no significant difference between sheep and goat ownership for families with more than 10 small stock.

In the Rasht Valley of the mountainous eastern part of Tajikistan, the general trend is similar, with the poorest village households likely to have goats but no sheep (AKF, 2004). Households in the lowest income quartile had a statistically higher likelihood of owning goats.

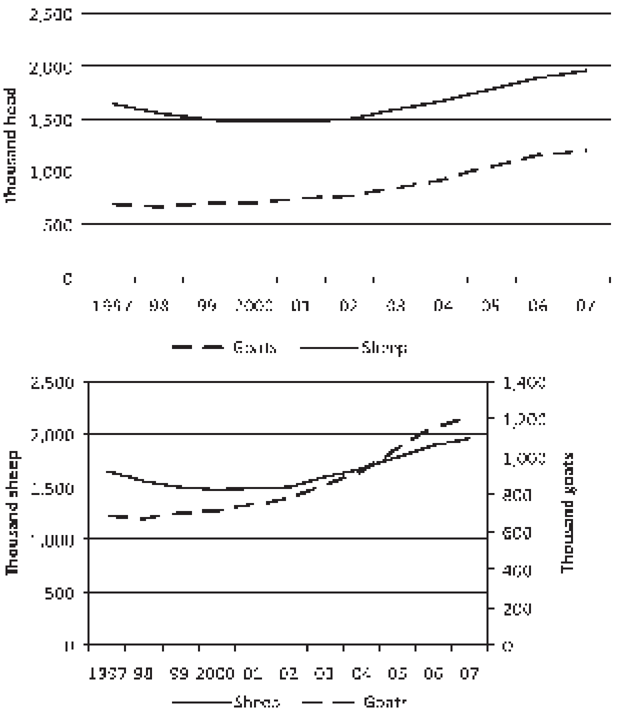

Figure 7. Goat and sheep populations of Tajikistan, 1997–2007. Part A sheep and goats on one axis and part B sheep and goat on two axes. *Source:* FAOStats (2009).

Thus, 88% of households in the group having between 1 and 10 animals had goats whilst 56% have sheep.

According to farmers and village leaders interviewed in the Zerafshan Valley (Kerven and Redden, 2007), poorer households prefer to keep goats rather than sheep. The reasons are that goats are cheaper to buy and cost less to feed over winter than sheep. Villagers explained that, as goats are browsers and can forage on bushes and a wider variety of plants than sheep, goats are kept in the high mountain pastures for longer periods (10 months) than sheep which have to be brought down in late autumn after 7 months in the mountains and then housed in sheds in the valley villages and fed on cut fodder over the coldest winter months. Preparation of winter feed is labour intensive and costly.

Table 5. Cashmere fibre diameter from 142 goats sampled in Rasht Valley and Gorno Badakhshan, Tajikistan, in 2003.

Province and District	No. samples	MFD (μm)	SD
Rasht Valley			
Jirgitol	16	14.0	2.5–3.6
Tojikobod	16	15.3	2.5–3.6
Rasht	16	15.3	2.5–3.2
Gorno Badakhshan			
Murghab	31	17.8	3.1–4.3
Shugnon	31	18.1	2.8–4.3
Vanj	32	14.6	2.4–4.0

Note: MFD, mean fibre diameter; SD, standard deviation.
Source: Kerven and Redden (2003).

Prices in 2007 for cashmere sold by villages in remote high regions of Badakhshan (eastern Tajikistan) were US $7/kg for combed and $4.75/kg for shorn fleeces (Robinson, 2008). In northern Tajikistan, in proximity to cities in

Figure 8. Tajik cashmere goat, Zerafshan Valley (*Source:* Carol Kerven).

Uzbekistan, traders paid farmers up to US $11.70/kg for combed cashmere in the same year. Farmers supplying combed and high-quality cashmere to traders in the city of Khojand (Tajikistan) received US $17.50/kg (Kerven and Redden, 2007). This was a considerable increase from prices in 2001–2002 when villagers bartered a kilogram of cashmere for bars of rough soap from foreign traders (Kerven, 2003b).

Conclusions

In Afghanistan, much of the cashmere available is not sold as producers are not linked into markets. In the former Soviet republics of Kazakhstan, Kyrgyzstan and Tajikistan, small-scale farmers are now looking beyond simply surviving; instead they are seeking new techniques, probing new markets and planning new investments. Selective breeding of the current local high-quality goat stocks can increase the value of cashmere produced, thereby benefitting low-income farmers and the revenues of national economies. Producers' new focus on goats provides an opportunity to introduce improved breeding stock at a time when the expansion of the national flock will multiply the impact of upgraded genetic material.

Laboratory tests show that there are cashmere goats in the sampled districts of Afghanistan and Central Asia which produce the highest qualities of cashmere by international standards. The vast majority of these samples are fine, have low variation in fibre diameter and have fibre curvature (crimping) typical of Chinese and Mongolian cashmere, which is the world standard for best quality (McGregor, 2004). Some of the native goats have very fine cashmere, and these animals could serve as a gene pool for national breeding programmes.

The results show that cashmere production has the potential to provide better income for livestock farmers. However, some farmers, villages and districts have better cashmere goats than others. As a first practical step, farmers need training in the identification of the finest cashmere bucks, ability to purchase such bucks and more information on commercial prices for better quality cashmere to motivate them to select the best bucks. Farmers should also be advised that goats should be sold or slaughtered that produce the coarsest cashmere, the least amount of cashmere and the least number of kids. Farmers need training about the relationship between cashmere crimp (fibre curvature) and MFD both for buck selection practices and for preparing cashmere for sale. These are visual characteristics that farmers can easily observe after receiving basic training in village workshops (GL CRSP, 2006; Kerven *et al.*, 2008).

National researchers and government officials concerned with livestock in Central Asia are not generally aware of the world market requirements and prices for cashmere, but they have the mandate to inform producers on current market conditions and advise on methods for increasing the value and price of their cashmere. They therefore need training on these topics.

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Genetic improvement in the Australasian Merino – management of a diverse gene pool for changing markets

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Summary

The Australasian Merino population has declined significantly over the last 15 years in response to a decline in the price of apparel wool, both in absolute terms and relative to the price of sheep meat. Over the same period, a national genetic evaluation system based on BLUP methods has been introduced, that is achieving steady growth in adoption by breeders. Genetic parameter estimates for the population provide evidence for considerable genetic diversity for all recorded traits, providing ample opportunity for genetic improvement. More recently, there is considerable evidence for increasingly rapid progress, both in fleece traits and a range of meat production and adaptation traits. The Merino population is evolving towards two broad types – one focused on high quality apparel wools finer than 19 µm and used in enterprises with a wool/meat income ratio of about 3:1, and the other a more dual-purpose animal producing 19–21 µm wool and an enterprise wool/meat income ratio between 1.5:1 and 1:1. Underlying these trends is a growing focus on adaptation traits including worm resistance; reduced need for veterinary interventions; and increased early growth, fertility and mothering ability. Together these trends point to increasingly 'easy-care' sheep and exploitation of the available genetic diversity to rapidly increase profitability.

