So, how dense are you?

How to select alpacas with improved fleece yields.

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Alpaca are fleece animals, and as such breeders are trying to produce animals with improved fleeces. However, there is still considerable debate over what constitutes an "ideal" alpaca fleece. In the decades to come, alpaca will no doubt be bred - just as sheep are - for a number of different specialized fleece types for the production of different textiles. Already, suri and huacaya fleeces are used to produce very different types of garments. But whatever the fleece type you are breeding for, it makes economic sense that each animal should produce as much "top-grade fleece" per year – and over its lifetime - as possible.

Improvements come about by the process of selective breeding, carefully pairing sire and dam so each generation is better than the one before. For selective breeding to be effective you must know what heritable trait you are trying to improve, and how to measure it to select appropriate animals. A trait is a distinct phenotypic character of an organism. A "good fleece" is not a trait; it is a collection of many different distinct traits. Staple length, color, average micron, etc. are all traits that can be successfully selected, measured, and bred for. The reality of genetics is that the more traits you select for simultaneously, the slower your progress will be. Alpacas have many traits that need improvement, so breeders need to choose what they will address first.

The challenge is to identify the heritable traits that produce the largest possible top-grade fleece yield, and breed for them.

Let's split the discussion of increasing the usable fleece yield from an alpaca into two distinct categories; Maximized Fleece Yield (getting more of that top-grade fleece off an individual animal), and Density (getting more individual fibers per square millimeter of animal). I'll deal with each in turn.

Part 1: Maximum Fleece Yield

First, it's important to distinguish maximum fleece yield from a maximum fleece weight. If all we wanted was more kg of fleece, we would breed 40 micron animals. When the mills of Peru bought fleece purely by weight, breeders there began to select for coarse animals, as that was the easiest way to increase fleece weight[1]. What we want to do is breed an animal with the maximum load of *superior* fleece (however you choose to define "superior").

The traits listed below are all probably heritable, though many have not been studied individually and intensively. Some of the traits may be linked (breeding for one carries along others automatically), or they may in fact arise from a single gene (multiple traits, like consistency of fineness/character/staple might all be due to one gene, we don't know yet). It will take years and the efforts of many different breeders to create animals that strongly express each of these traits. These improved animals

can then be cross-bred to generate an animal that is strong in all the traits listed below. If you're a new breeder just starting out, and are not sure what you should breed for, any of the following would be a good choice that will improve the breed.

Density - the number of follicles per square millimeter. An animal with *n* number of fibers per square millimeter is not giving you as much usable fleece as an animal that packs twice that number into the same sized patch of skin. This seems like an easy trait to "eyeball" – and in cases where the difference in density between animals is enormous, it's pretty straightforward - but it's much trickier to get a specific measurement, and there are some pitfalls that can trip you up. I'll discuss this trait in more detail in section 2.

Staple Length - the length of fiber grown in 12 months. To be effectively spun into yarn the fiber must be long enough (7-10 cm).[2] All other things being equal, an animal that takes 24 months to grown 10cm of fleece will, over its lifetime, give you half as much usable fleece as one that can grow the same amount in 12 months. The lack of staple-length measurements in most herd-sire advertisements suggests that maybe we're overlooking this important trait.

Primary/Secondary Ratio - The hair follicles in the skin are composed of individual primary follicles, each surrounded by a number of secondary follicles. Broadly speaking, the primary follicles are what generate guard hair, where the secondary follicles tend to produce finer fibers. Thus by increasing the ratio of secondary follicles we have more fine fibers, producing a better average micron, and a lower standard deviation. This may also help to improve the density of the fleece.

Similarity in primary and secondary fibers - The primary and secondary follicles can differ wildly in the hairs they produce- as seen in the classic "double coated" llama. But this does not have to be: it is possible to breed an animal where the hairs emerging from the primary and secondary follicles have the same micron, crimp, and growth rate. These animals have little or no visible guard hair, and produce a very consistent fleece (low standard deviation).

Consistency of fineness within the fleece - Most alpaca grow fiber across a wide range of fineness -- a histogram will show results between 15 and 40 micron from one mid-side sample. It is possible to breed much more consistent animals, where all the fiber is in a much narrower range. This is expressed in a low standard deviation of the mean micron in a fiber test. For fine animals a low standard deviation (SD) significantly improves handle by reducing the number of fibers over 30 micron.

Consistency of fineness over fleece - Alpaca fleece tends to be finest in the saddle region, but then coarsens as you move up the neck or down the legs. Taking a grid sample (multiple fiber samples from points all over the body) shows how the fineness varies, and lets you then select animals that have a more consistent micron over the entire fleece area.

Consistency of character (crimp, luster, etc.) over fleece - If you are breeding for a particular characteristic like crimp, it should express evenly over the whole animal. Together with consistency of

fineness, above, this expands the "blanket" region that can be harvested and used as top-grade fleece. The characteristic should be even across the body, up the neck, down the flanks and into the legs.

