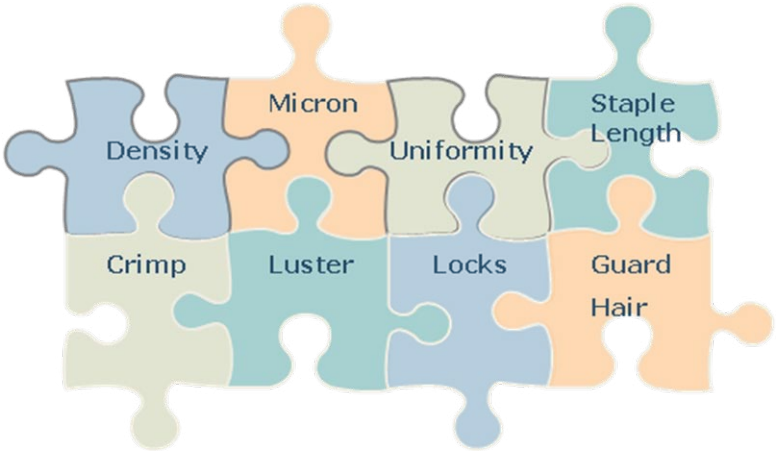
The North American Alpaca Federation

Alpaca University

Alpaca Fiber for Profit Course

Module 2: Alpaca Fiber Evaluation - The Objective & Subjective



Jim Tomaszek

Editorial assistance provided by Pam Welty

Note: This material is presented as a support for the alpaca industry and is not verified by any administrative or authoritative body or the AOBA at present

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Introduction: Alpaca Fiber for Profit

Question: What do you do to achieve profit with alpaca fiber?

Answer: We selectively breed alpacas to maximize profit realized through the eventual sale of fiber end products and/or fiber-related services.

Question: With a limited fiber supply or demand, how do we sell our fiber for profit?

Answer: As breeders, we come together as partners, rather than competitors, to build appropriate sales & marketing channels for alpaca fiber. In addition, we work in cooperation to educate North American consumers about the value of alpaca fiber in textiles.

Question: Where do we begin?

Answer: We begin with a complete understanding of alpaca fiber, its potential value, realistic market demands (current and potential), and selective breeding goals and strategies.

Question: What is the North American Alpaca Federation's (NAAF) role in this alpaca fiber for profit initiative?

Answer: NAAF is simply an alpaca marketing organization made up of fellow alpaca breeders dedicated to and focused on marketing and sales. NAAF's mission is to promote the North American alpaca and to amplify the demand for the alpaca, its fleece, and related end products through timely education and appropriate related strategies, in support of individual alpaca owners and breeders.

NAAF's goals are to:

Work cooperatively with any and all reputable alpaca industry resources to advance the alpaca industry in North America.

Offer marketing support to Independent Alpaca Businesses for marketing & education.

Develop and implement a comprehensive model for achieving sustainable profit from alpaca fiber.

Continue to attract new customers for sales of alpaca breeding stock.

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Course Disclaimer:

The alpaca is a relatively new and exotic sight in pastures and backyards all over North America. Less is known about alpacas than perhaps any livestock animal in America. As we learn more about our relatively rare alpacas, both through research and experience, our current "facts," theories, and speculation are sure to adjust accordingly.

Many of the "how's and whys" of alpaca fiber are still hotly contested issues and some scientific research contradicts previous research. Study contradicts study. It is the intent of this module to attempt to separate pure opinion from responsible research, documented experience, and common sense. It is our sincere hope that this module will evolve into a more refined and accurate knowledge base as you and others question this material, engage in lively discussion, and contribute to improve this workshop.

This module is based on collective breeder experiences, independent university studies, research conducted in Australia (CSIRO), and articles written by Dr. Sumar, Ian Watt, Mike Safely, Dr. Jim Watts (SRS), Mr. Villarone, Dianna Jordan (AFCNA), and Robyn Kuhl (NAAFP), along with many other sources.

Every attempt has been made to exclude unsubstantiated claims made by those who might choose to skew facts to favor sales of their own animals, breeding services, or fiber end products. For example, comparing alpaca to other fibers, as in "alpaca is seven times warmer than wool," still needs to be qualified. Just as a steak cooked to perfection can be a delight to the gourmet's palate, one burned to a crisp does not reflect a great steak at its best. Similarly, a thick micron and dirty alpaca fleece, mixed with long primaries and guard hair (the proper term is "kemp"), which is then poorly processed, can be thought of as the equivalent of a burned steak. It neither represents the standard, nor reflects the potential. As another example, Yokum McCall states that alpaca fiber is 50% stronger (1.5x) than wool, which refers to tensile strength, or the pressure point at which healthy fibers snap. However, we cannot say that an alpaca sweater is necessarily 1.5 times stronger than a wool sweater. What if the alpaca sweater was made with fiber from a sick alpaca? We must be careful not to mix apples and oranges. So, "branding" North American alpaca is a must for quality control, customer perception, and the finished product.

