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Swedish University of Agricultural Sciences

Faculty of Veterinary Medicine  
and Animal Science  
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# Fibre quality and fertility in male alpacas in Cusco region, Peru

*Fanny Bengtsson*



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# Fibre quality and fertility in male alpacas in Cusco region, Peru

## Fiberkvalitet och fertilitet hos alpackahannar i Cuscoregionen, Peru

*Fanny Bengtsson*

**Supervisor:** Prof. Jane Morrell, Department of Clinical Sciences

**Assistant Supervisor:** Assoc. Prof. Renée Båge, Department of Clinical Sciences

**Assistant Supervisor:** Assoc. Prof. Joel Pacheco Curie, Universidad Nacional Mayor de San Marcos

**Examiner:** Prof. Eva Axnér, Department of Clinical Sciences

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## SUMMARY

The aim of this study was to evaluate if there is any correlation between fibre quality and male mating behaviour (as a marker of fertility) in alpacas. The theory was that the more masculine males would have coarser fibres with a larger diameter because of higher testosterone levels. The higher testosterone could result in them be able to mate with more females than males with finer fibres, thus passing on their genes for poor fibre quality. No studies on this subject or articles discussing the relationship between mating behaviour and fibre quality in this particular species have been found in the literature. The animals used in the study were 189 adult male alpacas in the Cusco region of Peru. The animals belong to two different universities, the National University of San Marcos in Lima (UNMSM) and the National University of San Antonio Abad of Cusco (UNSAAC). The fertility data included only the animals belonging to the San Marcos University and consisted of hand-written records from the breeding season January – April 2015. The data were converted into individual quotients for each male. Fibre samples were taken from all males in September 2015. The samples were washed and analysed using the OFDA 2000 fibre quality analyser. No significant correlation between fertility quotient and any of the fibre quality parameters was observed (p-value for quotient and fibre diameter correlation = 0.9590). The alpacas' body condition score (BCS) was graded in a parallel study, and the results were used to evaluate the correlation between BCS and fibre quality. There was no significant difference in fibre diameter between animals with different BCS (p=0.1953). It is known that young alpacas have the finest fibres, which was also the case in this study. This result was significant (p < 0.0001). Fibre samples were taken from both white (n=137) and coloured (n=57) alpacas. The white alpacas had significantly longer (p=0.0093) and thinner (p=0.0001) fibres.

## SAMMANFATTNING

Syftet med studien var att undersöka om det finns något samband mellan fertilitet och fiberkvalitet hos alpackahannar. Inga studier eller artiklar som diskuterar sambandet hos denna art har hittats i litteraturen. Djuren som ingick i studien bestod av 189 vuxna alpackahannar i Cuscoregionen i Peru. Djuren tillhörde två olika universitet, Universidad Nacional Mayor de San Marcos i Lima och Universidad Nacional de San Antonio Abad del Cusco. Fertilitetsdatan inkluderade endast djuren tillhörande San Marcos-universitetet och baserades på handskrivna journaler från avelssäsongen januari – april 2015. Datan omvandlades till individuella kvoter för varje hanne. Fiberprover togs från samtliga hannar i september 2015. Proverna tvättades och analyserades med hjälp av fiberkvalitetsanalyser OFDA 2000. Ingen signifikant korrelation mellan fertilitetskvot och fiberkvalitet kunde ses (p-värde för korrelation mellan fertilitetskvot och fiberdiameter = 0,9590). Alpackornas hull - body condition score, BCS - bedömdes i en studie som utfördes parallellt med denna. Denna information användes för att undersöka korrelationen mellan BCS och fiberkvalitet. Det var ingen signifikant skillnad i fiberdiameter mellan alpackor med olika BCS (p=0,1953). Det är välkänt att unga alpackor har de finaste fibrerna, vilket också visade sig vara fallet i denna studie. Detta resultat var signifikant (p<0,0001). Fiberprover togs från både vita (n=137) och färgade (n=57) alpackor. De vita alpackorna hade signifikant längre (p=0,0093) och tunnare (p=0,0001) fibrer.

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## **ABBREVIATIONS**

CF – comfort factor

CV – coefficient of variation

FD – fibre diameter

MFD – mean fibre diameter

NWC – New World Camelids

OWC – Old World Camelids

SAC – South American Camelids

SD – standard deviation

## INTRODUCTION

The Peruvian alpaca population constitutes nearly ninety percent of the world's alpacas. The alpaca was domesticated about 6000 years ago, and the breeding of alpacas for its wool, called fibre, proceeded from the Inca period. At this time, breeding was extremely successful and animals of excellent fibre quality were bred. After the Spanish conquest, fibre quality decreased due to loss of knowledge, crossbreeding with llamas, and exportation of animals with genes for good fibre quality, among other factors.

The indigenous peoples of the Andes are totally reliant on alpaca herds for their livelihoods, in the form of fibre production and meat. Many of them live in harsh environments, below the poverty line. Improvements in fiber quality would allow many of them to escape the poverty trap. The interest in alpacas is increasing around the world, including Sweden, both for their fine fibres which are of interest in the textile industry, but also as companion and show animals.

The alpaca has a long generation time and, according to the literature, a low fertility rate. It is therefore of much interest to increase fertility in alpacas, along with fibre quality.

## LITERATURE REVIEW

### About the alpaca

#### History

Alpacas belong to the order Artiodactyla (even-toed ungulates). This order is divided into three subgroups; Suiformes, Ruminantia och Tylopoda. Suiformes contains animals such as pigs and hippos and Ruminantia contains cows and deer. The subgroup Tylopoda consists of one single family, the Camelidae family. This is divided into two different genera, which were separated from each other about 3 million years ago. One is named Old World camelids (OWC) and consists of the Asian and African camelids such as the two humped camel (*Camelus bactrianus*) and the dromedary (*Camelus dromedarius*). The genera New World camelids (NWC) or South American Camelids (SAC) consists of four animals, of which two are wild and two are domesticated. The wild species are the vicuña (*Vicugna vicugna*) and the guanaco (*Lama guanicoe*). The two domesticated SAC are the llama (*Lama glama*) and the alpaca (*Vicugna pacos*) (Fowler 1989, Wheeler 1995).

The alpaca and the llama were domesticated about 6000 years ago (Wheeler 1995). At the time of the Spanish conquest, Incas were breeding both species for wool, although the llama was primarily used as a beast of burden. The alpaca was bred for its unique fine fibre, and both the llama and the alpaca were also bred for their meat (Wheeler, 1995).

#### Basics

Alpaca males are traditionally called machos, females are called hembras and new-borns are called crias. There is also a name for juvenile alpacas, tuis.

