**Reference:** Watts, J.E. (2008). *Reinventing the Alpaca.* World Alpaca Conference Proceedings, Sydney, Australia, 28-30 March 2008 pp.28-33.

# Reinventing the Alpaca

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## Introduction

'Guard hair', the coarse and medullated primary fibres that form the outer coat of many alpacas, is a major problem for textile manufacturers. It spoils the look and feel of finished products.

Adult alpacas produce fleeces that average about 24 to 25 microns for fibre diameter with the primary fibres being about 35 microns diameter (Table 1).

By contrast, approximately 1000 years ago the Incas bred alpacas with fleeces of superb fineneness and quality (Wheeler et al 1992). Alpacas with 18 micron fleeces, and possibly as fine as 12 to 13 micron, existed. The fleeces were each remarkably uniform for fibre diameter with standard deviations of about 1 micron. Such low variability of fibre diameter within the fleece could only occur if the primary wool fibres were as fine or finer than the secondary wool fibres. The animals must have been free of 'guard hair'. This high standard of fibre quality in alpacas is not seen today, and the reasons are well-documented.

You can imagine what the commercial value of such fleeces might be. Cashmere (dehaired), at about 16 microns, is currently worth at least $100 per kilogram. Fibres of about 12 micron could be almost priceless.

If we were to try to reinvent such quality in alpaca fleeces, how might we go about it ?

## Breeding objective

My approach is to breed alpacas with low primary fibre diameter and high levels of fibre density and fibre length.

Primary fibre diameter is a highly heritable trait whilst fibre density and fibre length are moderately heritable. The phenotypic correlation between fibre density and fibre length in alpacas is close to zero (Watts, unpublished data), and it would be reasonable to expect the genetic correlation to be similar, indicating that co-selection for high fibre density and high fibre length is feasible.

If an alpaca has low primary fibre diameter, it will have less guard hair. If the primary fibres (and secondary fibres) are about 17 microns in diameter, there will be no guard hair and no medullation in most alpacas (see Figure 5).

If the alpaca has high fibre density and length, that is, many fibres on its body, and these fibres are long, then it will produce high fleece weight. And as density increases, the fleece becomes finer in diameter, the fibres highly aligned, uniform in size and shape, and exquisitely soft. The processing performance of the fibre and the quality of the finished products escalate.

The scope for genetic improvement of both fibre density and length in alpacas is at least two-fold, or a four fold increase in the fibre production of the animal. This would change the fleece of an alpaca, for example, from producing 3 kgs of 25 micron wool per year to one producing about 7.5 kgs of 20 micron wool or 4.2 kgs of 15 micron wool per year.

**Regulation of fibre growth**

Moore et al (1984,1989, 1998, unpublished data) proposed that fibre density, fibre length and fibre fineness are regulated genetically by the number, distribution pattern and activity of pre-papilla cells in the foetal skin (Moore et al, 1984,1989, 1998; Moore et al, unpublished data).

High density and length of fine fibres are thought to be the result of:

- a large starting population of pre-papilla cells being available in the foetal skin to form wool follicles
- these pre-papilla cells being distributed as small clusters to form a high density of wool follicles
- because all the clusters are small, the fibres, whether from primary follicles or secondary follicles, are fine in diameter and non-medullated.
- these small clusters emitting strong signals to stimulate the growth of long fibres

Considerable experimental evidence exists to indicate that the genetic regulation of wool follicle formation and fibre growth differs between primary wool follicles and secondary wool follicles. This biological reality needs to be addressed in the design of breeding programs. If primary fibre diameter, or an accurate indicator of primary fibre diameter, is not used as a selection criterion, then the alpaca is likely to remain two-coated and producing guard hair.

**Current industry standards**

Measurements of follicle and fibre characteristics from 392 Huacaya alpacas, averaging 45 months of age, and 83 Suri alpacas, averaging 39 months of age, are summarised in Table 1. The testing of skin and fleece samples from alpacas located in Australia, Canada, New Zealand, Peru and USA was done at my laboratory between 2001 and 2006.

The Huacaya samples are biased toward alpacas whom the owners consider to be among the best in the herd. The Suri samples are a more random sampling of herd animals.