The alpaca comes from a diverse genetic background. While DNA studies show the domesticated alpaca to be the closest relative of the undomesticated vicuña, further studies reveal significant breeding history with the llama. As a result, there are many "types" of alpaca, depending on various ancestries. This fact manifests itself in the alpaca's fiber, which also comes in many varieties. While some styles will be in greater demand than others, dictated more by fashion than true worth, all styles of fiber have value. It is up to owners and breeders to create niche markets. In addition to creating an ever-growing supply and demand for fiber, we must also continue to educate the American public (as well as ourselves) on our harvests' value. To accomplish this, we must be sure we fully understand the value of alpaca fiber ourselves. It is in the spirit of this challenge that this module was produced.

Note: NAAF remains neutral on the need for a North American alpaca breed standard.

The Fiber for Profit Workshop consists of four interrelated modules:

Module #1 – The Current & Potential Value of Alpaca Fiber
Module #2 – Alpaca Fiber Evaluation – The Objective & the Subjective
Module #3 - Histograms, Follicular Skin Biopsies, & EPDs
Module #4 – How to Make Money with Alpaca Fiber and the Value Chain

The modules interrelate in order to present a comprehensive understanding of alpaca fiber, its benefits and shortcomings, how it compares to like fibers, and how it can be measured objectively to maximize profit. Module #4 presents case studies showing how it is currently possible to pay for the upkeep of a herd through fiber sales. It is hard work, multi-faceted, and requires that the industry focus on both maintaining open sales and marketing channels to attract an ever-growing population of alpaca breeders, as well as creating breeding and end product standards to ensure the success of an increasing variety of revenue streams for alpaca end products.

Module 2: Alpaca Fiber Evaluation – The Objective & Subjective

The alpaca is classified as a two-coated animal. The coverage over its entire body consists of two different types of fiber, each having a specific purpose. By way of comparison, consider ducks or geese, which have rugged outer feathers, with a finer layer underneath. We call this finer layer ”down.” Down helps insulate the birds from cold water and air, and is used in the manufacture of warm down blankets, jackets, and the like. The same concept applies to alpacas. The rugged outer fibers are called primary fibers, while the softer inner fibers are known as secondary fibers. When we hear the term alpaca down, think soft, insulating fibers. When you have a fleece with an average fiber diameter (AFD)of 16 microns and a standard deviation (SD) of 3, the fleece is very uniform and it is not possible to isolate the primaries from the secondaries. At this micron level and below, all fibers are considered to be down.

A. Primary fibers

The primary fibers in a blanket are just that – primary fibers and not necessarily "guard hair." Guard hairs are hollow – completely hollow. Primary fibers offer needed strength and support to the finer secondary fibers. Indeed, without primary fibers there would be no secondary fibers, for the primaries must be present for secondaries to grow and thrive. Primary fibers emerge from larger follicles that have both an associated sweat gland and a sebaceous or wax gland, as well as an erector muscle. The sebaceous gland provides each fiber with a protective coating before the fiber reaches the skin, keeping the skin and fibers soft. The sweat gland allows for thermal regulation within the alpaca, which is essential to the alpaca's health. The erector muscle has the ability to contract, which in turn causes the primary fiber to expand, thereby increasing

the amount of air trapped in the fleece. This results in increased insulating effects for the alpaca and provides additional protection to the secondary fibers beneath it.

The primary follicle produces only one fiber, which is a primary fiber. Primary fibers can have a variety of medullation, ranging from completely solid fibers to partially, as well as fully, medullated hollow fibers. These hollow-core fibers are relatively stiff and are known as "guard hair." Not all primary fibers are guard hair but all guard hairs are Primary fibers. Meullation within alpaca fiber gives alpaca its unique and superior insulation abilities. Primary fibers in general protect the alpaca's secondary fibers from the elements, including from possible felting on the animal. Moisture from rain, humidity and other factors can cause the alpaca to felt, which not only de-values the fleece, but also reduces the ability of the blanket to properly insulate the alpaca.

B. Secondary fibers

Secondary follicles are smaller, more numerous, and grouped around primary follicles, with the grouping being expressed by a ratio called the secondary to primary follicle rratio ("S/P ratio"). The secondary follicles produce only secondary fibers and do not have sweat glands or erector muscles, but do contain a sebaceous gland. Some secondary follicle sheaths allow "derived secondary fibers" to develop along the same sheath, but each follicle can only produce one hair. Note that secondary fibers can be medullated, just as can primaries. The S/P ratio indicates the number of secondary follicles surrounding a primary follicle. This varies between breeds of fiber-producing animals and also within a breed itself. This ratio can be an indicator of density. But, what it really comes down to is how many fibers are actually coming out of those secondary follicles.

C. "Guard Hair"

Alpaca breeders tend to throw the term "guard hair" around quite a bit and think of it as "the enemy." But, to the alpaca in its natural environment, guard hair is critical to survival. "Guard hair" is defined as fiber with a core that is more than 60% hollow or medullated. Guard hairs are straight, mostly hollow, and stiff; they protect the grazing alpaca by helping to deflect damaging grasses, twigs, leaves, and reeds. The guard hair helps part the way through vegetation by covering the alpaca's chest and underside, thereby diverting material from under the belly, armpits, and between the legs, both front and back, while protecting the soft insulating secondary fibers (down).