All four species of SAC have 37 pairs of chromosomes (Taylor 1968) and produce fertile offspring when interspecies breeding occurs (Fowler 1989). A hybrid of alpaca and llama is referred to as a Wari. First generation hybrids are easily recognized, but identifying subsequent generations is not always possible. Interspecies breeding has probably been going on since the Spanish conquest (Wheeler 1995). At least one case of a successful hybridization by artificial insemination between New World camelid and Old World camelid has occurred (Skidmore *et al.* 1999).

All species of camelids have similar anatomy, despite the size differences. Camelids are foregut fermenters. They have a three-compartment stomach and similar gastric digestion to ruminants. Ingested forage is regurgitated and re-chewed, but digestion is more efficient in extracting protein and energy from poor forage than in ruminants. Camelids are also different from ruminants in that they have soft pads with toenails instead of hooves, and the second and third phalanges are horizontal. Alpacas prefer soft ground because of their sensitive feet and they also prefer moist and tender grasses to dry or rough pasture (Fowler 1989). Camelids do not have horns or antlers, and the upper lip is split in two (Wheeler 1995).

The erythrocytes of all camelids are smaller and appear in larger amount than in other mammals and they have an elliptical shape. This shape and size result in fewer problems during dehydration, when blood viscosity increases, and is thus an adaptation to life in dry areas (Fowler 1989).

## **Suri and Huacaya**

There are two different phenotypes of the alpaca. By far the most common is the Huacaya which has soft, compact and highly crimped fibres. The coat grows perpendicularly from the body. The less common Suri phenotype has less crimped, silky fibres which make corkscrew-shaped, long locks hanging parallel to the body. Both phenotypes are single-coated, in contrast to their ancestor the vicuña, which possesses a double-coated fleece. Huacaya is often considered the wild type, while Suri is thought to have developed from Huacaya through gene mutation (Presciuttini, Valbonesi et al. 2010).

The heredity of the two different phenotypes is still unclear, but Presciuttini *et al.* (2010) suggests that the Huacaya phenotype derives from homozygous recessive alleles at two linked loci. According to Fernandez-Baca (1994) the Suri phenotype is less well adapted to high altitudes (> 4200 m.a.s.l.) in that it shows lower reproductive efficiency and higher mortality among new-born crias than Huacayas. This may have led to a decrease in the number of Suris in Peru over the last 30 years, from 22% to 5% of the alpaca population.

## **Alpacas in Peru**

Peru's alpaca population consists of approximately 3 million animals (Quispe *et al.* 2009), which constitutes nearly 90% of the world's alpaca population (Montes 2013). The alpacas' economic value lies in its wool, more often named fibre. Around 90% of the alpaca fibre is exported and the major importing countries are China, Italy and Japan. Most of the fibre exported is in the form of brushed fibre or yarn. Between the years 1996 – 2001 the yearly amount of fibre produced was around an average of 3369 tons (Fairfield 2006).

Fibre prices are constantly changing, due to demand on the world market and the limited amount of fibre produced. This creates a four to five year cycle where prices vary depending on market and production factors, as well as speculation by the industries (Fairfield 2006).

Alpaca herders, or alpaqueros, live mainly in the highland regions in the south of Peru; Puno, Ayacucho, Huancavelica, Arequipa and Cusco, on altitudes above 3000 m.a.s.l. Up to 80% of the alpaca population exists in Puno region (Fairfield 2006). The weather in the high Andes varies from temperate to cold, depending on the altitude. In the highest areas the annual average temperature is below 0°C. The year is divided in two seasons, wet and dry season. The amount of precipitation peaks between January and March. The presence of clouds during this period prevents the daytime heat from escaping during the night. In May to August, nights and mornings are very cold due to the absence of clouds (Wikipedia).

The alpaca sector is dominated by small producers, most of whom (80-90%) own less than one hundred animals. A herd of this size is considered too small to maintain good genetic quality and this is one of the most important problems facing small producers. High levels of interbreeding due to small herds have been found. Also, alpacas crossbreed with llamas producing offspring of lower fibre quality, limiting the economic value. Over the past decades, large numbers of high quality alpacas have been exported both legally and illegally, threatening Peru's alpaca gene pool. The decrease in fibre quality lowers the price offered and thereby, the chances for small herders to escape poverty are reduced. Most of the alpaqueros live in extreme poverty. An average yearly income for a family with 80 animals range from 345 to 800 US Dollars (Fairfield 2006).

## Fibre

Alpaca fibre is renowned throughout the world for its softness and good textile quality. To evaluate the quality of the fibre, several features can be analysed. Some features are more important in the early stages of textile production, while some matter more in later stages of production or in the final product. For example, comfort factor (CF), percentage of fibres with diameter less than 30  $\mu\text{m}$ , gives information on how much of a prickly feeling the fibre gives when used in a garment. Other features are important throughout the whole process, such as fibre diameter (FD). The diameter is the main criteria when setting the price and determining the use of the fibre (Canaza-Cayo *et al.* 2013). FD is also the major criteria in selection of breeding animals (Gutiérrez *et al.* 2014).

According to Peruvian practical standards the fineness of alpaca fibres is divided into four classes; extra fine ( $\leq 23\mu\text{m}$ ), fine (23-26.5 $\mu\text{m}$ ), semi-fine (26.5-29 $\mu\text{m}$ ) and coarse ( $\geq 29\mu\text{m}$ ). Coloured fibre are classified in the same way as coarse white fibres (Montes 2013). Samples of alpaca fibres obtained from 1000 years old El Yaral mummies had mean fibre diameters of 23.6 ( $\pm 1.9$ ) and 17.9 ( $\pm 1.0$ )  $\mu\text{m}$ , representing fine and extra fine fibres (Wheeler 1995). Since the Spanish conquest, cross-breeding between alpacas and llamas has made the alpaca fibres in the Andean Plateau region coarser than it was in pre-conquest animals (Wheeler 1995). A second factor that may have contributed to the decrease in fineness of alpaca fibres is the industry's demand for white fibres (Montes 2013). The alpaca's unique reproduction features, making it difficult to develop technologies to improve breeding, and loss of animals of high quality to other countries are other factors implicated in the decline in fibre quality (Fairfield 2006).

The fibre diameter of an individual is not constant throughout its life, but increases with age (Davis *et al.* 1991, Gutiérrez *et al.* 2011, Montes 2013). Because of this, it is preferable to breed animals which keep a thin fibre diameter (FD) through their lives. Gutiérrez *et al.* (2011) found a positive correlation between FD at birth and the growth of the fibre. There are also two variabilities within an animal; the variability of diameter within fibres in the same animal, and the variability between shearing periods. The variability within fibres is measured by the standard deviation (SD) or coefficient of variation (CV) (Gutiérrez, Varona *et al.* 2011). Mayhua *et al.* (2012) found a slight difference in fibre quality in white alpacas between two shearing periods, December and March, with shearing in December resulting in a better fleece.