**Table 1. Mean values and ranges of follicle and fibre characteristics of 392 Huacaya alpacas and 83 Suri alpacas .**

| **Parameter** | **Huacaya** | | **Suri** | |
|---|---|---|---|---|
| | **Mean** | **Range** | **Mean** | **Range** |
| **Follicle density (per square millimetre)** | **43.3** | 14.8 to 91.4 | **31.5** | 17.0 to 59.1 |
| Primary follicle density (per square millimetre) | 3.8 | 1.6 to 7.6 | 3.3 | 2.0 to 5.1 |
| **Fibre length (millimetres per day)** | **0.34** | 0.17 to 0.69 | **0.42** | 0.22 to 0.61 |
| **Primary fibre diameter (microns)** | **34.7** | 17.3 to 58.3 | **36.9** | 27.3 to 53.6 |
| **Primary fibre medullation (%)** | **97.7** | 0 to 100 | **99.8** | 94 to 100 |
| Standard deviation of primary fibre diameter (microns) | 5.5 | 1.8 to 11.1 | 5.6 | 3.0 to 11.1 |
| **Secondary fibre diameter (microns)** | **24.0** | 13.5 to 39.2 | **25.1** | 18.3 to 35.3 |
| **Secondary fibre medullation (%)** | **50.9** | 0 to 100 | **58.4** | 1 to 100 |
| Standard deviation of secondary fibre diameter (microns) | 3.6 | 1.7 to 7.4 | 3.9 | 2.4 to 8.5 |
| S/P ratio | 10.0 | 5.9 to 16.2 | 8.2 | 5.2 to 12.5 |
| Fibre length to staple length ratio | 1.11 | 0.71 to 1.46 | - | - |
| Crimp frequency (per 10 mm) | 2.2 | 0.3 to 3.9 | - | - |
| Crimping time (days) | 16.6 | 6 to 66 | - | - |

The key points arising from Table 1 are:

- Huacaya alpacas have higher follicle densities (43.3 follicles per square millimetre) than Suri alpacas (31.5 follicles per square millimetre).

- Suri alpacas grow longer fibres (0.42 millimetres per day) than Huacaya alpacas (0.35 millimetres per day).

- alpacas can have densities as high as 91.4 follicles per square millimetre

- alpacas can grow fibres as long as 0.69 millimetres per day.

- primary fibre diameter needs to be reduced by at least 10 microns to produce a uniform fleece in which the primary fibres are similar in diameter to the much finer secondary fibres.

- the current mean diameter of alpaca fleeces is about 24 to 25 microns which is at least 5 microns and perhaps 10 microns coarser than it needs to be to become a prestige fibre in the luxury retail market.

- medullation is a major problem for the quality of alpaca fleeces. The medullation levels of both primary fibres ('guard hair') and secondary fibres ('gare') need to be greatly reduced or eliminated.

- there is much scope to increase the crimp amplitude of Huacaya fleeces.

- Huacayas produce, on average, fibres that are only 11% longer than the fleece (a fibre length to staple length ratio of 1.11 to 1). A fleece that forms a crimp wave equivalent to a semi-circle (ideal shape) will have fibres that are about 50% longer than the fleece length.

- Huacaya fibres crimp, on average, every 16.6 days, although there is great variation (6 to 66 days) between animals.

**Animal selection**

The fleece traits under selection, namely primary fibre diameter, fibre density and fibre length, can be visually assessed on the animal as well as measured in the laboratory. Both methods are used in SRS® breeding programs.

Figure 1 shows the fleece structure of a Huacaya alpaca with measurably high density.

**Figure 1. High density brings to the Huacaya fleece an assembly of thin, not thick, staples that are soft and lustrous and have high crimp amplitude. Even though this is a high density alpaca, the wool follicles occupy no more than about 15% of the skin area (photo courtesy of Halcyon Alpacas).**

At 21 months of age, the Huacaya alpaca shown in Figure 1 had a density of 68 follicles per square millimetre. The mean diameters of the primary fibres and secondary fibres were 24.8 microns and 18.6 microns respectively. The fibres were growing in length at the rate of 0.33 millimetres per day.

As density increases, guard hair disappears, and the fibres become fine and evenly sized, deeply crimped and smooth surfaced (Figure 2).