Secondary fibers are instrumental in helping alpacas regulate body temperature by providing soft, dense insulation. The vast majority of heat loss in alpacas occurs from the belly region, where alpacas typically have less fiber. As a result, alpacas tend to cush in cold weather to help retain body heat. While the fiber industry focuses on secondary fibers, because they tend to be finer and softer, those fibers do not provide the same degree of protection from the environment

as do the guard hairs and other primary fibers. It is also thought that there may be a difference between the primaries and secondaries in terms of durability. Fabrics we wear closer to our body are generally softer, but less durable. Fabrics we wear to shield us against the elements must be more durable. A luxuriously fine alpaca sweater worn next to the body, combined with a less fine and soft, but more durable, alpaca over-coat, may be the ideal compromise. All alpaca fiber has value. The key is to identify the appropriate processing method and end-use for each grade and/or blend of alpaca.

Trying to breed out guard hair completely could result in more vulnerable alpacas. While all guard hairs are primary fibers, not all primary fibers are guard hair. This is an important distinction. The alpaca's blanket area, where the best fiber in terms of fineness and uniformity is generally located, is made up of both primary fibers and secondary fibers. While the primary fibers in the blanket are usually thicker than the secondaries, they generally are not thick enough to be classified as guard hair, particularly in relatively young alpacas. At least that is what most breeders would hope to produce. The alpaca needs less protection from the elements on its back, thus the secondary fibers require less support from very thick primaries, like guard hair. The somewhat, and perhaps only slightly, thicker primary fibers in the blanket area are sufficiently protective. Some blankets, however, contain primary fibers that are very thick, straight, and undesirable to both breeders and manufacturers, as they cause "prickle," contribute to "pilling," and take dye differently than secondaries, creating significant issues of quality control.

Coarse fibers and guard hair can be removed from fleeces through the "dehairing" process. Dehairing machines are specifically designed to accomplish this. Fleeces that have relatively few thick fibers may not require dehairing, as any thick primary fibers may disappear during the combing or carding processes. Coarser fibers are heavier, tending to drop to the floor of the mill as a fleece is combed or carded. In fleeces with numerous thick fibers, dehairing can be used to enhance the quality of the finished product, but that extra step will not only increase processing cost, it will also result in a substantial loss in finished weight and, therefore, profit. Dehairing is not perfect, it can only remove a percentage of the coarser and/or longer primaries. In addition, dehairing has a tendency to not only remove primaries, but to pull out some secondaries as well, reducing total yield. The level of waste as a result of dehairing can sometimes exceed 60%. Clearly, it is far better to try to breed coarse blanket fibers out up front!

D. Medullation

Medulla

The medulla refers to the hollow, cylindrical cell that is found along the long center axis of some animal fibers. The degree of medullation can vary from broken or interrupted to fully medullated fibers, in which there is a thick hollow core or medulla, with a thin cortex. This hollow core may run continuously along the length of the fiber or it may be intermittent. Alpacas tend to have more medullated fiber than sheep, although when guard hair is present in sheep, it is medullated and referred to as kemp. Medullation can occur in both primary and

secondary fibers. Medullated fibers cannot be discerned by the naked eye. While characteristics that can be indicative of medullation may be easily discernable, such as with thick and/or stiff fibers, medullation itself cannot be verified except by means of microscopic examination. Guard hair and thick primary fibers are relatively easy to detect in Huacaya alpacas, sometimes simply because they lack crimp; but to determine the degree to which those fibers may be medullated, they must be examined by microscope.

The impact of medullation in a fleece depends on the desired end product. An end product that is intended to provide superior insulation may benefit from the presence of medullated fibers, as those hollow and/or semi-hollow cores can help trap heat, effectively helping a person stay warm in cold weather or cool in hot weather. Medullation can help provide an effective thermal barrier. On the other hand, if a dyed end product is desired, medullation is problematic. The hollow areas within a fiber do not absorb dyes the way the substantive parts of the fiber do. As a result, highly medullated fibers tend not to produce colors that are either as vivid or as consistent as non-medullated fibers. In general, coarser alpaca fiber tends to be more medullated than finer fibers. However, with respect to any particular fiber, a microscope is needed to accurately determine the degree of medullation. The degree of medullation within a fleece is not only a function of genetics; it can also be affected by climate, stress, nutrition, and parasite load.

Fully medullated fiber is true "hair" fiber – straight, smooth, hollow, and ending in a point. Any fibers over 30 microns will create a prickly, itchy, or scratchy effect, whether or not they are medullated. Both the shear-cut end of the fiber and the outside, pointed end of the fiber contribute to the prickle factor. Frequently, those prized, thick Scottish and Irish wool sweaters are warm, as a result of medullation, but also prickly because the fibers are relatively coarse.

Most Huacayas carry guard hair on the chest and in the britch area, and many carry it also up the neck. In some, guard hair creeps further into the fleece and through the blanket. Coarse primary fibers are undesirable in alpacas, particularly when carried within the blanket. With careful selection techniques, breeders should be able to make good progress at producing alpacas with less variation in micron size between primary and secondary fibers within a fleece. In other words, thoughtful breeding choices can result in increased fiber consistency and decreased overall AFD. However, both degree of medullation and AFD can be influenced by outside factors, including environmental stressors, general health, and nutrition. In addition, it appears that as density increases, often the number of guard hairs decrease, and primary fibers instead evolve into finer fibers, less distinguishable from the secondaries within the blanket.