Keywords: *economics, genetic diversity, genetic improvement, wool production*

Résumé

La population des mérinos australasiens a baissé de façon considérable au cours des 15 dernières années en raison de la chute du prix de la laine cardée, en termes absolus ainsi que par rapport aux prix de la viande ovine. Au cours de la même période, on a introduit un système national d'évaluation génétique basé sur les méthodes BLUP qui est de plus en plus adopté par les sélectionneurs. Les estimations des paramètres génétiques de la population prouvent une diversité génétique considérable pour tous les caractères enregistrés, offrant ainsi de grandes opportunités d'amélioration génétique. Plus récemment, on constate des progrès rapides dans les caractères de la toison ainsi que dans un éventail de caractères de production de la viande et d'adaptation. La population de mérinos évolue vers deux grands types d'animaux: un type concentré sur la production de laine cardée de haute qualité inférieure à 19 microns et utilisé dans les entreprises ayant une ratio de revenu laine:viande d'environ 3 à 1; et un autre type d'animal plus à double fin qui produit une laine de 19-21 microns et utilisé dans des entreprises ayant une ratio de revenu laine:viande entre 1:5 et 1:1. Ces évolutions sont soulignées par la focalisation croissante sur les caractères d'adaptation comme la résistance aux vers, le besoin réduit d'interventions des vétérinaires et l'augmentation de la croissance, de la fertilité et de l'aptitude à la reproduction précoces. Toutes ces évolutions indiquent des moutons toujours plus faciles à entretenir et l'exploitation de la diversité génétique disponible pour accroître la rentabilité de façon rapide.

Mots-clés: *économie, diversité génétique, amélioration génétique, production de laine*

Resumen

La población de Merino australiano ha disminuido de forma significativa a lo largo de los últimos 15 años como respuesta a una bajada del precio de las prendas de lana, tanto en términos absolutos como en lo relativo al precio de su carne. Durante el mismo periodo de tiempo, se ha presentado un sistema nacional de evaluación genética basado en los métodos BLUP, cuya aceptación por parte de los criaderos va creciendo de forma progresiva. Los parámetros genéticos estimados para la población indican una importante diversidad genética para todos los rasgos registrados, proporcionando una gran oportunidad para la mejora genética. Más recientemente, determinadas pruebas han puesto de manifiesto un progreso, cada vez más rápido, con respecto a las características del vellón, así como a una serie de características relacionadas con la adaptación y la producción de carne. La población de Merino está evolucionando hacia dos grandes grupos – uno centrado en la producción de lana para ropa de alta calidad cuya sección de fibra es inferior a las 19 micras y utilizadas en empresas con unos ingresos en la proporción lana-carne a razón de 3 a 1 respectivamente, y otro más centrado en la cría de un animal de doble propósito que produce una fibra de lana cuya sección se encuentra entre 19 y 21 micras y utilizadas en empresas cuyos ingresos corresponden a la proporción lana:carne a razón de 1.5 a 1:1 respectivamente. Detrás de estas tendencias existe un creciente enfoque en las características de adaptación que incluyen una resistencia a parásitos, una menor necesidad de intervenciones por veterinarios, y un mayor crecimiento en edades tempranas, así como un aumento de la fertilidad y de la capacidad maternal. Juntas,

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estas tendencias apuntan hacia un ganado ovino cuyos cuidados son cada vez más sencillos, así como a la explotación de la diversidad genética disponible para aumentar rápidamente la rentabilidad.

Palabras clave: *economia, diversidad genética, mejora genética, producción de lana*

Submitted 3 September 2009; accepted 10 September 2009

Introduction

The sheep industry, and in particular the wool produced from it, has been a significant contributor to the Australian economy for most of the time since European settlement in the late 1700s. Sheep were bought to the country on the first British ships; in subsequent years further importations were made from Britain, the Indian sub-continent, Southern Africa and Europe. Many 'breeds' were introduced over a period of time characterized by much experimentation via crossing of breeds and strains, but it became apparent that the Merino was eminently suited to producing fine wool across much of Australia. This history is intensively described in Massy (2007), and captured in literature by McDonald (2005), and both works give a flavour of the enormous cultural significance of the wool industry in Australia.

Massy describes in detail the sources which contributed to the Merino gene pool via infusion, crossing, upgrading and selection and which led to the range of 'strains' which existed for much of the 20th century. In modern terminology, the Australian Merino flock comprises a number of genetically related composites or synthetics, based ultimately on Merinos deriving from Spain, but with various infusions from populations developed in a range of countries from the original Spanish, and more widely, from other sheep breeds. This history can be expected to have generated significant genetic diversity.

The combination of climate and availability of pasture for grazing meant that Australia rapidly came to dominate world wool production, especially in the finer, apparel end of the micron range (Merino wool ranges from 14 to 28 µm, with the majority of production in the 22–24 µm range for much of the period up to 2000). Exports of wool from 1800 to 1940 were focused on British markets whereas after World War II the markets in Russia, China, Italy and Japan became more important. Italy and Japan sought wools from the finer end of the Merino production spectrum, whilst the Russian and Chinese markets relied on broader wools used in the manufacture of blankets and coats for their armies. This dichotomy – finer wools used in more expensive apparel products, and broader wools used essentially as a source of warmth – underpins recent significant changes in the demand for wool.

At its height, the Australian Merino flock numbered some 180 million animals. This peak was underpinned by a price maintenance mechanism introduced by the wool industry, known as the Reserve Price scheme (Massy, 2007). This was introduced in the late 1960s after a period of decline in real wool price from its peak in the early 1950s and led to stabilisation of the real price through the 1970s and into the 1980s. In the mid-1980s the reserve price was successively raised following apparent growth in demand, and production was expanded to follow essentially guaranteed prices. After the mid-1980s this market support mechanism collapsed.

In the period since 1980 demand for the broader Merino has declined significantly to the point where production of wool above 22-µm diameter has become uneconomical. This has led to very significant reduction in the number of animals and significant concerns about Australia's ability to supply its markets for both wool and sheep meat.

The key points from this brief historical overview are the following:

- Merino wool production has been a very significant component of the overall Australian economy for most of the period since European settlement.
- The Australian Merino evolved over that period under selection from a range of source populations and as such is essentially a composite or series of genetically related composite populations, suited to particular climate-by-market niches.

This paper briefly summarises the data on the economic importance of Merino wool production, the evidence for genetic diversity within the Merino population and recent changes in both the markets for Merino wool and technological changes in Merino breeding.

Importance of fibre production for farmer livelihoods

Wool is produced in Australia from sheep flocks managed with a range in focus on wool – in simple terms from flocks producing finer and more valuable wool, mainly in cooler regions with shorter growing seasons, to flocks where meat production or livestock sales are more important, typically in the dryer and warmer regions (particularly in South Australia and Western Australia). The exact balance between wool and meat income varies with the actual prices, but this range is from approximately 85% of total income derived from wool down to approximately equal shares for wool and meat.