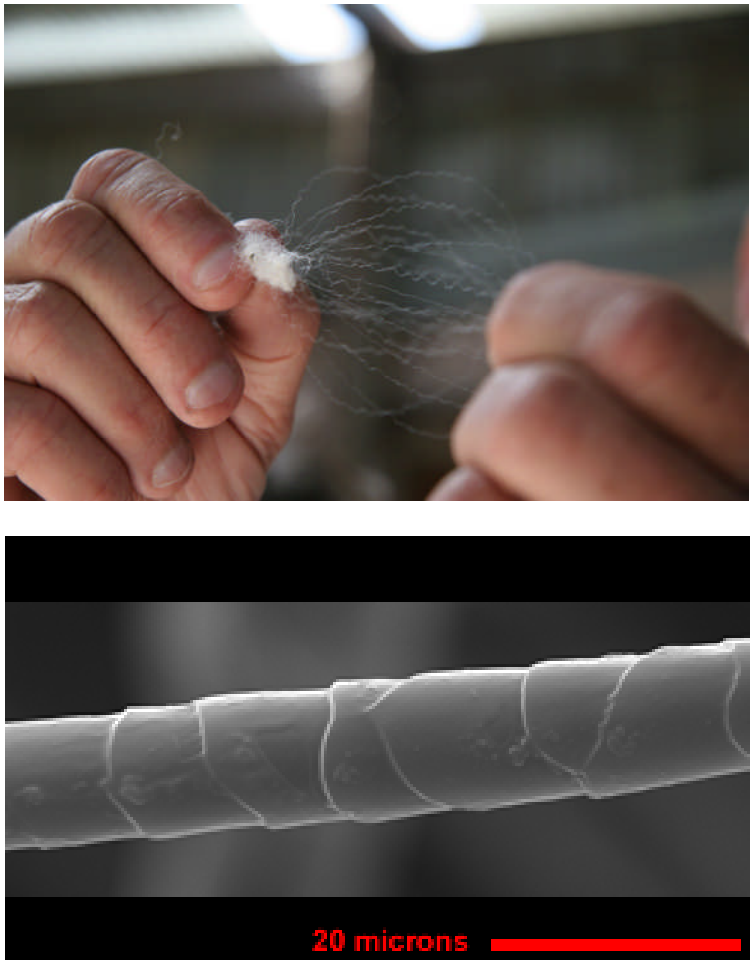


**Figure 2.** **<u>Top</u>: The fibres, when withdrawn from the thin staple of a high density Huacaya alpaca are seen to be fine and uniform in diameter, deeply crimped and elastic.**
**<u>Below:</u> a magnified view of a single fibre shows that the outer scales are long and flat, creating a smooth fibre surface.**

Figure 3 shows the patterning of wool follicles in the skin of another high density alpaca. It is compared with an alpaca of average density.