Primary fibers can be fully medullated, partially medullated, or not medullated at all. Secondary fibers, likewise, can be fully medullated, partially medullated, or not medullated at all, even when the micron is extremely low. Medullation has been noted to as low as 12 microns.

E. The "Halo Effect"

The "halo effect" refers to the look of a fleece in which there are a number of apparently longer fibers protruding beyond the majority of fibers within the fleece. This halo may be present over most of the animal, as may be the case with a cria, or it may be evident only in some areas, as is often the case on the chest or bib of an adult alpaca. In adult alpacas, a halo is often indicative of guard hair. The halo effect is a topic of much debate at shows and breeder gatherings. Is a halo a good thing or a bad thing? It can depend on many factors. Not only is each alpaca different genetically, but nutrition and environmental factors can also play a big part in how and when blanket fiber develops.

A halo on a cria's blanket is generally not the result of guard hair, but simply primary fibers that are longer than secondaries. On a crias, primaries are frequently longer because they start to grow in utero earlier than the secondaries. In addition, a cria's primary fibers may appear even longer because they may lack the crimp that is produced as a result of a group of fibers growing together in close proximity. Once the secondary fibers begin to grow, the entire group or bundle of closely clustered fibers will begin to exhibit crimp, both primaries and secondaries alike. Finer and more densely packed fibers, primaries and secondaries together, will tend to produce more highly defined crimp. Finer fibers bend more easily than thick and the more densely packed they are, the greater the pressure for them all to grow in the same fashion. A cria has the densest fleece per unit of skin area that it will ever have. As the alpaca grows and matures, the skin will expand like a balloon, forcing the skin follicles farther and farther apart. Because of these variables, both in the initial growth rates of primary versus secondary fibers and in the changing follicular density as the cria matures, experienced breeders often say that the quality of an alpaca's fleece cannot be fully evaluated until after its second shearing.

In adult alpacas in particular, a halo of primary fibers may be indicative of an alpaca that lacks density. When fiber is not densely packed, the primary fibers are not under pressure to perform like the secondaries. In contrast, when many fibers are growing together in a relatively small area they must conform to a like growth pattern, and primary fibers, especially fine ones, will tend to exhibit the same crimp character as the surrounding secondary fibers. A densely fibered alpaca, therefore, will tend to have highly organized fleece architecture in terms of bundling, staple and micro staple size, and crimp style.

F. Fiber Evaluation

Question: How can alpaca breeders increase profit from fiber production?

Answer: First and foremost, breed for uniformity in fleece characteristics.

If a breeder drastically increases the number of alpacas owned, this increases the fleece harvest, but also increases the need for feed, vet support, shearing, and maintenance costs in general. What we, as breeders, want to achieve is a way of increasing the quality of our product, though

not *necessarily* the quantity on any particular farm, in order to improve our return on investment. The strategy is one of choosing quality over quantity.

We evaluate our alpacas on conformation (physical build and proportions), largely by using our senses, and on fiber producing characteristics, often using scientific measurements to verify what we cannot necessarily confirm through our senses. Subjectively, we use our senses of sight and touch to evaluate alpacas. Conformation, crimp style, lock structure, staple length, fineness, density, and general fleece weight are all things we can, with experience, subjectively evaluate through our senses. However, when it comes to fleece traits, in particular, most are capable of objective measurement, which can be used to corroborate our initial perceptions.

Objectively, we can measure many fiber traits that are largely controlled by genetics.

- Density - primary, secondary, and derived secondary follicle set
- Primary/Secondary fiber ratio
- Derived secondary follicles
- Follicle organization
- Follicle blood supply system
- Crimping
- Staple length

Some of these objectively quantifiable fiber traits are also influenced by environmental factors and nutrition, and are, therefore, capable of manipulation by the breeder even after an animal is "on the ground."

- Fiber diameter
- Crimp
- Fiber medullation
- Fleece weight
- Fiber tenderness

Certain fiber traits are largely subjective and our evaluation of these falls mainly into the realm of opinion and/or esthetics.

- Brightness (can now be measured, but is a very new process.)
- Luster (same as above)
- Handle/Softness

A good eye, coupled with knowledge and experience, can produce a subjective measure. But, "my eye is not a microscope and my arm is not a scale." For breeders without substantial experience, relying on subjective assessments can go hand-in-hand with "barn blindness" – the inability to clearly and accurately evaluate one's own animals.

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We will now open our selective breeding "toolkit" and investigate each implement we have available to evaluate and produce high quality alpaca fiber for profit.

1. Density

Technically, alpaca fiber density is a sampled measure of the number of hair follicles per square millimeter of skin. The number of follicles is measured quantitatively using a skin biopsy. In a skin biopsy, a small core of the alpaca's skin, about the size of a pencil eraser (10mm/0.5 inch), is taken from the alpaca's mid-section and then evaluated scientifically in a lab to produce a specific density measurement expressed in terms of primary and secondary follicles per square mm.