Consistency of staple length over fleece - Some animals produce wonderful long fleece along the back, but little on the neck or upper legs. Look for animals that produce long fleece across the whole body. Measure the staple at points on the body, neck, flanks and legs to get a measure of the consistency of staple growth.

Consistency of color throughout the fleece - For sorting and combining with other fleeces to produce commercial quantities the fiber must usually all be of a consistent color. Along with obvious spots, this can include keeping an eye out for fleeces that have "off colored" fibers within -- we have a couple light-colored animals with surprisingly dark primaries, for instance -- and selecting against that trait. It may also include selecting against animals that "go grey" and start generating white hairs as they age, a trait most visible in black animals.

Stability of staple length over lifetime of animal - The staple length of animals tends to decrease as they age, but some hold onto long-fleece production late into life. This is a valuable trait that will allow an alpaca to produce useable fleeces for longer, and thus increase its overall lifetime yield of fleece.

Stability of fineness over lifetime of animal - Like staple length, most animals lose their fineness (a.k.a. "blow out") as they age, but some alpaca hold onto that fineness or only coarsen to a small degree. An animal that keeps its fineness will be able to produce more valuable fleece in its lifetime.

Stability of other traits over time - Many other positive traits of alpaca fleece decline over time. In each case it may be possible to select for animals that maintain those traits for longer. This will require you to measure and enumerate the traits where possible, and keep fiber samples for historical comparisons. For example, if you are breeding for crimp, you should try and measure the amplitude and frequency of crimp of each animal every year to see how it changes over time, so you identify those animals that maintain the characteristic.

Resistance of fleece to dietary coarsening - It is well known that alpaca are susceptible to "starvation fineness," that is, when they are put on a diet just barely sufficient to sustain them, they tend to grow a finer (lower micron) fleece[3]. Take an average alpaca from a bare-dirt drought paddock and put it on lush grass and a 5 micron coarsening, or more, would not be a surprise. It is theoretically possible for a "breeder" of fine animals to be nothing more than a careful manager, with fineness of fleece due to environment or feeding regime, and not genetics. Some animals, though, seem to produce a consistent fleece no matter the diet, which is obviously a very useful trait and may be driven by a genetic predisposition towards fineness.

Size of the animal – A larger animal has more room for fleece than a smaller one. A smaller animal consumes less pasture. The balance between animal size, fleece yield, and stocking rates has yet to be determined.

Part 2: Fleece Density

Half of all breeders in the last health survey listed "density" or "fleece weight" as a breeding goal. The problem is that different breeders sometimes use the word “density” to refer to different fleece traits – or conversely point to different fleece traits as evidence of “good density”.

Strictly speaking, the “density” of a fleece is a measure of the number of hair follicles per square millimeter of skin.

It is possible to directly measure this trait: a skin biopsy is taken and the hair follicles are counted under a microscope. This is, however, an invasive procedure, and the costs and time required make it impractical as a means for screening large number of animals. What to do, then?

People often speak of the fleece weight of the animal as evidence of its density. But as a measure for selective breeding, a fleece weight is not nearly as predictive a tool for density as you might think, and in some cases it can be downright deceptive, leading to incorrect breeding choices. There are four reasons why fleece weight is a bad measure of density:

You often don't know how much fleece was included in the total. Sometimes a fleece weight is blanket-only; other times it can include fleece from the belly, legs or neck. The region cut as "blanket" can also vary widely.

The average micron has a very large affect. A high micron fleece requires fewer hairs to generate a given weight, but because weight goes as a square of fiber diameter, it can be very difficult to correctly estimate "by eye" the influence of fiber diameter on weight.

The staple length is rarely included. A long fleece weighs more.

The size of the animal is never mentioned. Because density is based on a unit of area, the size of the animal affects the total area available for fiber.

The other common tool for measuring density in the field is the "hands on" approach. This too can be deceptive, as a number of fleece characteristics can distort the results. For example fiber alignment and bundling can make a fleece very "springy" and resistant to compression, which makes it feel like there is more fleece present. A coarse animal will look and feel denser than a fine one with the same actual number of follicles per millimeter, because the larger fibers are stiffer and take up more space.

So if fleece weight and a good grope are unreliable, what else can you do? I have devised a simple formula to create a “normalized fleece weight” that takes into account the three main variables- average micron, staple length, and animal size. Once a fleece weight has been normalized, it can be directly compared to other normalized fleece weights – apples to apples -- and this will give an idea of the relative density traits of those animals. This is a good way to identify a sire or dam with a higher density trait. Note that a "normalized" fleece weight is not an annualized fleece weight. Annualizing is a correction factor that lets you estimate what one year’s production would be; normalizing is a process that corrects for multiple variables to allow better inter-fleece comparison.