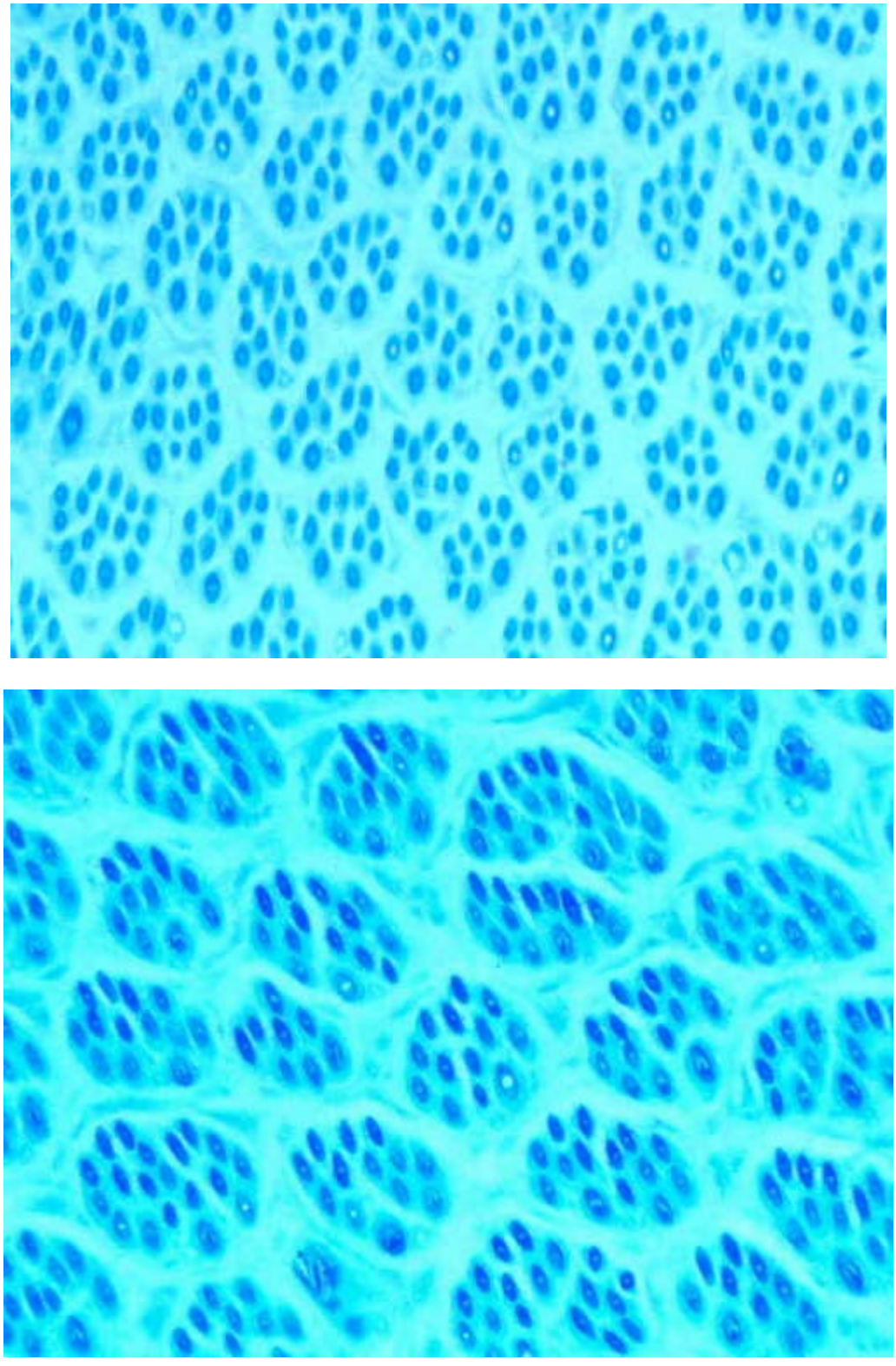

**Figure 3.** **Horizontal skin sections (x 60 magnification) from: <u>Top:</u> a high density alpaca (Huacaya) with 73 follicles per square millimetre. <u>Below</u>: and an alpaca with a density of 34 follicles per square millimetre. The wool follicles (blue rings) contain wool fibres (white centres) embedded in a matrix of connective tissue (open spaces).**

The high density alpaca in Figure 3, at 23 months of age, had 73 follicles per square millimetre , and fibres growing in length at 0.37 millimetres per day. The fibres appear similar in diameter and non-medullated (no guard hair ). Wnen measured, the primary fibres were found to have a mean diameter of 28.9 microns and a low standard deviation of 2.8 microns. The secondary fibres had a mean diameter of 19.9 microns and also a low standard deviation of 2.7 microns.

The average density alpaca in Figure 3, at 17 months of age, had 35 follicles per square millimetre, and fibres growing at the rate of 0.40 millimetres per day. The fibres appear to vary considerably in diameter and most of the fibres are medullated. When measured, the primary fibres were found to have a mean diameter of 39.6 microns and a high standard deviation of 7.5 microns. The secondary fibres had a mean diameter of 26.3 microns and a standard deviation of 3.5 microns.

Note in Figure 3 that the follicles are arranged in oval shaped groups.

In the high density alpaca shown in Figure 3, each follicle group is about 0.75 millimetres (750 microns) wide (actual size) and about 78 microns apart. Within each follicle group, there are about 34 follicles, each follicle being spaced about 20 microns apart. The follicles are packed closely together, and much closer than the distance between each follicle group. Consequently, the fibres that grow out of each follicle group in the skin and into the fleece tend to lie side by side without entangling, and clearly separated as a cluster of fibres from the clusters growing from adjacent follicle groups. The cluster of fibres growing from each follicle group is called a '**fibre bundle'** to distinguish it from a staple (lock). The fibre bundle will only be about 0.75 millimetres wide as its size corresponds to the size of the follicle group.