While density can be *estimated* by hand and through some visible indicators, results can be inaccurate. Some breeders evaluate density by grabbing a handful of fleece and assess density by feel. This method can be handy for comparing one animal to another, to obtain a qualitative sense of which is more dense. In the show ring, judges do this all the time, often bringing the animals side-by-side to compare each to the other in terms of fineness and density. Individual Huacaya staples or Suri locks can also be assessed , both visually and by feel, to evaluate the amount of material within the staple or lock, thereby estimating an animal's overall density. These sensory methods, however, are fairly subjective and a significant amount of experience is required to accurately estimate an alpaca's fiber density by hand. To the inexperienced, a handful of 40-micron fiber would tend to fill the hand easily and may produce the illusion of a very dense fleece. To the untrained hand and eye, a coarse alpaca can feel both soft, perhaps due to fiber uniformity, and dense. In contrast, a handful of 16-micron, ultra-soft fiber can feel very lightweight, which may result in an inaccurate assessment that the fleece is not very dense. The "take-away lesson" here is that, density is very tricky to measure qualitatively and requires a great deal of practice to do so accurately.

- Visual clues to density include compact, solid staples, with little skin visible upon parting the fleece. Often only a thin jagged line of skin shows in the fleece of a very dense animal. Very fine fiber can produce the *illusion* of a lightweight, less dense fleece. Excellent fleece coverage on the legs and head, including a thick topknot and full cheeks, *may* be indicative of density. Consistency within the fleece also often goes hand-in-hand with density. However, it is important to note that there are exceptions to all of these "indicators." For example, leg coverage on many high quality, very finely fleeced animals is often not as thick as on alpacas sporting coarser fleeces. Therefore, there are animals that may exhibit the indicators identified above, but nonetheless lack density. In general, however, these indicators are useful tools in our "breeders' toolkit."

A highly organized lock or staple, exhibited by Suri twist or Huacaya crimp, may be an indication of density. The reason density matters so much to a breeder is that increased density results in increased shear weights, and therefore a breeder's profit from fleece sales increases as well. In addition to density, an animal's body size also impacts shearing weight. This is one reason why some have bred alpacas to llamas – to increase the size of the alpaca. The idea is to

produce alpaca quality fiber on a llama's larger frame. Although the strategy has resulted in bigger alpacas, in general the fiber produced is coarser. Quantity went up, but quality, in terms of a fine uniform fineness, went down. Essentially, a compromise was reached, which may or may not be considered desirable.

Some scientific studies indicate that fleece follicles tend to develop farther apart in large animals. This would reduce density. Sheep breeding history and analysis shows the densest fleeces in the Merino industry were on small to medium-sized animals with thick bodies. These animals also turned out to be most efficient grazers. They required less water and fodder to sustain their bodies. Bigger may not always better. Fine fiber sells for a premium, so quality can "outweigh" quantity when it comes to producing fiber for profit. An alpaca advertised as having produced 15 pounds in one shearing may sound impressive. However, if that fleece is high-micron fiber, not only will it naturally weigh more due to the coarseness of individual fibers, but it will lack the key advantage of alpaca, which is it's luxurious softness resulting from uniformly fine fibers. According to one source, an increase in AFD from 25-microns to 30-microns will cause fleece weight to double.

In addition to providing protection from the elements to secondary fibers, primary fibers are the building blocks around which density is built. The ratio of the number of secondary fibers to primary fibers (S/P ratio) becomes a highly valued statistic for analyzing a fleece for density. The higher the ratio between the number of secondaries to the number of primaries, the denser, softer, and more consistent the animal is likely to be. On a fleece where there is a low S/P ratio, the thicker primary fibers will be more noticeable as we run our hand along the fleece, as there will be few secondaries to contribute greater consistency and fineness. In an animal like this, the histogram will show an "average fiber diameter" (AFD) that is skewed higher. Studies show that, while there are exceptions, the denser the alpaca, the finer it will tend to be. Breeders should strive for a high S/P ratio of 15:1 or greater, which will generally result in better handle, lower AFD, and greater uniformity, while increasing fiber density. Increased density, combined with fineness, results in increased profits.

While density usually goes hand-in-hand with fineness in alpacas, some animals can produce very dense fleeces that are not especially fine – Lincoln sheep are an example. In alpacas, density or a high S/P Ratio will generally result in fleeces that exhibit consistency in terms of both AFD, staple length, and crimp or lock style. In both Suris and Huacayas, the pressure of tightly packed fiber pushing outward together from skin follicles forces the fibers to align with uniform lock or crimp styles.

Why does density matter?

Focusing on density as a breeding goal, may be a better strategy than focusing on fineness alone. The majority of very dense animals have fine micron counts. It is not true, however, that very fine animals are necessarily dense. Extreme fineness alone may be counterproductive to maximizing a breeder's profits. While vicunas are incredibly fine, with amazing handle and uniformity, Vicuna fiber is not as strong, durable, warm, or water resistant as alpaca fiber. As a result, it is not as commercially marketable as alpaca. In the worldwide sheep wool industry, breeders have

found that focusing on fineness alone results in a loss of staple length over the course of four generations, which reduces overall shear weights and, therefore, profit.