Since fibre diameter varies greatly over the body of the animal, it is important to know where to take samples for analysis. Aylan-Parker *et al.* (2002) described the midside of the animal (Figure 1) as the most representative area, if the animals are to be selected for low mean fibre diameter (MFD) and high fleece weight.



Figure 1. The circle shows the midside of the alpaca, where the most representative fibre samples are taken according to Aylan-Parker *et al.* (2002).

Photo: Jakob Killander

As mentioned above, age is an endogenous factor that affects FD. Another factor that is being discussed as a possible endogenous factor is sex. Montes (2013) found that females had coarser FD than males, while Aylan-Parker *et al.* (2002) found the opposite. According to the authors of Montes (2013), the result of their study could depend on the fact that the males represented selected breeding material while the females were of different genetic origin. Other authors have found no significant difference between sexes (Wuliji *et al.* 2000, Lupton *et al.* 2006).

Lupton *et al.* (2006) found a difference between sexes in fibre strength, where male alpacas had stronger fibres than females. This was the only fibre characteristic weighted by sex in the study, where mean diameter and staple length among other characteristics were measured.

Fleece colour is another factor that may have an impact on fibre diameter. Wuliji *et al.* (2000) reported no evidence that coloured fleeces makes coarser FD, while Lupton *et al.* (2006) found that darker fibres had a higher mean fibre diameter than white and brighter fibres. Twenty-two natural colours exist, ranging from white to black (Fowler 1989).

## Reproduction

Reproductive anatomy is in many respects similar in SAC and OWC, as well as reproductive behaviour. Interest in studies on SAC reproduction has increased over the last years, partly because of the relatively low reproduction rate in these animals (Fowler 1989). Compared to other domestic mammals, alpacas and llamas show poor breeding performance. Several factors cause this. Both males and females are older than many other animals at time of first breeding, gestation is long and the alpaca is a monotocous species, meaning they normally give birth to one cria (Brown 2000).

### Male anatomy

The penis of the alpaca has a sigmoid flexure located just ventral to the pubic bone. The penis is long and narrow, measuring 35 – 40 centimetres in length when erected. On the tip of glans penis there is a cartilaginous projection, which is assumed to make penetration through the cervix easier. The prepuce is non-pendant and pointing caudally, with the result that the male alpaca urinates backwards between the hind limbs. At copulation, the prepuce is pulled cranially by the cranial prepuce muscles and the penis is extruded cranially (Fowler 1989).

It is common to use alpaca males for breeding from 3 years of age, but they start to show interest in females at 1 year. However, at this age, they are incapable of mating because the penis is adherent to the prepuce. This feature depends on low testosterone levels, and remains until puberty is reached and testosterone levels increase. At 3 years of age, all alpaca males show complete disappearance of the adhesions (Fernández-Baca 1993, Sumar 1996).

Three accessory sex glands are present in the male alpaca; a pair of bulbourethral glands located dorsal and lateral to the pelvic urethra by the ischial arch, and a small prostate located dorsal to the urethra, close to the neck of the urinary bladder. The alpaca has no seminal vesicles. The scrotum and testicles are located close to the body, below the anus. The mean size of testicles in adults is 3.7x2.4 cm (length x transverse axis). The epididymis is oriented in the same manner as in boars, with the head of epididymis cranio-ventrally and the tail caudo-dorsal (Fowler 1989).

### **Semen characteristics**

The semen of SACs is highly viscous and forms a coagulum after copulation. This causes the spermatozoa to make oscillating movements and they do not move forward as is normal in other domestic mammals. The spermatozoa are trapped within the gelatinous semen, which is thought to act as a reservoir since it is deposited intracornually up to 2 days prior to ovulation (Brown 2000). Because of the gelatinous consistency of alpaca semen, evaluation of sperm motility and morphology is difficult. For clinical use, the most successful way to collect semen is from the hembra after copulation. For research purposes, using an artificial vagina is the best method. The semen has a pH between 7.2 and 7.8. The biochemical composition resemble that of semen from other livestock animals, with the exceptions of low citric acid and fructose (Fowler 1989). The amount of live spermatozoa ranges from 58% to 83% and morphologically normal spermatozoa range from 71% to 84% (Brown 2000).

### **Mating behaviour**

When a male alpaca is being introduced to a receptive female, he will try to make her lie down by attempting to mount her and putting pressure on her pelvis. Sometimes she becomes recumbent immediately, but in many cases she moves away and the male will chase her for several minutes before she lies down. Courtships lasting longer than 4 minutes tend to result in no mating or forced mating (Brown 2000), and a male with good libido will try for at least 5 minutes (Fowler 1989). The body weight and libido of the male are hence essential in successful copulation (Fowler 1989). During copulation, the female is in sternal recumbency with her legs beneath her. The male mounts her in a squatting position with his hocks flexed and the metatarsi on the ground. His front legs are stretched forward or bent on either side of the female (Tibary *et al.* 2006). During the copulation the male constantly makes a special guttural vocalization called “orgling”, while the female most often is quiet (Brown 2000, Tibary *et al.* 2006). The copulation lasts for about 20 minutes on average but ranges from 5 minutes up to 45 minutes (Pollard *et al.* 1994, Vaughan *et al.* 2003). According to Vaughan *et al.* (2003), no significant differences in conception frequency could be seen between copulations of different duration.

### **Female anatomy and physiology**

The vulva of the female alpaca is small, the orifice measures about 3-5 cm in length. The vestibule is about 5 cm long and the vagina measures 13-15 cm in length. The cervix has two or three ring-like folds. The penis of the male alpaca penetrates through these folds and semen is deposited into the bicornual uterus. The ovaries are globular in shape and resembles those in the sow, with multiple follicles on the surface, measuring 5-12 mm. (Fowler 1989, Brown 2000).

Female alpacas are induced ovulators, meaning they do not show periods of heat followed by spontaneous ovulation. Their hormonal physiology differs from that of other induced ovulators, such as the cat or the rabbit. The alpacas do not have estrous periods and are practically receptive to the male at all times when they are not pregnant or recently bred. Their follicles grow, mature and regress in an overlapping pattern. (Fowler 1989). The dominant follicles persist for relatively long periods of time, which could explain the almost constant levels of oestrogen that enable continuous receptivity to males (Brown 2000). The follicle must be at least 7 mm in diameter for ovulation to occur after copulation. Sexual receptivity is not related to the size of the follicles (Fowler 1989).

Ovulation is induced by penile penetration of the vagina and cervix and is not related to the length of the copulation. The time from copulation to ovulation ranges from 26 to 42 hours, with most of the females ovulating on the second day after copulation. A corpus luteum is detectable on day 3 after ovulation, and reaches its maximum size between days 8-10. Plasma progesterone concentrations and reduction in corpus luteum diameter are observable by day 12. Complete regression of corpus luteum occurs by day 18 (Brown 2000).