This range partly reflects the diversity of production characteristics within the Merino population which will be discussed further. The key point is that in different

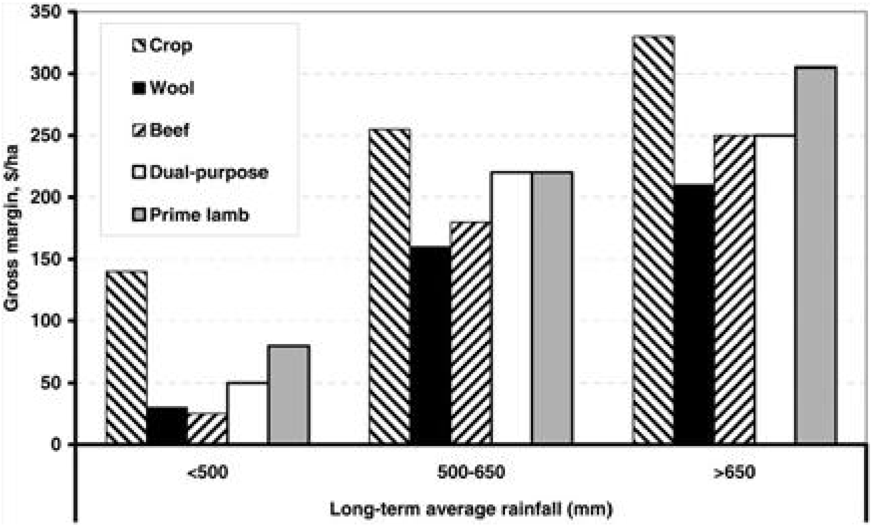

Figure 1. Enterprise economic comparison for 1999–2008. Note that many farms will have more than one enterprise, and mixed sheep and crops are common particularly in the medium and lower rainfall areas.

regions the flock structures are geared to different income mixes. Current economic performance for these regions has recently been analysed (Holmes-Sackett, 2009) and can be summarised by enterprise type and by region.

Figure 1 summarises economic performance for three sheep enterprises as well as cropping and beef production over the last 10 years. The three sheep enterprises are the following:

1. Wool, where all ewes are Merinos and are mated to Merino rams, and approximately 75% or more of enterprise income is from wool;
2. Dual purpose, where the ewes are Merinos but a portion are mated each year to non-Merino rams for either lamb or hogget (12- to 24-month-old sheep) production, and 55–65% of enterprise income is from wool; and
3. Prime lamb, where the ewes are typically not Merino, the rams are meat-breed rams, all or most progeny are sold for slaughter and 65% or more of enterprise income is from meat.

Three main points can be highlighted from Figure 1:

1. Gross margins need to be in excess of approximately $100, $150 and $200/ha in the low (<500 mm), medium (500–650 mm) and high (>650 mm) rainfall zones, respectively, for farm business sustainability. On this basis, wool-focused enterprises have not been financially viable on average over the last 10 years.
2. In all regions of Australia where sheep are run, over the last 10 years profitability from cropping exceeds that of any sheep enterprises. Note that capital requirements are usually higher for cropping as is variability between years, such that cropping is more financially risky than livestock.
3. Dual-purpose enterprise profitability has significantly exceeded that of wool focused enterprises in all regions through the last 10 years.

This situation of relatively poor returns from wool production is predominantly the result of the relative prices

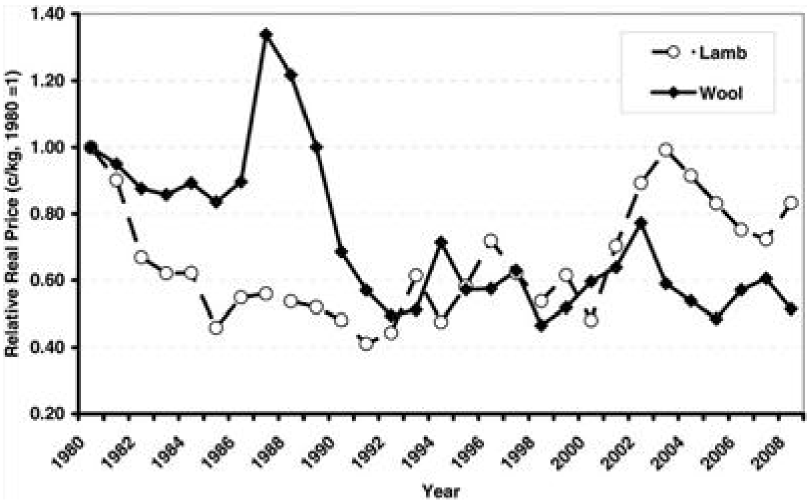

Figure 2. Relative real prices for wool and lamb, 1980–2009.

of wool and sheep meat. The prices for these have followed very different paths over the last 30 years, as illustrated in Figure 2.

Figure 2 clearly shows the following:

- Between 1980 and 1990, real prices for wool and lamb both declined, albeit with a very steep rise in the real price of wool to 1985. The subsequent crash in wool prices was simultaneous with the collapse of the Reserve Price scheme.
- Since 1990, the real price of wool has fluctuated around 60% of its price in 1980, whereas the real price for lamb has risen to around 80% of the 1980 price. The price trends for wool and lamb for these periods are 0 and 2.4% pa., respectively. (This rise has not been smooth, because it has been affected by both widespread droughts which have affected supply and by tariff barriers in the United States in the late 1990s.) Medium-term forecasts are for demand for lamb to remain strong, and with it, prices.

Within the overall price trend for Merino wool, there are different patterns for different micron (fibre diameter) categories. Swan (2009) provides a comprehensive review of these trends and the market forces behind them. The overall effect on production has been that, although the total volume of wool finer than 20 μm rose slightly from 1991 to 2009, that for wool broader than 20 μm collapsed to approximately 25% of its former level.

Thus, whereas wool was historically a very important source of livelihood for farmers across much of Australia, over the last two to three decades that contribution has declined significantly. In response, sheep numbers (and particularly Merino sheep) have declined from the peak of 180 million in the mid-1980s to approximately 75 million sheep in 2009, with approximately 45 million of those being ewes.

Information on genetic diversity within the Merino population

As outlined earlier, the Australian Merino of the 20th century is a composite or synthetic evolved via a mixture of infusion, cross-breeding and selection to become an overall population comprising three broad types or strains:

1. Fine wool: small to medium frame sheep which produce fleeces in the fibre diameter range of 16–19 μm, with clean fleece weights averaging 2.5–3.0 kg in adult sheep grazing pastures. This strain is typically run in cooler, higher-rainfall areas and includes Saxon and Spanish bloodlines.
2. Medium wool: somewhat larger sheep producing fleeces averaging 20–22.5 μm and 3.0–3.5 kg fleece weight. These are predominantly Peppin bloodlines.
3. Strong wool: even larger sheep, producing fleeces averaging 22–24 μm and 3.0–4.0 kg fleece weight. These are predominantly South Australian bloodlines.

Note that these ‘bloodlines’ have typically been referred to as breeds. Particularly the Peppin and South Australian bloodlines were at times infused with genetic material from other recognized breeds (such as Lincoln). To Merino sheep breeders and producers, the distinction among these ‘breeds’, strains or bloodlines were quite clear; and a detailed history of the derivation of each was effectively part of industry knowledge (and folklore). In the genetic sense, there was always some limited mixing of genetic material between the broad categories. However, this has increased greatly in the last 20–30 years.

Within these types, ram-breeding studs traditionally formed a tiered structure, with parent studs at the peak of the pyramid, supplying rams to ‘daughter studs’ to multiply rams, who in turn supplied rams to commercial woolgrowing flocks.