There are 4 ways to increase blanket weight

- Breed for increased follicular density
- Breed for increased staple length
- Breed/feed to increase the micron count ☹
- Add or leave dirt in a fleece ☹

Clearly, of the above options, only the first two make good sense. From the perspective of producing fiber for profit, we want to breed for increased density *and* a good staple length. If successful, these attributes will result in quality (fineness, uniformity) and quantity (fleece weight), thus maximizing profit.

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a. Tips for a Subjective Density Analysis

When analyzing an animal's density look for:

- Small, tightly packed bundles or staples of uniform fibers.
- Bright fiber – generally fibers with lower scales appear brighter; light reflects differently from high scale edges and dust is caught in the scales, dulling the appearance of the fiber.
- In Huacayas, a well defined, uniformly expressed crimp from skin to the tip.
- Less contamination inside the fleece (look at the shoulder fiber for this evaluation as the fleece ages), as dirt and dust are less able to penetrate a very dense fleece.
- Lack of obvious primary fibers, which is indicative of uniformity among fibers as a result of density.
- Staple thickness and resistance, when pressed between your fingers; staples should be three dimensional instead of flat.
- There should be no cross-fibering (fly away fleece) in dense fiber. There are rigid rules for growth in dense fiber and little "room to roam."
- Extension of blanket fiber characteristics into the shoulder, neck, chest, belly, and/or upper leg areas.
- "Cracks" in the fleece – dense fleece often appears to crack open, "like a book."

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- Dense fleeces frequently present more resistance when opened.
- Look for a thin, jagged line of skin at the base of the fleece; the more skin showing when the fiber is opened, the less dense the animal.
- Long staple length, which can be indicative of density.
- Pressing down to feel if there is resistance between the outside of the fleece and the backbone is an indicator of density *only if* the fleece is also fine. A wire hairbrush will provide a great deal of resistance, but that's because it is stiff, not dense.
- Grab a handful of fleece at the side; with experience and through practice comparing animals with known fleece characteristics, this can become a useful gauge of density.

b. Considerations for Objective Density Analysis

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There are a number of factors that relate to the scientific measurement of density:.

- Follicles generally appear in groups of between 15 and 50. The more follicles per square millimeter, the denser the animal.
- If the fleece is dense, the fibers within each follicular group will grow in a highly aligned fashion.
- The relationship between the para and ortho cortex determines the crimp style. The hard protein keratin bends the fiber and the soft keratin reacts to it.
- In a very dense alpaca, primary fibers (as well as secondary fibers) do not tend to be as coarse simply because of the competition for nutrition within a finite area of skin.
- The ratio of stretched fiber length to un-stretched staple length is a key measurement. The goal is 1:1.2, which means that the fiber can stretch 20% farther than the un-stretched staple. This indicates the crimp is deep, which translates to greater elasticity.
- The coefficient of variation (CV) should decrease as density increases, as we would expect the fibers in a dense fleece to be more uniform.
- With density generally comes increased crimp definition. Crimp and the scales along the fiber shafts combine to reflect light, producing brightness in Huacayas. In Suris, it is longer scales and straightness that create luster.
- Small clusters of pre-papilla indicate density and fineness. Large clusters indicate coarseness and less density.

- The wax from the sebaceous glands, which coats each fiber as it gowns, gives alpaca fiber its water repellant properties and adds to the look of a well-nourished, bright fleece.
- Dense alpacas may exhibit a wide variety of crimp styles, from "zipper" (low amplitude, high frequency crimp) to "French fry" (high amplitude, low frequency crimp).

- Staples (naturally bundling groups of fibers) should stretch when pulled, indicating longer actual fiber length.

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c. Factors to Consider When Breeding for Density

Finer primary fibers and smaller primary follicles are associated with increased follicular density overall.

- Assuming each alpaca has a set number of prepapilla skin cells, the greater the number of secondary fibers using those prepapilla cells in a fleece, the fewer prepapilla cells available for the primaries. This translates to primaries that have fewer root cells and so develop thinner hair. Follicular development is thought to be mainly a function of genetics, but may also affected by nutrition and other environmental factors that can affect a growing fetus.

- Some feel that selecting for narrow staples, rather than wide staples, may be another step toward improved density.

- As fleece length increases in a highly dense animal, the crimp may tend to develop higher amplitude and lower frequency because it grows faster, although this is not always the case.

- Follicle and fiber measurements from skin and fleece samples allow us to select animals that have fine primary fibers, high fiber density, and good staple length.

- Based on lessons learned from the sheep industry, breeding decisions based on density factors alone are likely to lead to shorter staple lengths and higher micron fiber over the course of four generations or so. Similarly, breeding for fineness alone may lead to loss of density, short staple length, and lower shear weights.

- Relying on either density figures or fineness alone is a recipe for long term breeding disaster!

- Breeding for fleece weight alone is likely to result in increased micron count and shorter staple length, which may not be a good trade-off if you are trying to increase profit from alpaca fiber production.