The high density alpaca in Figure 1 is producing thin staples, each about 5 millimetres wide. It is not at the stage where follicles are so closely packed together that fibre bundles are visible in the fleece but it is nearing that standard.

When this standard is reached, the fleece will consist entirely of fibre bundles (Figure 4).

**Figure 4** **This is a high density and length fleece from an adult Merino ewe. Note that it consists entirely of fibre bundles. The animal's density was 120 follicles per square millimetre, and its fibre length, 0.50 millimetres per day. The ewe produced 8 kilograms of 16.0 micron wool for 12 months fleece growth.**

It can be concluded that the fibre bundle is the basic unit of fleece structure originating from the basic pattern of follicle arrangement in the skin, the follicle group.

In the average density alpaca shown in Figure 3, each follicle group is about 1.0 millimetres (1000 microns) wide (actual size) and about 370 microns apart. Within each follicle group, there are about 31 follicles, each follicle being spaced about 42 microns apart. Since the follicles are not packed closely together, the fibres grow in more or less random directions, and become entangled with fibres from adjacent follicle groups, and form staples.

So what is a staple or lock ?

It is a structural artefact that occur when fibres entangle. Fibre entangle when the distance between the follicles within the follicle group increases, that is, as density decreases. The fibres then grow in more or less random directions and intermingle with fibres from adjacent follicle groups, resulting in a staple. The thicker the staple is (and it can be as much as 40 millimetres wide), the lower the density is and the greater is the degree of fibre entanglement.

Being able to measure primary fibre diameter allows us to determine with certainty that we are selecting alpacas with less guard hair. When the skins of the high density alpacas shown in Figures 1 and 3 were examined under the microscope, there was still a difference of 6.2 microns and 6.3 microns respectively in diameter between the primary fibres and the secondary fibres. You could say that coarse and medullated primary fibres can still be 'invisible' in stylish fleeces, but not invisible when the top or fabric is made. Skin testing allows more selection pressure to be placed on eliminating guard hair and meeting our customer's requirements.

In Suri alpacas, similar visual and tactile indicators of high fibre density and length can be used as described for Huacaya alpacas. However, since Suri fibre twists rather than crimps, fibre bundles from adjacent follicle groups will merge at the point where the first coil is formed in the fleece. Instead of reaching the final stage of a fleece being composed of fibre bundles, the advanced Suri fleece will consist of uniformly thin and long staples that coil gently from base to tip and are exquisitely soft and lustrous (Figure 5).

**Figure 5. A Suri alpaca with high fibre density and length. Note that the staples are consistently thin from base to tip throughout the fleece. Fibre bundles can be seen emerging from the skin, only to twist together into thin staples (photo courtesy of Surilana Alpacas).**

It is appears to be more difficult to estimate visually density in Suris than in Huacayas. The common practice of not shearing Suris until two years of age means that the fleeces are overgrown and may appear to have high fleece weight and good density. This can be misleading. Also, the smoother fibre surfaces of Suris impart a softer handle which could be mistakenly judged as density and fineness.

It also appears more difficult to estimate ‘guard hair’ content in Suris. Because the Suri fibre twists rather than crimps, the fibres are tucked away into the body of the staple. Again, because the fibres have smoother surfaces, ‘guard hair’ is not readily distinguished on handle or sight. An additional factor might be that Suri fibre, moreso than Huacaya fibre, tends to grow intermittently throughout the year, with the ‘guard hair’ being hidden in the body of the staple as short fibres.

These considerations suggest that skin testing has a critical role to play in Suri breeding programs.

**New breeding standards**

What are the new breeding standards required to produce alpaca fleeces that are:

- free of medullation
- as fine as cashmere
- of high fleece weight
- of high processing performance and product quality

Currently, nearly all alpacas have medullated primary fibres and medullated secondary fibres. The proportion of medullated fibres is close to 100% in the primary follicle population and about 58 % in the secondary follicle population (Table 1). Figure 6 indicates that the mean fibre diameter of primary fibres and secondary fibres need to be reduced to about 17 microns before medullation disappears in most alpacas.