## **Aims**

The aim of this study was to evaluate if there is any correlation between fibre quality and male mating behaviour (as a marker of fertility) in alpacas. The theory was that the more masculine males would have coarser fibres with a larger diameter because of higher testosterone levels. In an uncontrolled mating system this could result in them be able to mate with more females than males with finer fibres, thus passing on their genes for poor fibre quality. No studies on this subject or articles discussing the relationship in this particular species have been found in the literature.

## **MATERIAL AND METHODS**

### **Literature review**

Journal articles were searched for and found in the databases PubMed and Google Scholar. Search words used were “alpaca”, “camelid”, “fibre”, “fiber”, “quality”, “fertility”, “male”, “white”, “colour”, “color”, “body condition” and “BCS” in different combinations. Information was also collected from books.

### **Animals**

189 male alpacas of varying age were examined regarding the length of the fibre. The animals were held in three different groups containing 57, 127 and 5 animals. The two groups of 57 and 5 animals belong to the National University of San Marcos in Lima and are kept at two different locations in Cusco region, Peru. The group of 57 males is kept in the La Raya highlands, together with llamas. The group of 5 males was at the time of sampling kept in Fundo, Marangani, and was grazing fertilized pasture. The larger group of 127 males is also kept in La Raya (separated from the first group) and grazed together with llamas, but these animals belong to the National University of San Antonio Abad of Cusco. The pasture offered to these animals was richer than that offered for the Lima animals in La Raya.

All animals had their fibres cut approximately one year before sampling. The animals in Marangani and La Raya are normally clipped once a year using scissors, rather than clippers.

### **Fibre sampling**

The animals were fixed by the neck by an assistant during measurements and sampling. The fibre was measured at one site on the midside of the animal using a calliper. There was no preference for one side over the other. The fibre was stretched out by hand and the length was measured to the nearest millimetre (Figure 2).

The fibre on the same spot was cut off using scissors, close to the skin. The fibre covering approximately 2-4 cm<sup>2</sup> of skin area was cut. The fibre samples were stored in individual plastic bags, with an identity label in each bag, and stored for later analysis (Figure 3).



Figure 2. Fibre is being measured with a calliper  
Photo: Joel Pacheco



Figure 3. Collected fibre samples in plastic bags and material for measurements  
Photo: Fanny Bengtsson

## Washing

The fibre samples were washed in three steps; every sample was individually washed by hand in 30 litres of hot water (60°C) mixed with approximately 100 grams of washing detergent (Opal Ultra). Thereafter they were rinsed in clean hot water at 60°C. Eventually they were rinsed in a third sink filled with clean hot water again to remove all residues of detergent (Figure 4). The samples were left in a horizontal position on a clean table in a ventilated room to dry for three or four days, prior to being analysed. Each sample had its own individual number written on the table (Figure 5).



Figure 4. Fibres are washed in three steps. Photo: Jakob Killander



Figure 5. Clean fibre samples are left to dry on a clean table. Photo: Jakob Killander

### Fibre analysis

When completely dry (Figure 6), the samples were cut into 2 mm snippets using a special guillotine and then spread out on a clean square glass slide (Figure 7), covered with a second glass. The samples were analysed using a laser scanner; OFDA 2000 Benchtop version (BSC Electronics) (Figure 8). OFDA stands for Optical Fiber Diameter Analyser. It is a video microscope that magnifies and captures images of the individual fibres using a video camera and then identifies and measures each fibre. The data measured includes fibre diameter, coefficient of variation, comfort factor, curvature and spinning fineness (BSC Electronics).



Figure 6. Dry fibre samples from Suri (second from top) and Huacaya phenotypes. Photo: Fanny Bengtsson

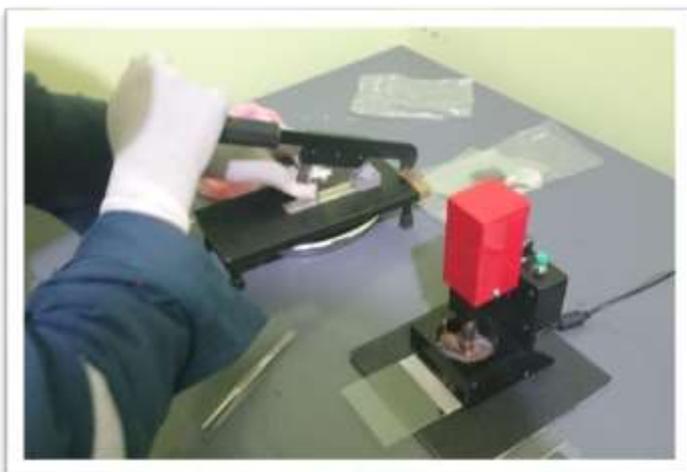


Figure 7. Fibre sample being cut in the guillotine. The unit to the right spreads the snippets on the glass  
Photo: Fanny Bengtsson



Figure 8. OFDA 2000  
Photo: Fanny Bengtsson

## Body Condition Scoring

To evaluate the alpaca males' body condition, they were palpated over the back. The hand was placed over the centre of the back, near the last ribs. To assess the body condition, the muscle mass on each side of the vertebrae was given a score from 1 to 5, including half points. At 1 point, the animal is very thin and at 5 points the animal is obese. Body Condition Score (BSC) 2.5 -3.5 are considered healthy for all alpacas except pregnant females and growing tuis for which BSC 3-3.5 is recommended (Australia Alpaca Association 2013).

## Fertility data

The data used to analyse fertility consisted of handwritten records from the previous breeding season, January to April 2015 (Figure 9). Notes had been made for every occasion when male and female were presented to each other. Either A for accept or R for reject was recorded. Different groups of females were presented to males for a different number of times. A few females were only presented to the males three times, while the females given the highest amount of occasions had six attempts with their male alpaca. Only a maximum of four occasions were included in the study. The reason why the alpacas had different number of attempts is unknown, since this was controlled by Peruvian researchers. However, the number of occasions were decided on beforehand and did not depend on the outcome of the attempts (A or R).



The image shows a page from a spiral-bound notebook with handwritten breeding records. The page is titled 'FERTILIDAD DE ALPACAS' and 'CANTON (3) 27-12-14'. The records are organized into columns with headers: 'Macho', 'Fem', 'Fecha', 'Hora', 'Resultado', 'Observaciones', 'Fecha', 'Hora', 'Resultado', 'Observaciones'. The data is written in black ink, with some red ink used for headings and checkmarks. The records show various dates and times, along with 'A' for accept and 'R' for reject. The page is numbered '11' in the top right corner.