- What breeders *should* do is select for fast growing fiber, with long staples, and high follicular density, which will generally deliver:

1) More fiber
2) Finer fiber
3) Greater fiber density
4) Greater uniformity (low CV)
5) A narrower range of micron variation over time (lingering fineness)
6) Brighter fleece
7) Less soil and parasite penetration
8) Fiber that is better suited to processing into high-end textiles

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Summary: With experience and practice, density can be visually *estimated* by the amount of fiber in a staple. Most dense animals are also fine. However, many fine animals are not also dense. If fiber is too fine, it will not be as strong, durable, warm, or water resistant. Dense animals are more resistant to skin parasites (e.g., ticks) and to contamination by dust, mold and pollen that could cause allergic reactions. When there is less dirt in a fleece, the fleece will appear brighter. Coarse fibers have shorter and higher scales, which can trap dirt and contribute to making the fleece seem dense and heavy.

2. Fineness

Fineness is paramount in the realm of textiles that are meant to be worn close to the skin. Frequently, the softer the fabric, the more expensive the garment, particularly when made of natural fiber. Consequently, cashmere, which is known for its soft feel, sells for top dollar. Wool, by contrast, is more affordable, but also more likely to be scratchy or itchy. Why? Fineness. While density is a production goal for most breeders, as it translates to more weight and often more profit, uniform fineness will result in fewer coarse fibers and improve handle or softness. Density is important to breeders, whereas only soft handle matters to customers. Breeders, therefore, must be concerned with both.

Alpaca fiber has an edge when it comes to softness. The height, number, and angle of fiber scales enable alpaca fibers to bend with less friction than many other fibers and result in a smoother, softer fabric. Also, a commercial processor can pack more fine fibers into a strand of yarn than they can coarser fibers. The resulting yarn will be stronger – the sum of the individual parts. Fineness impacts a yarn's "spinning limit," which means that, at any given count of yarn, the finer the fiber, the greater the number of fibers in a cross section. This, in turn, leads to a more uniform yarn diameter, greater yarn strength, and greater softness of handle. Alpaca fabrics can be manufactured to be very lightweight, yet strong, fine, warm, durable, and moisture wicking.

Manufacturers do test fibers for fineness prior to purchasing fleece. Japanese buyers are testing wool straight off the sheep's back, using the OFDA 2000 testing method, before buying it in the shearing shed. In Australia, 99% of all wool is tested by bale core samples before it is offered

for sale and most manufacturers worldwide currently rely on core testing of bales prior to purchase. These commercial processors value fineness and uniformity as primary prerequisites for purchase, because the customer values the finished softness that results from these traits. *Alpaca breeders, therefore, must consider fineness and uniformity to be key factors when making breeding decisions that will ultimately result in the production of fleece that will maximize profit.*

> Note: All alpaca fiber, of any fiber diameter, has an appropriate end-use and resulting market value. However, in general, the finest, most consistent fleece will command the highest prices in the marketplace.

A good breeding goal for maximum profit potential would be to produce most of our alpaca fiber below 26 microns. Alpaca, due to its scale structure, tends to feel approximately 5 microns finer than it actually tests, when compared to other fibers of the same micron. Where alpaca scales average 0.4 microns high, average sheep scales average 0.8 microns and have sharper edges. This gives alpaca an instant advantage in the softness category. A great deal of sheep wool is produced in the mid-20 micron range. Alpaca in that same range will have an advantage in terms of softness. In addition, the world does not produce much natural fiber that is finer than 20 microns and the fiber which is produced in that range commands a premium at sale. That is a niche on which many alpaca breeders will want to focus!

Most of us are familiar with the dreaded term "blowout," which is an expression loosely used to describe alpaca fiber that coarsens dramatically from one year to the next. This may happen for a variety of reasons, including natural growth of a cria to adulthood, environmental and nutrition factors, and, probably most of all, simple genetics. As a cria grows to maturity, follicles spread apart in the skin. Picture putting dots on a deflated balloon, then blowing it up. The dots will drift farther and farther apart as the balloon grows in size. Similarly, the follicles on a growing alpaca will spread farther apart, providing greater opportunity for fiber to thicken. On average, crias born with 15 micron fiber will have fiber in the 21-23 micron range by 3 years of age, and it may get as high as 30 microns. On average, alpacas are thought to increase in AFD by 2 microns each year, until the animal is four to five years old. The reasons for this common progression may be complex, but genetics clearly play a key role.

A principal breeding goal must be to identify and utilize both males and females that have evidenced their ability to hold fineness over time, hopefully without sacrificing density. *Those are the genetics we should all seek to add to our herds.* Fiber statistics should be maintained on an annual basis for all breeding animals, *at least* through the first five years, in order to enable breeders to identify these valuable genetics. Skin biopsies can also be valuable, when performed on animals in the 18 to 24 month age range, to determine the number of follicles per square millimeter and the ratio of secondary to primary fibers (S/P Ratio), among other things. Biopsy results can be excellent predictors of fineness, density, and uniformity.

> Note: It is recommended that skin biopsies be delayed until at least 18 to 24 months of age. Obviously a cria's biopsy result is likely to indicate greater follicular density than in a fully grown animal. It's a good idea to verify the age of the alpaca at the time the skin was biopsied when evaluating the result.