There is a rich literature of information from trials and experiments characterising the performance of these different types of sheep. Such work, both ‘scientific’ and practical, included examination of the performance of different strains under different environments, exploring genotype × environment interaction. This distinction between ‘scientific’ and ‘practical’ is made only to highlight a divide or communications gap which existed between the scientifically trained and stud breeders in particular, with rare exceptions, for much of the 20th century. Massy (2007) provides a comprehensive discussion of this issue, as well as summarising the material on strain evaluations and genotype × environment interaction.

In terms of analysing and describing genetic diversity more technically, the main approach until recently has been via genetic parameter estimates. Before summarising these estimates, it is necessary to outline a recent evolution in the broad genetic structure of the industry.

The structure of breeds, strains and bloodlines which evolved during the 1800s and early 1900s was relatively stable until the last decades of the 1900s. In that period, distinctions between the categories began to blur, stimulated in part by somewhat uneven adoption of performance recording and more ‘scientific’ approaches to making selection decisions and in part by the increasing need to reduce fibre diameter. The latter led to increased use of rams from the finer categories over the broader categories. More recently the desire to breed a Merino which is more suited to a dual-purpose enterprise has resulted in some mixing in the reverse direction. This trend has led to the situation today where distinctions between categories are considerably blurred and appear to be in a state of flux.

One expression of genetic diversity is phenotypic appearance. Figure 3 compares two images of Merinos, the first from 1910; the second is a modern animal with high genetic merit and selected for dual-purpose (meat and wool) goals including easy-care attributes such as resistance to internal parasites.

Figure 3. Phenotypic expression of diversity in Merinos – (left) three stud rams from Merribee, 1910 (Massy, 2007) and (right) Leachcim 72 (Sheep Genetics, 2009). Permission for Figs 3 & 4 is granted by Meat & Livestock Australia (2009).

Genetic parameter estimation from 1980 to 2000 suggested that there were some genetic differences between categories, as expressed by heritability estimates. Those for fibre diameter were higher in the finer wools than elsewhere, but other parameters were relatively similar across categories.

In the last 10 years, performance recording has grown, and a single national genetic evaluation is now in place for Merinos. The genetic parameters used in that analysis describe the genetic variation for the major traits. Table 1 summarises those parameters for hogget weight, hogget fleece weight and hogget fibre diameter. A comprehensive description of genetic parameters is provided in Huisman *et al.* (2008), Huisman and Brown (2008, 2009a, 2009b). Safari *et al.* (2005) published a review of genetic parameters for sheep and estimated these parameters in a large data set from research flocks (Safari *et al.*, 2007).

The parameters summarised in Table 1 are a very small subset of those estimated from the Sheep Genetics database and reflect a mixture of flocks from across the 'traditional' categories, that have become less distinct (as noted above). However, these are broadly consistent with the many sets of parameter estimates for the Australian Merino population from the literature.

The key point in the context of genetic diversity is that these three key economic traits exhibit considerable genetic variation, both in terms of heritability and absolute genetic variation. The other trait with significant economic significance (although not viewed this way by most breeders for most of the last 100 years) is reproduction, which has been intensively investigated in Merinos since the 1960s. Estimates of heritability of various aspects of reproduction in Merinos are typically in the range 0.05–0.10, and this is the finding in the current Merino data (Huisman *et al.*, 2008). Although this is suggestive of low levels of genetic variation (and hence diversity), when it is recognised that phenotypic variance for all reproduction traits is large, it becomes clear that there is substantial additive genetic variation for aspects of reproduction in Merinos, again suggestive of genetic diversity within the population.

Table 1. Genetic (co)variances for hogget body weight, fleece weight and fibre diameter in Australasian Merinos.

	Body weight	Clean fleece weight	Fibre diameter
Bodyweight	**0.41 (0.02)**	0.31 (0.01)	0.11 (0.01)
Clean fleece weight	0.06 (0.06)	**0.32 (0.02)**	0.22 (0.01)
Fibre diameter	0.21 (0.03)	0.44 (0.03)	**0.62 (0.02)**

Note: Heritabilities are on the bold type diagonal, genetic correlations are below the diagonal and phenotypic correlations are above the diagonal. Figures in parentheses are the standard errors of the estimates.
Source: Sheep Genetics database (2009).

Further evidence of genetic variation consistent with that from genetic parameter estimates is provided by responses to selection. There is an extensive literature on selection experiments, but one recent example illustrates the findings. In 1992, NSW Agriculture researchers initiated a selection experiment which included five selection goals (including controls) applied in three strains of Merinos (nine lines in total). The selection goals represented a range of multi-trait objectives with varying emphasis on fleece weight and fibre diameter. Ten rounds of selection were applied. A comprehensive report of the project is available (QPlus Open Day, 2006), but its results can be summarised as follows:

- Substantial improvements in clean fleece weight and fibre diameter were achieved in all selection lines *in accord with their prescribed breeding objectives* (italics inserted).
- It was demonstrated that it is possible to achieve such improvements in conjunction with maintaining performance levels for a range of visually assessed traits, suggesting that 'modern' performance-based selection approaches need not be antagonistic to more traditional aspects of Merino sheep.

A similar project was conducted from 1996 to 2009 in South Australia, using selection lines established within predominantly South Australian strong wool Merinos (Selection Demonstration Flocks, SARDI, 2009). A series of selection lines were established with a range of multi-trait objectives, and responses to selection were again consistent with predictions based on estimated genetic parameters.

These results, together with those from many other selection experiments, provide evidence that the genetic parameters estimated in Merinos are an accurate assessment of available genetic variation and hence of genetic diversity within the population.

More recently, molecular technologies are beginning to be applied to the sheep genome, and these will shed more light on diversity within and between populations and breeds (International Sheep Genomics Consortium, 2002–2009). At time of this writing no definitive estimates of various measures of diversity (effective population size and linkage disequilibrium) were available, but early indications are that genetic diversity in Merinos sampled from Australia is high (Kijas, 2009).

Research into genetic parameters (and hence diversity) in Merino is but a part of the considerable research and development effort that has been conducted since the early years after World War II. Other aspects include the design of breeding programs, development of performance recording and evaluation schemes and extension programs to breeders and commercial producers. A most useful reference covering the full scope of that work is the Merino Improvement Programs in Australia Symposium Proceedings (McGuirk, 1987).

This section has superficially outlined the volume of results on genetic parameters in Merino sheep, focusing solely on summarising what that literature implies in terms of genetic diversity. All of the evidence suggests that, no matter what traits are considered, there is considerable diversity within the Australasian Merino gene pool. The last section will briefly describe how that diversity is being exploited more recently.

Recent developments in genetic improvement in Australasian Merino sheep

As noted earlier, the adoption of approaches to animal breeding based on quantitative genetic theory has been limited. During the period from 1950 to the 1990s, some breeders applied performance recording and developed breeding programs utilising principles derived from animal breeding theory. However, overall, their impact and hence that of animal breeding theory was small.