Figure 9. Breeding records.  
Photo: Fanny Bengtsson

The fertility data regarding the animals belonging to San Marcos University (Lima) is based on a breeding system called "alternate breeding". The males and females are kept in separate groups during the whole year. When the breeding season starts, one male is let into a smaller pen with the female. If the female spits at the male, she is interpreted as pregnant. This is often named "spit-off" or rejection as in this case. If she lies down on the ground, she is accepting the male and thereby considered as not pregnant yet. This procedure is repeated at an interval of approximately 14 days during the breeding season. If a female does not accept the male one time, she is still presented with the same male on the next occasion. If she does accept the male this time, she is considered not pregnant again. This can occur due to early foetal death. Between the breeding occasions, the ani-

mals are let out on the fields of the highlands to graze, the sexes separated as during the rest of the year. The females are presented with the same male every time, which makes the records usable for evaluating fertility data among the males. The same male mates with between 1-8 females during the season.

The animals belonging to Cusco University are bred in a different system, called "controlled breeding". In this system, the males are presented to a group of females in a larger coral. He approaches each one of them, and the females either accept or reject him. The females who accept him are taken into smaller pens where the mating occurs. A female that rejects the male is considered pregnant in this system as well as in the alternate breeding system. The difference is that in this controlled breeding system, the females are presented to different males every time and evaluating fertility data on the males is not possible.

## Statistics

Statistical handling and analysis of data was performed using the SAS software (ver. 9.3; SAS Inst. Inc., Cary, NC). Analysis of variance was used to detect the effect of age class (three classes), body condition score (three classes) as well as colour (two classes, white/coloured) on fleece measurements. Residual correlation between the fleece measurements were calculated, after applying this statistical model.

The alpacas were divided into three different classes based on their age in months (Table 1). The mean age was 64 months (Table 4).

Table 1. *The three age classes used in the statistics. BCS – Body condition score*

AGE CLASS	AGE IN MONTHS	NUMBER OF ANIMALS
1	13-45	54
2	49-66	59
3	66-230	72
	<b>TOTAL</b>	<b>185</b>

The alpacas were also divided into three classes based on the BCS-number they were given (Table 2).

Table 2. *The three BCS classes used in the statistics. BCS – Body condition score*

BCS CLASS	BCS	NUMBER OF ANIMALS
2	≤2.5	38
3	3	74
4	≥3.5	75
	<b>TOTAL</b>	<b>187</b>

Based on their colour, the alpacas were placed in one of the following colour classes (Table 3). The actual colours are shown in Figure 10.

Table 3. *Distribution of white and coloured alpacas*

COLOUR CLASS	NUMBER OF ANIMALS
<b>WHITE</b>	<b>137</b>
<b>COLOURED</b>	<b>51</b>
	<b>TOTAL 188</b>

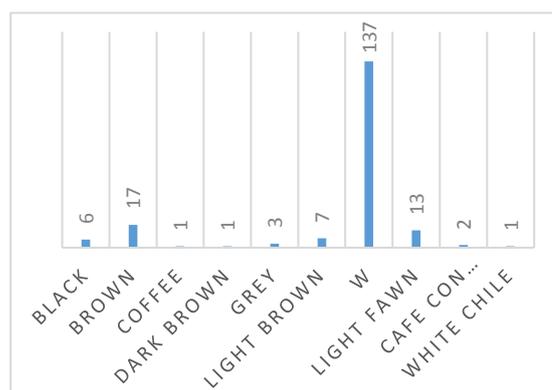


Figure 10. *Actual colours of the alpacas.*  
W - White

### Fertility

A quotient was calculated for every alpaca male used in the breeding season 2015. The males who mated only one female were not included. In the final group of males used in the statistics (n=26), 3 were of Suri phenotype and the remaining 23 were of Huacaya phenotype. Seven were coloured and 19 were white. The quotient was based on the number of times the females rejected the male divided by the total number of occasions the male was presented to his females. Every female's first occasion was not included since all females accepted the male on this occasion and were thereby considered receptive to the male and not pregnant. The females were presented to the male between three and six times. A maximum of four occasions were included in the study in order to make the quotients as fair as possible.

$$\text{Quotient} = \frac{\text{Number of rejections}}{\text{Number of occasions} - 1}$$

## RESULTS

The mean values for each measured parameter are shown in Table 4. The relationships where significance were found are shown in Table 5. The mean values for the animals belonging to the two different universities are shown in Table 6.

Table 4. *Mean values. BCS – Body condition score. CV – Coefficient of variation. CF – Comfort factor*

Age (months)	BCS	Fibre length (mm)	Mean fibre diameter (µm)	CV (%)	CF (%)	Spin fineness (µm)	Curve (deg/mm)	Fertility quotient
64 (13-230)	3.20 (1-5)	105.40 (65-206)	26.35 (17.96-36.42)	24.87 (16.24-40.48)	76.37 (22.77-98.71)	26.61 (18.41-37.93)	29.60 (9.12-45.45)	72.12 (33.30-100.00)

Table 5. Significant results. X – significant relationship ( $p \leq 0,05$ ). Pos – positive relationship. Neg – negative relationship. BCS – Body condition score. CV – Coefficient of variation. CF – Comfort factor

	Fibre length	Diameter	CV	CF	Spin fineness	Curve
Age	X neg	X pos		X neg	X pos	
BCS	X pos					X neg
Colour	X	X	X	X	X	

Table 6. Mean values of animals belonging to UNMSM (Lima university) and UNSAAC (Cusco university). MFD – Mean Fibre Diameter. BCS – Body Condition Score

	MFD ( $\mu\text{m}$ )	BCS	Age (months)
Lima university	25.30	3.05	48.70
Cusco university	26.87	3.32	71.52

### Effects of age

Age had significant impact on length, diameter, comfort factor and spin fineness of the fibre. The younger the animals, the longer were the fibres. The diameter was smaller in young animals, and coarser in older animals. This automatically affects comfort factor, which is higher in young animals, and spin fineness which is lower in young animals (Table 7).

Table 7. Mean values for each age group. BCS – Body condition score. CV – Coefficient of variation. CF – Comfort factor

AGE GROUP	MEAN LENGTH (MM)	DIAMETER ( $\mu\text{M}$ )	CV (%)	CF (%)	SPIN FINE-NESS ( $\mu\text{M}$ )	CURVE (DEG/MM)
1	110.93	24.93	25.82	81.30	25.40	30.79
2	104.74	27.50	25.51	71.39	27.96	28.33
3	92.63	27.50	24.82	72.02	27.78	30.68

### Effects of BCS

Body condition had a significant impact on the length of the fibres ( $p=0.0002$ ). Animals with BCS  $\geq 3.5$  had the longest fibres. Animals with BCS  $\leq 2.5$  had fibres longer than those of animals with BCS 3, but shorter than animals with BCS  $\geq 3.5$  (Table 8).

The curvature value (degrees/mm) was higher in animals with lower BCS, and lower in animals with higher BCS.