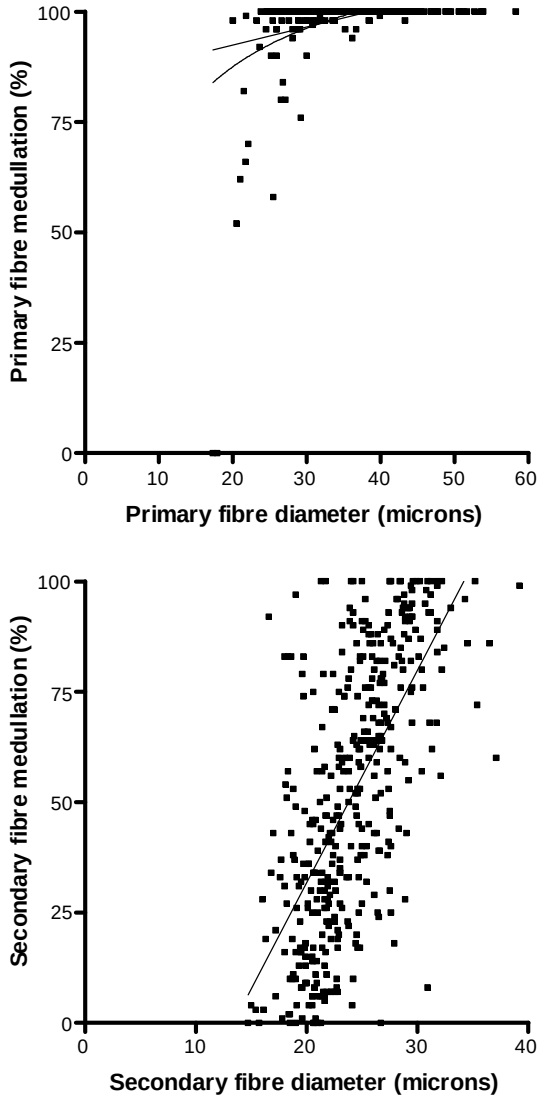


**Figure 6.** **The fibre diameter of both primary fibres and secondary fibres needs to be reduced to about 17 microns before medullation disappears. Note that whilst the diameter and medullation of secondary fibres are closely correlated phenotypically ($r = 0.68$, $P < 0.001$, $n = 210$), the relationship for primary fibres is non-linear.**

To produce a cashmere fine (16 micron) fleece with high fleece weight, the alpaca needs to have a follicle density of at least 60 follicles per square millimetre (Figure 7).