Beginning in the mid-1980s, the Australian lamb industry introduced a national genetic evaluation system, LAMBPLAN (Sheep Genetics, 2009), which has grown from very simple beginnings to now running large multi-trait animal model BLUP evaluations for all major 'meat breeds' and has high adoption amongst stud breeders. The development of LAMBPLAN stimulated interest from Merino breeders, initially predominantly those already convinced of the merits of performance recording. Over the period from 1995 to the present, this interest has encouraged the growth of genetic evaluation for Merinos to the point where there is now a single national across-flock genetic evaluation system in place: MERINOSELECT (Sheep Genetics, 2009).

Genetic evaluation analyses in MERINOSELECT are run monthly; include over 50 traits covering weight, carcass, fleece weight and quality, reproduction, disease and welfare; and include over 1.2 million animals in each analysis. This total is growing by approximately 80 000 new animals each year, and more than 15 000 sires are included in the data set.

The numbers of animals being evaluated suggest a diversity of genetic material. This is reinforced by the fact that considerable research has had to be conducted into how best to handle the genetic structuring of the population within the analyses. Currently, genetic groups – broadly reflecting the historical breeds, strains and bloodlines – are included in the analytical models, whilst comprehensive pedigree information (either sire or sire plus dam information are required for inclusion into the full across-flock analyses) simultaneously accounts for the increasing mixing amongst these historical categories.

The evidence for genetic progress available from the genetic analyses is as important as the growth in numbers of animals being evaluated within the Merino population. Swan *et al.* (2009) summarise genetic trends in the range of sheep populations using LAMBPLAN and MERINOSELECT, and they present results suggesting that the rates of progress in Merinos are increasing. Figure 4, that is based on Swan *et al*. (2009), shows genetic trends in the industry for two indexes in flocks using MERINOSELECT.

The market penetration of MERINOSELECT is now estimated at approximately 35% of all Merino rams being sold. However, this proportion is rising as the overall numbers of Merino rams which are sold declines essentially in line with declining ewe numbers.

The Australasian Merino population and sheep industry are at a most interesting point in their history. The intersecting challenges and opportunities present, and the role of genetic diversity in addressing them, are outlined briefly in the concluding section.

Conclusions

There are four main messages of this brief discussion of the wool industry in Australasia and its genetic diversity:

1. The industry has been a major contributor to the economic development of both Australia and New Zealand, at times essentially the sole source of export income.
2. Over the last three decades that contribution has declined as prices for broader wools have collapsed and finer apparel wools have fallen to lower levels

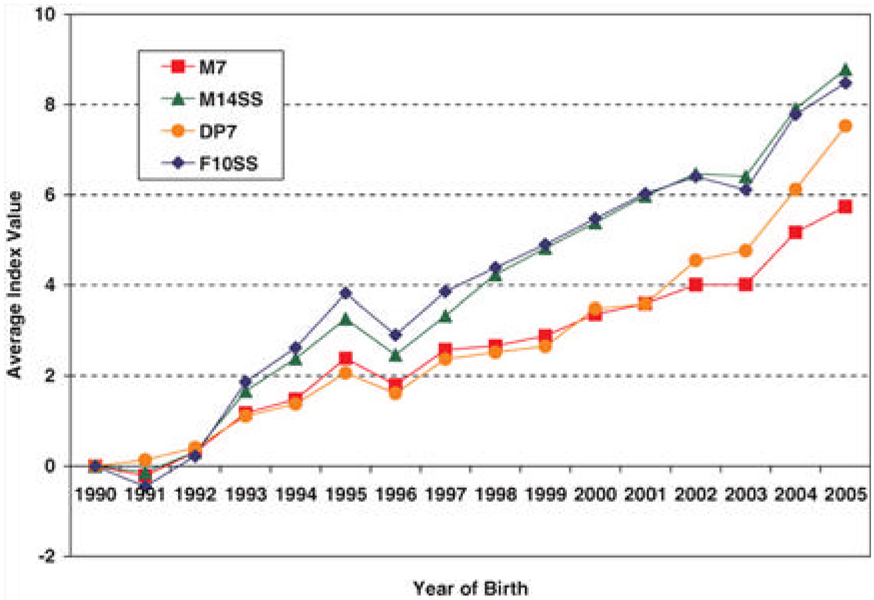

Figure 4. Genetic trends in industry flocks using MERINOSELECT (based on Swan *et al*., 2009. A full explanation of the four indexes is provided in the reference). Permission for Figs 3 & 4 is granted by Meat & Livestock Australia (2009).

than historically and apparently stabilized in real terms, while returns from other enterprises have grown.

3. The Australasian Merino population has developed through sampling a range of populations coupled with selection and exhibits substantial genetic diversity at both the pedigree and molecular levels.
4. In the last decade, a comprehensive national genetic evaluation system has been established, which is being adopted by a growing proportion of stud breeders and being used with increasing effectiveness to make substantial genetic improvement in a range of production and fitness traits.

What the future holds for the Merino industry cannot be predicted, but it is clear that two trends are at play: the decline in wool prices and sheep numbers could lead to the disappearance of wool production as a viable industry. This would represent the outcome of a failure to respond to consumer signals about product quality and more broadly about the way in which the product is produced. This would be a somewhat sad end to the story of Merino sheep in Australasia. Moreover, in the context of the human contribution to that story it would represent a failure to maintain the exploratory and innovative spirit which played such a significant role in its development (Massy, 2007).

The alternative is that essentially a new generation of breeders and producers must respond positively to the challenges of ethical and environmentally sustainable production coupled with the demand for constant improvement in product quality and price competitiveness. In doing so, they will inevitably have to make intelligent use of modern breeding methods combined with traditional animal assessment skills. There is clear evidence that a significant number of breeders are meeting this challenge. Making increasingly effective use of the genetic diversity contained within the Merino population will be central to this version of the future.

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Genetic improvement for alpaca fibre production in the Peruvian Altiplano: the Pacomarca experience

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Summary

Pacomarca is an experimental ranch founded by the INCA group to act as a selection nucleus from which basic genetic improvement of alpaca fibre can spread throughout the rural communities in the Peruvian Altiplano. State-of-art techniques in animal science, such as performance recording or assisted reproduction including embryo transfer, are applied to demonstrate their usefulness in the Altiplano conditions. Pacomarca has developed useful software (Paco Pro) to carry out the integral processing of production and reproduction data. Mating is carried out individually, and gestation is diagnosed via ultrasound. Breeding values estimated from a modern genetic evaluation are used for selection, and embryo transfer is applied to increase the selection intensity. However, the objective of Pacomarca goes beyond, extending its advances to the small rural communities. Training courses for farmers are organised while searching for new ways of improving the performance of alpacas both technically and scientifically.