Table 8. Mean values for each BCS group. BCS – Body condition score. CV – Coefficient of variation. CF – Comfort factor

BCS GROUP	MEAN LENGTH (MM)	DIAMETER ( $\mu\text{M}$ )	CV (%)	CF (%)	SPIN FINENESS ( $\mu\text{M}$ )	CURVE (DEG/MM)
2	99.16	26.12	25.93	76.70	26.65	32.37
3	97.77	26.59	24.81	74.95	26.80	30.66
4	111.38	27.24	25.41	73.07	27.68	26.76

Table 9. Distribution of number and percentage of animals of different age with different BCS – Body condition score

<i>Age group</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>Total</i>
<b><i>BCS group</i></b>				
<b>2</b>	17 9.19%	6 3.24%	14 7.57%	37 20.00%
<b>3</b>	19 10.27%	23 12.43%	32 17.30%	74 40.00%
<b>4</b>	18 9.73%	30 16.22%	26 14.05%	74 40.00%
<b>Total</b>	54 29.19%	59 31.89%	72 38.92%	185 100%

### Effects of colour

The white animals had significantly longer fibres and smaller fibre diameter which affects CV, CF and spin fineness (Table 10).

Table 10. Mean values for each colour group. BCS – Body condition score. CV – Coefficient of variation. CF – Comfort factor

COLOUR	MEAN LENGTH (MM)	DIAMETER ( $\mu\text{M}$ )	CV (%)	CF (%)	SPIN FINE-NESS ( $\mu\text{M}$ )	CURVE (DEG/MM)
COLOURED	97.86	27.77	26.30	70.09	28.42	29.26
WHITE	107.68	25.52	24.47	79.71	25.67	30.61

### Fertility

No significant relationship could be found between fertility based on the quotients, and fibre quality. None of the fibre quality parameters showed relationship to fertility quotients. The alpaca males' individual fibre diameter and quotients are shown in Figure 11. The correlation between fertility quotient and fibre diameter had a p-value of 0.959.

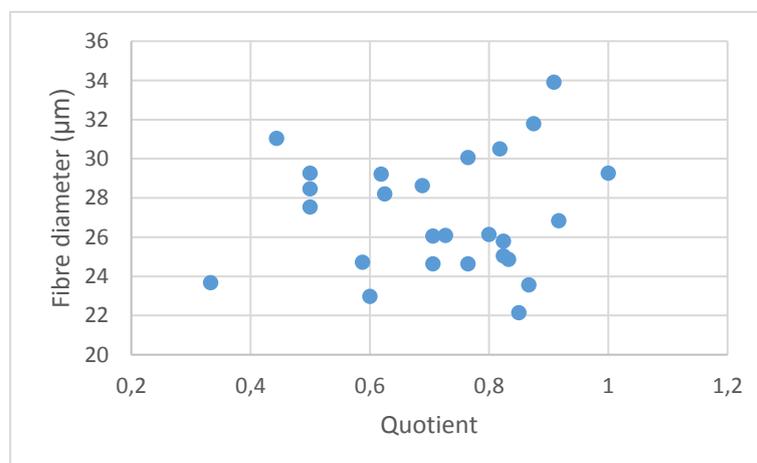


Figure 11. The alpaca males' individual fibre diameter and quotients.

## DISCUSSION

### Age

The fact that age has an effect on fibre quality and more specifically diameter is well known. The results of this study are in agreement with former studies (Davis *et al.* 1991, Gutiérrez *et al.* 2011, Montes 2013). Age group 1 had a mean MFD of 24.93  $\mu\text{m}$ , while both age group 2 and 3 had the same mean MFD of 27.50  $\mu\text{m}$ .

In this study, fibre length was significantly weighted by age, with the youngest animals having longer fibres and the oldest having shorter fibres. The difference in mean length between age group 1 and 3 was 18.30 millimetres. Both Newman *et al.* (1994) and Russel *et al.* (1997) found that a higher level of feeding resulted in increased fibre length, but no increase in mean fibre diameter. This could be used to explain the result of this study if the young animals tended to be better fed than older animals. This does not seem to be the case, since BCS was not higher in young animals.

The division in three age groups based on the alpacas' age in months was made to create three groups with approximately the same number of animals in each group to use in the statistics. Age group 1 consisted of the youngest animals, ranging from 13 to 45 months (1.08-3.75 years). Age group 2 had a smaller range, from 49 to 66 months (4.08-5.50 years). The third group had a greater range from 67 to 230 months (5.58-19.17 years). However, the oldest alpaca was 67 months (5.58 years) older than the second oldest alpaca which was 163 months old (13.58 years). Based on this, it is possible that the age of this alpaca was not interpreted correctly. The date of birth for each alpaca was collected from its ear tag and might have been misread.

### BCS

BCS significantly affected staple length and curvature of the fibres. These results may depend partly on the fact that the Suri phenotype in general has a higher BCS. The longer and less crimped fibres belong to the characteristics of the phenotype, which corresponds to the results. No consideration was given to the different phenotypes in the statistics.

There was a tendency for animals with a  $\text{BCS} \leq 2.5$  to have finer fibres than animals with higher BCS.  $\text{BCS} \leq 2.5$  is most common in age group 1, the youngest animals (Table 8). Because of their age they have finer fibres than the other groups. BCS 3 is most common in age group 3.  $\text{BCS} \geq 3.5$  is most common in age group 2 (P-value for Chi-square 0.0456, Likelihood ratio Chi-Square 0.0454).

The animals belonging to UNSAAC grazed on richer pasture and had higher BCS than the animals belonging to UNMSM (see Table 6). They did have a higher MFD than the UNMSM animals but were also 22.82 months older on average, which (according to our results) is likely to have more of an influence on MFD than the higher BCS.

### Colour

The white alpacas consistently showed higher fibre quality. All fibre quality parameters except curvature were to their advantage. The industry's demand for white fibres is higher than for coloured fibres because of its ability to be dyed to any colour. Coloured fibres, however, are also sought after and used in products with natural colours. It is possible that the white animals have been selected for fine fibres to a greater extent than the coloured animals, and thereby have developed a better

fibre quality. Since there are more white animals than coloured, there is a wider range of white animals to choose from when it comes to selection of breeding animals.

Montes (2013) suggests that industry pressure to increase production of white fibres as a possible reason for the overall decline in fibre quality. According to our study, this might only affect the coloured animals, since the genetic material could be decreasing while the white animals' genetic material is increasing.

There might also be a difference in white and coloured fibres regarding diameter, without the influence of genetics. Wuliji *et al.* (2000) reported no significant differences in fibre diameter among colours, while Lupton *et al.* (2006) found significant but small differences, where dark fibres were coarser than light fibres. McGregor *et al.* (2004) reported a 1µm difference between light and dark fibres, with the light fibres being finer.