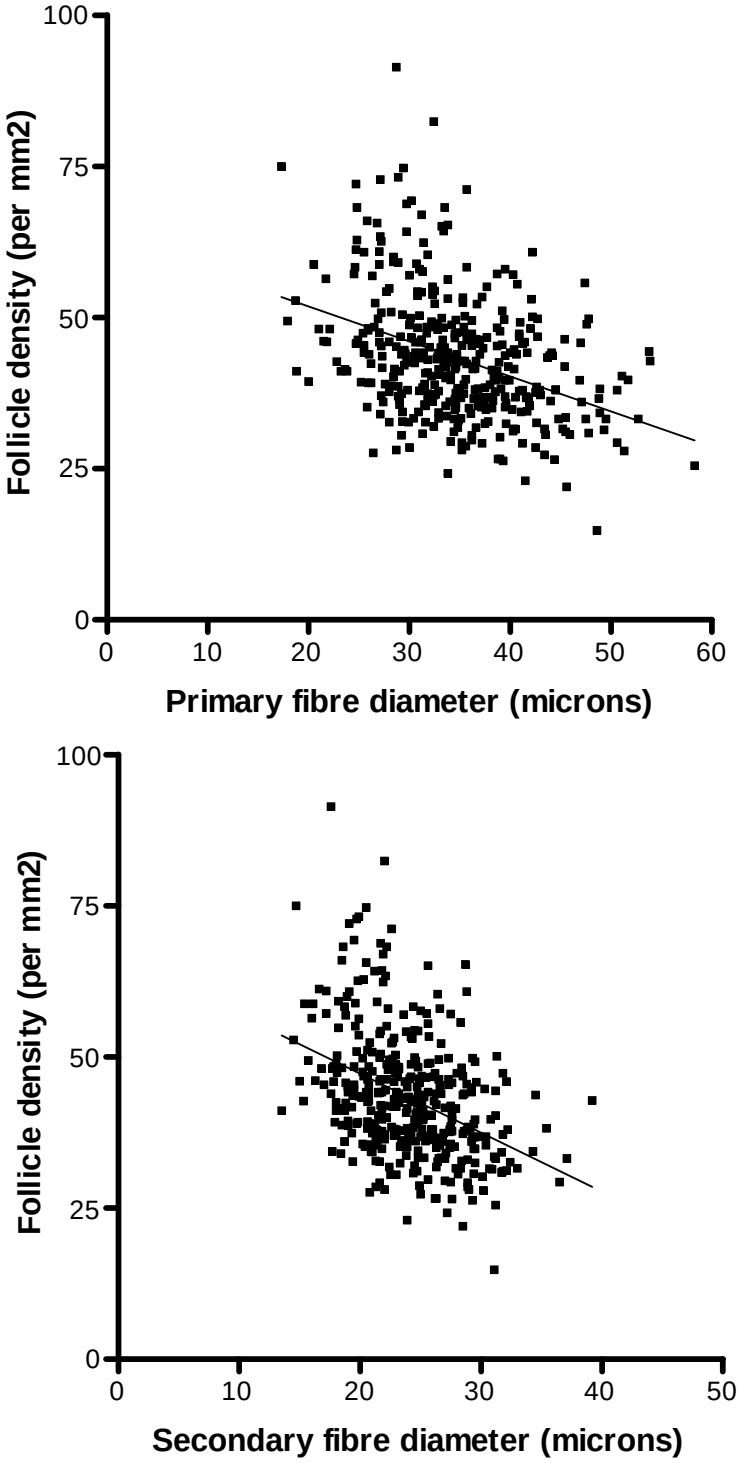


**Figure 7.** **Fibre diameter decreases as follicle density increases. The phenotypic correlations between follicle density and fibre diameter are: r = - 0.39, P < 0.001, n =210, for primary fibres and r = - 0.42, P<0.001, n = 210 for secondary fibres.**

Fibre length decreases rapidly with age in both male and female alpacas. Table 2 illustrates this well-known effect, using Huacaya data as an example.

**Table 2. Fibre length decreases with age.**

| **Age** | **Fibre length** (millimetres per day) | **Range** | **Number of animals** |
|---|---|---|---|
| 1 to 2 years | 0.39 | 0.27 to 0.69 | 76 |
| 2 to 3 years | 0.38 | 0.26 to 0.57 | 57 |
| 3 to 4 years | 0.33 | 0.19 to 0.47 | 36 |
| 4 to 6 years | 0.30 | 0.19 to 0.60 | 43 |
| Older | 0.28 | 0.17 to 0.33 | 35 |

Huacaya alpacas crimp, on average, every 16 days, or about twice the period Merino wool takes to crimp. However, the crimping time varies from 6 to 66 days between individual alpacas (Table 1). Much of this variation is avoidable (genetically) as it is due to 'dogginess' associated with ageing and slow fibre growth.

To overcome this problem, it is probably necessary to select for reduced crimping time (suggest about 12 days) whilst maximizing fibre length. This may require alpacas to be bred which are more efficient converters of feed and have much better organized blood networks to the wool follicles (the latter accompanies selection for high follicle density).

Crimp amplitude needs to be improved (genetically) in order to improve fibre elasticity which in turn, improves drape and drape retention in finished products. Fibre length to staple length ratio is an indirect measure of crimp amplitude. A fleece with a fibre length to staple length ratio of 1.51 to 1 forms crimp waves that resemble semi-circles; close to perfect crimping in fibres.

Huacayas have a mean fibre length to staple length ratio of 1.11 to 1, ranging from 0.71 to 1 to 1.46 to 1 between animals (Table 1), well below the desired level.

## Conclusions

Alpacas have the potential to produce finer and more valuable fibre than cashmere. Each alpaca has the potential to produce about 40 times more fibre than a cashmere goat.

Alpacas that produce this high quality fibre will be in high demand as seedstock and for the fibre.

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