Keywords: *alpaca, fibre, genetic improvement, Peruvian Altiplano*

Résumé

Pacomarca est un ranch expérimental créé par le groupe INCA en tant que noyau de sélection pouvant répandre les bases de l'amélioration génétique pour la fibre d'alpaga dans toutes les communautés rurales du haut-plateau péruvien. A Pacomarca, on applique des techniques de pointe de la zootechnie, comme le contrôle des performances ou la procréation médicalement assistée, y compris le transfert d'embryons, pour démontrer leur utilité dans les conditions productives du haut-plateau. Pacomarca a élaboré un logiciel (Paco Pro) utile à entreprendre l'élaboration intégrale des données sur la production et sur la reproduction. Les accouplements sont réalisés de façon individuelle, la gestation est diagnostiquée par le biais de l'échographie, les valeurs génétiques, estimées par des techniques modernes d'évaluation génétique, sont utilisées pour la sélection, et le transfert d'embryons est appliqué pour accroître le taux de sélection. Cependant, l'objectif de Pacomarca va au-delà de ces activités et vise à transmettre ces progrès aux petites communautés rurales. On organise des cours de formation pour les agriculteurs tout en cherchant de nouvelles façons d'améliorer la performance des alpagas du point de vue technique ainsi que scientifique.

Mots-clés: *alpaga, fibre, amélioration génétique, Altiplano péruvien*

Resumen

Pacomarca es un rancho experimental fundado por el grupo INCA para actuar como un núcleo de selección que permita extender la mejora genética de la fibra de alpaca en el altiplano peruano. En Pacomarca se aplican técnicas estándar en producción animal, como el control de rendimientos o la reproducción asistida incluyendo la transferencia de embriones, para demostrar su utilidad en las condiciones productivas del altiplano. Pacomarca ha desarrollado una aplicación informática (Paco Pro) que permite una gestión adecuada de la información productiva, reproductiva y genealógica necesaria para llevar a cabo un programa de mejora genética: los apareamientos se llevan a cabo de forma individualizada, la gestación se diagnostica mediante ecografía, los méritos genéticos estimados mediante modernas técnicas de evaluación genética se usan para la selección de reproductores y la transferencia de embriones se utiliza para aumentar la intensidad de selección. En todo caso, el objetivo de Pacomarca se cumple esencialmente organizando periódicamente cursos de formación para miembros de pequeñas comunidades rurales del altiplano en los que se produce la diseminación de sus avances en manejo, reproducción y producción de la alpaca resultado de las experimentaciones realizadas en Pacomarca.

Palabras clave: *alpaca, fibras, mejora genética, Altiplano Peruano*

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Introduction

Within the four South American camelid species of llamas, guanacos, alpacas and vicuñas (Kadwell *et al.*, 2001), the alpaca is the most numerous. With a population of 3.5 million in Peru, representing 75% of the world's total, the alpaca provides the main means of sustenance for thousands of families in the high Andes. Other countries which breed alpacas are mainly Bolivia and Chile in South America, and, after exportation, New Zealand, Australia, the United States, and Canada.

Thousands of rural Peruvian families raise flocks of alpacas at elevations of more than 4000 m above sea level among impressive landscapes where the daily temperature ranges between −15°C and 20°C. They do what has been done for thousands of years, shearing the animals and selling their fibre every year, to provide their families with their principal income.

There are two breeds of alpaca: the Huacaya and the Suri (Wuliji *et al.*, 2000). The Huacaya are the most numerous type in Peru, representing 93% of the population; their hair has relatively short fibres which are dense, curly and voluminous. Hair covers almost all of the body, and only the face and lower parts of the legs have a covering of short fibres. Suri alpacas have long, straight hair which is silky and exceptionally lustrous. If Suri fleece is allowed to grow, it can sweep the floor and drape like curtains. This type of Suri is called "Wasi", and it has been used in the past to protect the herds.

Under the current usual management, alpacas are shorn with knives or shears, usually once a year between November and April. The colour of the fibre is variable; up to 22 colours have been defined which range from white to black through greys, fawns and browns. The fibre is classified manually according to its fineness and sorted into the qualities shown in Table 1. One animal will have all of the qualities in different percentages throughout its body. Therefore, meticulous manual sorting is necessary to separate the different qualities, colours and lengths. The finer qualities have more value in the international market, so finer alpacas have higher market value. The names of these quality classes do not necessarily reflect the age of the animals or other phenotypic characteristics. The appellation 'Baby', for example, is applied to products (tops, yarns, cloth etc.) where the average fibre diameter is 22.5 µm. The fibre used to obtain this quality does not necessarily come from baby animals; it could easily come from an adult animal with a very fine coat.

Table 1. Alpaca fibre categories according to textile industry (Inca tops super-fine alpaca).

Category	Fibre diameter (µm)
Royal alpaca	19.5
Baby alpaca	22.5
Super-fine alpaca	25.5
Huarizo	29
Coarse	32
Mixed pieces	>32

There is increasing international interest in the study and production of fine alpaca fibre (Wuliji *et al.*, 2000; Frank *et al.*, 2006; Lupton *et al.*, 2006; McGregor, 2006). In the last 45 years alpaca fibre has become thicker, warning about the need of establishing a genetic selection program. The low educational level of alpaca farmers makes the implementation of a bottom-up initiative difficult, and it is only conceivable with the joint efforts of public administration and market operators. This was the initial reason that led the INCA Group to found its ranch known as Pacomarca, that today is one of the most important sources of genetically improved Alpacas in the Altiplano.

Pacomarca

Origin

Pacomarca (Figure 1) is an experimental farm run by the INCA Group in the department of Puno since 1992. It occupies approximately 1500 ha (3706 acres) and lies at an altitude of 4060 m (13 320 ft) above sea level on the Altiplano. The farm raises approximately 2050 selected alpacas. The objective of the INCA Group was to try to reverse the tendency to abandon alpaca raising, that was occurring in Peru. Pacomarca S.A. decided on its own initiative to undertake a project to recover the fineness of the alpaca fibre produced in Peru. This effort is also a continuation of the original work of the Sallalli farm, located at the foot of the Sabancaya Volcano, which was destroyed when the volcano erupted some years ago. The site is appropriately located in the high Andean plains (Altiplano) with an easily accessible location, that is close to the main alpaca-raising areas, electricity supply, land area sufficiently large to be able to grow crops, a water supply and title deeds in legal order.

The initial genetic stock was composed of animals selected and bought according to the information available from the

Figure 1. A panoramic view of the Pacomarca Ranch.

purchasing fibre activity of the INCA Group during 50 years. Animals were individually identified from the beginning. Software called "Paco Pro" was developed to manage all of the information generated by the herd in order to administer animal performance, mating and health. This data set now consists of about 2.5 million records of variable nature.

The Pacomarca experimental ranch (Figure 1) is considered the leading genetic improvement center in Peru, and its influence in the Alpaca breeding and scientific world is proving essential for the future of this precious resource in its native country. The final goal is to act as a resource from which basic genetic improvement can be spread throughout rural communities in the Peruvian Altiplano.

Objectives

Even though the original aim of the ranch was to develop a population with high genetic value, the day to day running of the ranch taught their managers about several other perspectives of alpaca production and other objectives were discovered which could be carried out at the ranch. Some of them are summarised as the following:

1. to carry out a genetic selection scheme to improve fibre quality;
2. to learn management practices which help to better commercialise alpaca fibre;
3. to teach successful management practices to the farmers on small surrounding farms;
4. to become a farm which acts as a selection nucleus; and
5. to research genetics, reproduction and other animal sciences.