## Fertility

No relationships were found between fertility quotients and fibre quality in this study. However, several factors made the evaluation of fertility difficult. Different breeding systems were used at the different locations, and it was only possible to receive usable data from one of them. This dramatically decreased the number of males to evaluate in the study. No ultrasonography or other diagnostic aid other than "spit-off" was used to identify pregnant females. It is possible that already pregnant females accept the male again under certain circumstances, for example if he is particularly aggressive or if she is very submissive. Not all females that reject the male are pregnant; embryonic loss could have occurred, but the regression of corpus luteum has not yet occurred (Brown 2000). Using this method alone to verify pregnancies, it is also difficult to interpret why a female who has rejected the male at one occasion accepts him again on the next one.

The females were divided in different groups that were presented to the male for different number of times, ranging from 3 to 6 times, though a maximum of four occasions were included in the study. This fact, combined with the fact that some males mated many more females than others (ranging from 1 to 8 females), made it difficult to obtain reliable data to use in the statistics.

No studies on the relationship between fibre quality and fertility in alpacas have been found. Safari *et al.* (2005) compiled results from several studies regarding genetic parameters for wool and fertility, among other traits, in sheep. Few estimates of correlation between reproduction and fibre diameter and staple length were found in the literature, and they were generally low. All correlations between wool fleece weight and fibre diameter and the different reproduction parameters were close to zero. According to Adams *et al.* (2003), maternal factors are more likely to contribute to reproductive disadvantages in fine wool sheep than male reproduction traits, and no relationships between fibre diameter and ram fertility, poor sperm transport or early embryonic mortality have been reported.

## CONCLUSIONS

The results of this study indicate a poor relationship between male fertility and fibre quality in Peruvian alpacas. However, there were several problems with the data obtained and it would be advisable to perform further studies and consider alternative methods. The most optimal way to evaluate male fertility is to examine semen. However, this is a rather complicated procedure in alpacas. Other methods of evaluation, such as testicular measurement, may be seasonally dependent and should be related first with semen characteristics. The males need to be trained to use an artificial vagina, and their semen shows special features which makes handling and examination of it more difficult than in other domestic species. Furthermore, the study described here was performed during the months of September - October, which is not the natural breeding season for alpacas in the Andes. Females may refuse to mate at this time of year (Winblad von Walter 2015).

The study was partly based on records from the breeding season. Since the records were not produced for the sake of the study, they were not perfect for this purpose. For example, the males mated different numbers of females and had different numbers of occasions when they were introduced to the females. The records were not controlled before the start of the project, and there was hence little time to change the design of the study. To make the results more reliable, it would have been useful to include mating behaviour of the males as well as semen examinations. Also, a larger number of males included in the study would have been desirable.

## REFERENCES

- Adams, N. R. and P. B. Cronjé (2003). "A review of the biology linking fibre diameter with fleece weight, liveweight, and reproduction in Merino sheep." *Australian Journal of Agricultural Research* 54(1): 1-10.
- Australia Alpaca Association. (2013). "Alpaca fact sheet #4 Body Condition." Retrieved 5 Dec, 2015, from <http://www.alpaca.asn.au/>.
- Aylan-Parker, J. and B. McGregor (2002). "Optimising sampling techniques and estimating sampling variance of fleece quality attributes in alpacas." *Small Ruminant Research* 44(1): 53-64.
- Brown, B. W. (2000). "A review on reproduction in South American camelids." *Animal reproduction science* 58(3): 169-195.
- BSC Electronics. Retrieved 5 Dec, 2015, from <http://www.ofda.com/Index.html>.
- Canaza-Cayo, A., D. Alomar and E. Quispe (2013). "Prediction of alpaca fibre quality by near-infrared reflectance spectroscopy." *animal* 7(07): 1219-1225.
- Davis, G., T. Wuliji, G. Moore and G. Bruce (1991). Growth, reproduction and fibre production of alpacas imported from Chile. *Proc. NZ Soc. Anim. Prod.*
- Fairfield, T. (2006). "The politics of livestock sector policy and the rural poor in Peru."
- Fernandez-Baca, S. (1994). "GENETIC EROSION ON CAMELIDAE." *Animal Genetic Resources / Resources génétiques animales / Recursos genéticos animales* 14: 91-98.
- Fernández-Baca, S. (1993). "Manipulation of reproductive functions in male and female New World camelids." *Animal Reproduction Science* 33(1): 307-323.
- Fowler, M. E. (1989). *Medicine and surgery of South American camelids: llama, alpaca, vicuña, guanaco*, Iowa State University Press.
- Gutiérrez, J., I. Cervantes, M. Pérez-Cabal, A. Burgos and R. Morante (2014). "Weighting fibre and morphological traits in a genetic index for an alpaca breeding programme." *animal* 8(03): 360-369.
- Gutiérrez, J., L. Varona, A. Pun, R. Morante, A. Burgos, I. Cervantes and M. Pérez-Cabal (2011). "Genetic parameters for growth of fiber diameter in alpacas." *Journal of animal science* 89(8): 2310-2315.
- Lupton, C., A. McColl and R. Stobart (2006). "Fiber characteristics of the Huacaya Alpaca." *Small Ruminant Research* 64(3): 211-224.
- Mayhua, P., E. Quispe, M. Montes and L. Alfonso (2012). Differences in fibre diameter profile between shearing periods in White Huacaya Alpacas (*Vicugna pacos*). *Fibre production in South American camelids and other fibre animals*, Springer: 59-64.
- McGregor, B. and K. Butler (2004). "Sources of variation in fibre diameter attributes of Australian alpacas and implications for fleece evaluation and animal selection." *Crop and Pasture Science* 55(4): 433-442.
- Montes, M., Quicaño, I., Quispe, R., Quispe, E., Alfonso, L. (2013). "Quality characteristics of Huacaya alpaca fibre produced in the Peruvian Andean Plateau region of Huancavelica." *Spanish Journal of Agricultural Research* 6(1): 33-38.