You will need three pieces of information for normalization: (1) the

fleece saddle-only weight in kilograms, (2) a mid-side sample from the fleece for analysis to give the average micron and staple length in centimeters, and (3) the length of the animal from the base of the neck to the top of the tail in centimeters. When collecting these samples consistency is very important. Collect the same region of fleece for the "saddle" region from each animal. Don't include any other fiber in the weight, even if it is of high quality, as it will distort the results (you can always sort the fiber for your own purposes later). None of the numbers need to be or should be annualized, as this is all accounted for in the calculations that follow. [footnote: The *length* of a fleece will change as the fleece grows during the year, but the number of individual fibers in it will not. The calculations specifically correct for length. The saddle-only weight is used to prevent differences being introduced because of differences in fleece coverage between alpaca.]

The method described here will not generate a density number in terms of follicles per square millimeter (though I would be very curious to see the correlation to skin biopsy data being collected by some breeders). It is a mechanism for estimating the *relative* density between your animals. Because cutting and measurement errors are inevitable, the number produced as a "normalized fleece weight" is not absolute. Since it will not distinguish small differences in animal density – for that you'd need to get that skin biopsy -- it would be safest if you considered animals within 10-20% to be equivalent.

Normalized Fleece weight:

Blanket Fleece weight in kg * (10 / staple length in cm) * (75 / back length in cm) * (micron correction factor from table) = normalized weight

(For an exceptionally fat animal, multiple the result by 0.95. For an exceptionally thin animal, multiply the result by 1.05.)

Case Study: A Fair Comparison

The picture shows three female alpaca. As you can see they range in size from the large long-backed brown Caraboo to the medium-sized fawn Concetta and the little brown and white Nazani. How can we compare their fleece weights fairly?

Their 12-month blanket-only shear weights and average microns were as follows:

Caraboo	3.5 kg	28 micron
Concetta	2.5 kg	25 micron
Nazani	1.2 kg	21 micron

From these numbers alone, how would you rank their density? What happens to the numbers if we use the fleece normalization calculation?

Animal	Fleece		Staple		Back		Micron		Normalized Weight
Caraboo	3.5 kg	*	10/10 cm	*	75/90 cm	*	0.8	=	2.33 kg
Concetta	2.5 kg	*	10/10 cm	*	75/75 cm	*	1.0	=	2.5 kg

Nazani 1.2 kg * 10/6 cm * 75/67 cm * 1.42 = 3.18 kg

It turns out that even though Caraboo's fleece weight was 40% greater than Concetta's, once you correct for the difference in animal size and micron, they are nearly equivalent. Nazani, with her short staple, small body, and fine fleece, actually has a significantly greater normalized weight (and thus density). This information shows that Nazani would be best matched to a sire with a long staple, as that is the primary deficiency in her fleece.

Table 1- Correction factors for fleece weights

Micron	Multiply By:
16	2.44
17	2.16
18	1.93
19	1.73
20	1.56
21	1.42
22	1.29
23	1.18
24	1.09
25	1
26	0.92
27	0.86
28	0.8
29	0.74
30	0.69
31	0.65
32	0.61
33	0.57
34	0.54
35	0.51
40	0.39

These numbers were generated by looking at the ratio of the cross-sectional area of fibers of different diameters. The area is calculated by $a = \pi * r^2$.

For example a 25 micron fiber (taken as the "mid point" of the table) has an area of $3.14159 * 12.5^2 = 491$ square microns. A 20 micron fiber has an area of $3.14159 * 10^2 = 314$ square microns. This is a ratio of 1.56 : 1.

Conclusion

The key to a successful breeding program must start with the clear knowledge of what you are aiming for. Broad generalizations like "breeding quality alpaca since 1922" are good for marketing, but worthless as a guide for animal selection. The harsh law of genetics means that you

can only rapidly breed for a handful of traits at once. If you are breeding for 10 traits simultaneously in a single line of animals, you are probably not making much progress at all.

Be as specific as possible about what you are breeding for. Make sure that it is actually a genetic (heritable) trait. Find a way to measure that trait, so that you can keep track of your progress generation to generation. These records are important, as animals change over time. It is not fair to place a grandmother (age 15) next to a great-granddaughter (age 2) and speak of the huge improvements. You must be able to compare the grandmother's traits when she was 2 versus the granddaughter's traits at the same age to see if there has been actual improvement.

Keep records besides those directly related to your trait. When it comes to genetics, more information is always helpful. You may discover that you have an un-noticed "genetic gem" in your herd that may be worth keeping. (For example, by keeping records you might discover that one of your blood lines has an increased resistance to parasites based on Fecal Egg Counts. Such a bloodline could be hugely valuable.)

The heritability of many of these traits is not currently known, nor has any association (linkage) between these traits yet been identified. Good records can be used by a geneticist to determine all these factors, thus increasing our knowledge of the alpaca, to the benefit of the whole industry. Even data on a handful of animals on a small farm can increase our overall understanding.

References

Eric Hoffman "The Complete Alpaca Book", page 28-29

Ibid, page 256

Ibid, page 275