Performance recording

Today the organisation of performance recording reaches many of the daily practises carried out on the ranch. Animals are sheared every year which registers their performance, and a sample of wool is taken from the animal rib cage and sent for analysis in the laboratory. The animals are also periodically weighed and measured, and the mating is always individually carried out in specific boxes and the gestation is controlled by scan. Veterinary treatments are also carefully noted. All of the information is gathered in the data set managed by the Paco Pro software. This information covers the following:

- pedigree with identifications of individual, father and mother, birth date and sex;
- individual mating information, pregnancy tests and births;
- individual performance of fibre diameter, standard deviation, comfort factor and coefficient of variation;
- individual performance of the different fibre qualities of the fleece;
- individual shearing performance by corporal zones;
- individual heights and weights at different ages;
- disease registration and medical treatments;
- registering their origin and culling with destination and causes of culling; and
- defects.

In addition, Paco Pro registers the phenotype traits of the individual alpaca. The type traits, that are assessed using subjective scores from 1 (poor) to 5 (excellent) by expert classifiers, include the following:

Density scores the amount of follicles per square millimeter. The fleece is sampled at three locations (shoulder, mid-point and rump) by manual pressing and assessing the amount of fleece the hand can grab at once.
Crimp scores the number of fibre waves per centimeter. Crimp includes amplitude and frequency: amplitude is the height of the wave as measured from the crest to the trough and frequency is the number of waves for a given measurement. The trait we are looking for is high frequency and medium amplitude. Only Huacaya alpacas are scored for crimp.
Lock structure scores the formation of individual fibres into groups. A "lock score" includes the lock definition from the skin out to the tips of each lock, the independence of the locks from each other and the density and heaviness within the lock. We are looking for uniform independent locks throughout the body. Only Suri alpacas are scored for lock structure.
Head assesses the biometrical relationship between the head and the shape of the alpaca. The alpaca must have a small rounded head. The main areas of evaluation are the ears and snout. An animal with a score of 5 will have a short snout and proportional ears, giving the appearance of a rounded head.
Coverage scores the presence or absence of fibre in the alpaca extremities and head. A coverage score of 5 indicates much fibre in the extremities, potentially even covering the toes and the head to the point of producing wool blindness. A score of 1 designates an open face and very little fibre on the legs.
Balance scores the overall appearance of the alpaca: how the animal looks as a whole, including the proportionality of the body, neck, limbs and head.
Comfort factor is the percentage of fibres with a diameter below 30 μm.

Example of information extracted from the data set

We include brief examples of the information extracted from the Pacomarca data set, after a superficial analysis.

- Although the age of the parents at the birth of their offspring is an average of 6.2 years, the generation interval defined in the same way (but only for the animals that were selected as parents) is only 4.7 years, revealing the rapid replacement strategy adopted at the ranch.

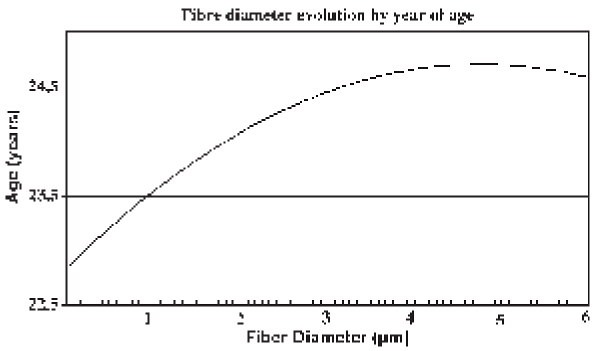

Figure 2. Mean values of the fibre diameter regarding age. Note: $FD = 22.8 + 6.6 \times 10^{-2}\ M - 5.72 \times 10^{-4}\ M^2$, where FD is the fibre diameter (µm) and M is the age (months).

- Factors affecting the fibre traits are the age, breed, colour, and month and year of shearing; sex, lab or body region have no significant effect.
- Factors affecting the weight and length of fleeces are the age, breed, and month and year of shearing, but not the sex.
- Only the age and the month and year of data recording affect the weight and height of animals.
- Fibre diameter increases with age. After fitting all other effects, the mean values of the fibre diameter regarding age in years are presented in Figure 2.
- Least squares estimates of the fibre traits within sex, breed, corporal region and month and year of shearing are provided in Tables 2 and 3.

Table 3. Number of animals (N), least squares means of fibre diameter (FD), standard deviation of fibre (SD), comfort factor (CF) and coefficient of variation (CV) within categories of month and year of shearing.

Month	Year	N	FD	SD	CF	CV
February	2001	85	19.88	4.10	94.23	19.88
August	2001	6	21.11	3.09	94.70	3.13
January	2002	106	20.76	4.96	94.48	20.76
October	2002	192	21.69	5.61	91.01	24.35
November	2002	7	24.22	5.40	87.30	22.51
December	2002	686	22.68	5.43	90.60	23.92
August	2003	121	21.13	5.08	94.07	24.03
September	2003	818	21.35	5.07	93.97	23.78
November	2003	9	23.33	5.49	90.00	23.34
December	2003	222	23.47	5.34	88.88	22.76
January	2004	103	20.60	5.00	94.23	24.33
June	2004	14	24.85	5.96	83.24	24.85
November	2004	139	19.31	4.72	96.55	19.31
December	2004	191	24.27	5.95	84.91	24.46
January	2005	198	23.13	5.17	89.47	23.13
May	2005	12	18.70	4.73	97.58	18.70
September	2005	259	21.61	5.44	92.14	25.03
October	2005	954	24.66	5.70	84.06	23.00
November	2005	52	18.74	4.77	96.60	18.74
March	2006	20	22.09	5.10	87.93	23.53
May	2006	159	21.08	5.63	93.09	21.08
June	2006	243	23.27	5.65	85.92	23.27
July	2006	104	21.98	5.46	89.50	21.98
August	2006	40	20.23	5.41	94.72	20.23
September	2006	1188	25.87	6.12	78.06	25.87
October	2006	8	24.81	5.71	84.22	22.71

Outstanding advances

Inca shearing method

The experience of the INCA Group in buying fibre throughout Peru showed that an important economic loss was due to practical lack of care at shearing, that is a management practice carried out once a year, usually in October.

Many farmers with a very low number of animals carry out shearing with the most rudimentary practices, such as using glass, tins or scissors in the best cases, and harming the animals. Moreover, disordered shearing and wool packing lead to heavy waste in a posterior treatment of the fleece. Alternatively, a correct ordered shearing practice allows a quick classification of the fleece, saving costs in personal and mechanical resources.

Table 2. Number (N) of animals, least squares means of fibre diameter (FD), standard deviation of fibre (SD), comfort factor (CF) and coefficient of variation (CV) within categories of breed, sex and corporal region of sample.

	N	FD	SD	CF	CV
Breed					
Huacaya	4718	22.82	5.27	89.03	23.12
Suri	1232	24.47	6.46	82.17	26.32
Sex					
Male	1068	22.39	5.50	88.60	24.52
Female	4882	23.34	5.52	87.39	23.62
Region					
Rib cage	4854	23.41	5.55	86.65	23.69
Thigh	548	21.96	5.36	92.26	24.12
Shoulder	548	22.21	5.44	91.51	24.27

Pacomarca has developed a shearing protocol called “Inca esquila” (Figure 3) which allows better performance of the animal and thus a better price for the fleeces of the animals. It is described in several steps:

1. Clean the shearing area.
2. Clean the animal with a brush to eliminate all debris.
3. Separate the fleece into three parts: blanket, neck and pieces.
4. Stretch one side of the animal on the mat; place the dumbbells on the four legs of the animal.
5. Shear the belly and skirts first and separate them in a plastic bag.
6. Shear the animal from the belly to the back without the neck, and turn the animal to shear the other side without damaging the fleece.
7. Take the sheared fleece to a table and clean and take out any guard hair.
8. Put plastic in the middle of the fleece before folding it.
9. Wrap the fleece “drum” style.