- Newman, S.-A. and D. Paterson (1994). Effect of level of nutrition and season on fibre growth in alpacas. PROCEEDINGS-NEW ZEALAND SOCIETY OF ANIMAL PRODUCTION, NEW ZEALAND SOCIETY OF ANIMAL PROD PUBL.
- Pollard, J., R. Littlejohn and I. Scott (1994). "The effects of mating on the sexual receptivity of female alpacas." *Animal Reproduction Science* 34(3): 289-297.
- Presciuttini, S., A. Valbonesi, N. Apaza, M. Antonini, T. Huanca and C. Renieri (2010). "Fleece variation in alpaca (*Vicugna pacos*): a two-locus model for the Suri/Huacaya phenotype." *BMC genetics* 11(1): 70.
- Quispe, E., T. Rodríguez, L. Iñiguez and J. P. Mueller (2009). "Producción de fibra de alpaca, llama, vicuña y guanaco en Sudamérica." *Animal Genetic Resources Information* 45: 1-14.
- Russel, A. and H. Redden (1997). "The effect of nutrition on fibre growth in the alpaca." *Animal Science* 64(03): 509-512.
- Safari, E., N. M. Fogarty and A. R. Gilmour (2005). "A review of genetic parameter estimates for wool, growth, meat and reproduction traits in sheep." *Livestock Production Science* 92(3): 271-289.
- Skidmore, J., M. Billah, M. Binns, R. Short and W. Allen (1999). "Hybridizing old and new world camelids: *Camelus dromedarius* X *Lama guanicoe*." *Proceedings of the Royal Society of London B: Biological Sciences* 266(1420): 649-656.
- Sumar, J. B. (1996). "Reproduction in llamas and alpacas." *Animal Reproduction Science* 42(1): 405-415.
- Taylor, K. M., Hungerford, D.A., Snyder, R.L., Ulmer, F.A. Jr. (1968). "Uniformity of karyotypes in the Camelidae." *Cytogenetics* 7: 8-15.
- Tibary, A. and J. Vaughan (2006). "Reproductive physiology and infertility in male South American camelids: a review and clinical observations." *Small Ruminant Research* 61(2): 283-298.
- Vaughan, J., K. Macmillan, G. Anderson and M. D'OCCHIO (2003). "Effects of mating behaviour and the ovarian follicular state of female alpacas on conception." *Australian veterinary journal* 81(1-2): 86-90.
- Wheeler, J. C. (1995). "Evolution and present situation of the South American Camelidae." *Biological Journal of the Linnean Society* 54(3): 271-295.
- Wikipedia. Retrieved February 12, 2015, from [https://en.wikipedia.org/wiki/Climate\\_of\\_Peru#Andean\\_highlands](https://en.wikipedia.org/wiki/Climate_of_Peru#Andean_highlands).
- Winblad von Walter, A. (2015). Inter-species embryo transfer in South American Camelids.
- Wuliji, T., G. H. Davis, K. G. Dodds, P. R. Turner, R. N. Andrews and G. D. Bruce (2000). "Production performance, repeatability and heritability estimates for live weight, fleece weight and fiber characteristics of alpacas in New Zealand." *Small Ruminant Research* 37(3): 189-201.

## APPENDIX 1 : BREEDING RECORDS FOR THE MALES IN THIS STUDY

A – accept, R - reject

Macho	Hembra	Occasion No 1	Occasion No 2	Occasion No 3	Occasion No 4
H070	70	A	A	R	R
H070	64	A	R	R	R
H070	25	A	R	R	R
H070	7	A	R	R	R
H049	81	A	R	R	R
H053	112	A	R	R	
H030	99	A	A	R	
H030	97	A	A	R	R
H030	68	A	A	R	R
H030	74	A	R	R	R
H030	41	A	R	R	R
H030	13	A	R	R	R
S012	45	A	R	R	R
S012	2	A	R	R	A
H013	50	A	R	R	R
H025	10	A	R	R	R
H025	57	A	A	R	A
H025	120	A	A	R	
S075	12	A	A	R	A
H106	33	A	A	R	R
H106	40	A	R	R	R
H106	98	A	A	A	R
H106	101	A	R	R	
H080	32	A	R	R	R
H080	47	A	R	R	A
H080	91	A	R	R	R
H080	105	A	R	R	
H091	102	A	R	R	
H091	95	A	R	A	R
H091	49	A	R	R	R
H091	59	A	A	R	R

H091	18	A	R	R	R
H091	15	A	A	R	R
H079	29	A	A	A	A
H079	46	A	R	R	R
H079	62	A	R	R	R
H079	67	A	R	R	R
H079	96	A	A	R	R
H079	119	A	A	R	
S021	84	A	R	R	R
S021	55	A	A	R	R
S021	44	A	R	R	R
S021	24	A	R	A	R
S021	5	A	R	R	R
H059	87	A	R	R	R
H059	80	A	R	R	R
H050	17	A	A	A	R
H050	79	A	A	A	A
H050	86	A	R	R	R
H012(09)	89	A	R	A	R
H012(09)	117	A	R	R	
H087(07)	52	A	R	R	R
H087(07)	60	A	R	R	R
H087(07)	83	A	A	A	R
H087(07)	113	A	R	R	
H081(07)	106	A	R	R	
H081(07)	75	A	A	R	R
H081(07)	82	A	A	A	R
H081(07)	14	A	R	R	R
H081(07)	30	A	A	R	R
H081(07)	35	A	R	R	R
H086	104	A	R	R	
H086	118	A	A	R	
H086	66	A	R	R	R
H086	54	A	A	A	R
H086	42	A	A	R	R
H086	19	A	A	R	R

H074	28	A	R	R	R
H074	63	A	A	R	R
H074	107	A	R	R	
H082	8	A	R	R	R
H082	16	A	A	R	R
H082	26	A	R	R	R
H082	38	A	R	R	R
H082	58	A	R	R	R
H082	92	A	R	R	R
H082	108	A	A	A	
S084	1	A	R	R	R
S084	6	A	A	R	R
S084	37	A	A	A	R
S084	43	A	R	A	R
S084	48	A	A	A	R
S084	85	A	A	R	R
S084	77	A	A	R	R
H054	115	A	R	R	
H054	90	A	A	A	R
H054	69	A	A	R	R
H054	36	A	R	R	A
H054	9	A	R	R	R
H054	72	A	R	R	R
H095	71	A	R	A	R
H095	78	A	A	R	R
H095	27	A	A	R	R
H095	4	A	R	A	A
H095	111	A	A	A	
H073(12)	94	A	R	R	R
H073(12)	109	A	R	R	
H073(12)	56	A	A	R	R
H012(11)	114	A	R	R	
H012(11)	20	A	A	R	A
H012(11)	65	A	R	A	A
H027(11)	3	A	R	A	A
H027(11)	21	A	R	R	R

H027(11)	23	A	A	R	R
H027(11)	110	A	R	R	
H027(11)	61	A	A	A	A
H027(11)	88	A	R	R	A
H087(12)	34	A	R	R	R
H087(12)	121	A	A	A	
H037	100	A	R	R	
H037	116	A	A	A	
H063	93	A	R	A	R
H063	39	A	A	A	A

Macho	Number of females mated	Total number of occasions (when max. 4 per female are included)	Quotient
H012(09)	2	7	80.0
H012(11)	3	11	50.0
H025	3	11	62.5
H027(11)	6	23	58.8
H030	6	23	82.4
H037	2	6	50.0
H050	3	12	44.4
H054	6	23	76.5
H059	2	8	100.0
H063	2	8	33.3
H070	4	16	91.7
H073(12)	3	11	87.5
H074	3	11	87.5
H079	6	23	70.6
H080	4	15	90.9
H081(07)	6	23	76.5
H082	7	27	85.0
H086	6	22	68.8
H087(07)	4	15	81.8
H087(12)	2	7	60.0
H091	6	23	82.4
H095	5	19	50.0

H106	4	15	72.7
S012	2	8	83.3
S021	5	20	86.7
S084	7	28	61.9