Figure 3. The shearing protocol called "Inca Esquila".

10. Repeat the same procedure for the neck.
11. Put the three separate bags (skirts, neck and fleece) into one plastic bag.

The INCA shearing method allows better yield of finer qualities such as Royal Alpaca and Baby Alpaca at the classifying process, allowing a better return to the alpaca producers.

Paco Pro data processing software

Data processing software was needed since the start of the ranch. Pacomarca invested in developing Paco Pro software, that carries out the integral data processing of the management of the ranch. Paco Pro is thus a strategic software system for the control and management of alpacas. The program keeps production and genealogical information about the alpacas such as their unique identifier, parents, sex, colour, breed, date of birth, date of death and progressive records of fibre diameter, fibre production, mating, diseases, births and much more.

All of the information recorded about individual alpacas can be rendered individually or in a set. Several groups may be created in many different ways, taking into consideration the location, type of nutrition, hierarchy, breed, colour, age and other characteristics.

Paco Pro also has specialised search tools for each module to allow the best management system for the animals. It can identify and explore a specific animal, its relatives and its entire genealogical tree. In addition, the system has a base animal attributes search, a finesse search tool and a production tool with records like fleece weight or staple length. All of the recorded data allow for easy access to records of a single animal and help to identify the elite group.

This integrated information makes control of the mating campaign easy and allows the planning of individual matings, taking into consideration the performance of previous campaigns. As a result, it provides demographic statistics so that we can plan accordingly for the following campaign.

All of the individual records are linked with each other in a relational database and are ready to render the expected progeny difference of each animal, so that a proper ranking of the best genetic material of the ranch can be obtained.

Animal breeding program

Pacomarca animals are bred according to their performance. Since 2007 the company has had an agreement with the University Complutense of Madrid to carry out genetic evaluations of their animals. The filters incorporated in Paco Pro provide a data set which is almost completely free of errors and makes data processing and generation of precise genetic evaluation easy to complete.

Genetic evaluation is carried out mainly for fibre related traits, including mean diameter and variability, but other traits have been also essayed such as fleece weight, fibre length, shearing interval, textile value or morphological traits (Gutiérrez *et al.*, 2009).

The international Best Linear Unbiased Prediction (BLUP) methodology was chosen to obtain the expected progeny

Table 4. Estimated heritabilities (diagonal) and genetic correlations (above diagonal) for several fibre and type traits in the Pacomarca data set.

	FD	SD	CF	CV	DE	CR/LS	HE	CO	GA
FD	**0.428**	**0.774**	**−0.974**	0.135	0.001	**−0.250**	**−0.201**	0.068	−0.080
SD		**0.459**	**−0.826**	**0.725**	−0.125	**−0.410**	−0.064	0.132	−0.017
CF			**0.306**	**−0.239**	−0.009	**0.284**	0.156	−0.105	0.046
CV				**0.369**	**−0.212**	**−0.395**	0.124	0.151	0.070
DE					**0.221**	**0.704**	**0.226**	**−0.073**	**0.234**
CR/LS						**0.339**	**0.345**	0.087	**0.367**
HE							**0.379**	**0.757**	**0.942**
CO								**0.418**	**0.809**
GA									**0.158**

Note: FD, fibre diameter; SD, standard deviation; CF, comfort factor; CV, coefficient of variation; DE, density; CR/LS, crimp (Huacaya) or lock structure (Suri); HE, head; CO, coverage; GA, general appearance.

differences of the individuals within breed. Previous estimation of genetic parameters is always mandatory, and the range of estimated heritabilities at the Pacomarca ranch allows for optimism. A sample of heritabilities in fibre and type traits (Cervantes *et al.*, 2009) estimated by restricted maximum likelihood using the VCE program (Neumaier and Groeneveld, 1998) is provided in Table 4.

The BLUP evaluation accounts for some non-genetic effects such as the sex of the animal, the coat colour and the month and year of shearing, allowing isolation of the additive genetic value. The influence on the animal which is not of genetic origin (the permanent environmental effect) is also removed. The breeding values are accompanied by a value measuring their reliability, allowing ranch managers to carry out an appropriate genetic selection. To our knowledge, this is the only Alpaca ranch in the world with a genetic value for each of its animals.

Embryo transfer

After the genetic evaluation experience, Pacomarca acquired the ability to identify its best animals. However, a quick genetic response is limited by the number of their offspring. In a natural way, only one cria is born for each female and year. If embryo mortality is also considered, then only one offspring is expected for each two fertile females.

To face this limitation, Pacomarca started an assisted reproduction program by means of embryo transfer. The males and females with the best breeding values are selected. Up to six embryos (average of four) are obtained from each elite female and transferred to females with high maternal abilities. In this way each elite female can provide a mean of four offspring yearly. Table 5 provides a summary of the data for 2009 concerning embryo transfer, showing 68% successful pregnancies by embryo transfer this year. Pregnancy is diagnosed by means of ultrasound regardless of whether the mating was natural or via embryo transfer.

Farmers training program

The small Andean farmers are the beneficiaries of technical and scientific advances achieved in Pacomarca. The

Table 5. Summary of embryo production in the 2009 campaign.

	Number	%
Donor females	31	
Recipient females	145	
Flushes	131	
Collected embryos	101	77.10
Transferred embryos	101	77.10
Gestations	69	68.32

Figure 4. Pacomarca's breeding training program.

training farmers program (Figure 4) has been enthusiastically accepted by farmers in Peru and other countries. Communities and organised groups spend time at the ranch attending specialised courses with the aim of transferring all advances. The improvement of the managing practices of these farmers will consequently help improve the entire textile world.

Future advances

The successes obtained by Pacomarca in just a few years have provided increasing encouragement which leads to new objectives. Some of them are the following:

- To monitor animals that are transferred to other farmers in order to know if the improvement accomplished at Pacomarca is maintained in other places.
- To incorporate animals of other farmers into the performance recording, particularly those with genetic relationships with the animals of the ranch.
- To investigate the high heritabilities found in the fibre traits which suggest the presence of genes with major effects. An initial objective in this sense would be to locate the carriers of such genes and select them, but a deeper molecular search of these hypothetical genes is not ruled out.
- To carry out a genetic evaluation using a technique known as canalisation, that is thought to reduce the variability (SanCristobal *et al.*, 1998; Gutiérrez *et al.*, 2006), and to compare the resulting breeding values with BLUP breeding values to assess the possibility of replacing the traditional BLUP technique.
- To innovate breeding and operational techniques in order to increase the economic output of these animals.

Pacomarca is thus becoming the most important selection nucleus in Peru, but extending its advances to the rural community is still dependent on the educational level. Additional efforts are needed in this area.

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