Factors to consider when breeding for fineness:

- Breeding for fineness alone, without attention to density, may tend to yield lighter and, possibly, less profitable fleeces.
- On the other hand, sometimes less is more and a finer fleece of lower weight can be more valuable that a coarser fleece of heavy weight.
- A finer fleece usually has a lower SD and may tend to be more uniform. Thinner fibers, if uniform throughout the fleece, offer less resistance to the hand, spin more consistently, and result in softer finished products. Micron count and uniformity, therefore, are the primary determinants for the selling price of fiber
- Focusing breeding goals on density first, followed by fineness, tends to produce better results than the reverse. Remember, from the discussion of density above, that breeding for density and fast growing fiber, often also increases fineness and uniformity.
- Geldings are typically finer than breeding males, which is thought to be the result of lower levels of testosterone. Males tend to stop coarsening once gelded. Geldings are excellent fiber herd candidates and will probably make up the greater portion of elite fiber production herds. This should answer the question, "What do we do with our males?" Treasure them! In general, females also tend to be finer than breeding males.
- Fineness can be related to nutritional and/or environmental stress. A stressed alpaca, whether physically or emotionally, will divert much of its energy to protecting its immune system. Frequently, the result is diminished fiber thickness. Sick or otherwise compromised alpacas can exhibit very fine, but "tender" or weakened fleece. This is one reason why halter and fleece judges test the strength of fiber, as fibers that break easily are worthless to processors.
- In many alpacas, excess protein increases fiber thickness and excessive weight or fat can result in shorter staple lengths. This situation may cause unsuspecting breeders, who assess density by hand alone, to believe that density is improving as an alpaca ages, when, in fact, the alpaca may simply be overfed, its fiber is coarsening as a result. Not all alpacas are equally predisposed to coarsen when on a high plain of nutrition, however, and genetics are another factor that impacts the extent to which coarsening occurs.

Fineness Designations

Uniformly fine fleeces result in soft end products and it is those fleeces that command premium sale prices. There are several systems used for designating fiber fineness according to "grade." Although the nomenclature is slightly different, each is based on similarly defined, although not identical, micron ranges.

Many of the U.S. fiber cooperatives use a system similar to the South American system. The grades are labeled descriptively, rather than numerically.

- Royal Baby (<20)
- Baby (20-22.9)
- Superfine (23-26.9)
- Adult (27-31.9)
- Strong (>32)

Another descriptive approach identifies similar, although not identical, micron ranges.

- Ultra fine (< 20)
- Super fine (20-22.9)
- Fine (23-25.9)
- Medium (26-28.9)
- Intermediate (29-31.9)
- Coarse (>32) (also called "Robust.")

A more practical approach for purposes of "Alpaca Fiber for Profit" is a production grading system that combines both descriptors and numerical identifiers.

- Grade 1, Ultra fine (<20) (best for fabrics used next to the skin)
- Grade 2, Superfine (20-22.9) (good for gently used items like shawls, baby items)
- Grade 3, Fine (23-25.9) (the most versatile grade; fits many categories)
- Grade 4, Medium (26-28.9) (suited for socks, throws, outerwear, felting applications)
- Grade 5, Intermediate (29-31.9) (good for batts, duvets, outerwear, felting applications)
- Grade 6, Robust (≥32.0) (appropriate for batts, insulation, rugs)

Note that markets exist for alpaca fiber from under 20 microns to 35-plus microns. The best way to maximize return on investment will be discussed in Module 4, which will focus on the "nuts and bolts" of turning alpaca fiber into profit.

Fineness summary

No single fiber attribute is the "be-all and end-all" that will ensure profitability from the production of alpaca fiber. Fleece attributes must be balanced, both to protect the alpaca from the environment in order to help maintain health and to provide producers with the most profitable fleeces for the marketplace. Fineness not only varies between animals, it can also vary from one region of the country to another, based on different environmental conditions (hot vs. cold, humid vs. dry). Fineness is further affected by an alpaca's age, health, nutrition, and, probably most significantly, by its genetics. An 8-year-old dam, pregnant with her fifth cria, that maintains a uniform AFD of 25 microns, may not place well in the show ring, but she has great value in a breeding program due to her lingering uniform fineness. She is precisely the sort of

breeding animal on which we should focus if we wish to create a sustainable and profitable alpaca fiber industry.

3. Huacaya and Crimp

Crimp is a much-debated topic. We know it wins in the ring. But why? In general, it is felt to be *an indicator* of a variety of desirable fleece characteristics, from fineness to density to uniformity. From a production standpoint, some people feel crimp adds loft, memory, or elasticity to an end product. Others say that it is easier for commercial mills to process fleece that has crimp. Some believe high frequency, low amplitude crimp (known as "zipper" crimp) is superior to a deep and bold crimp (often referred to as "French fry" style crimp). We won't let these differences of opinion crimp our style. ☺

Huacaya crimp is often compared to the crimp in sheep wool. While Merino sheep, and others bred for fine textiles, have a higher frequency of crimps per inch than Huacaya, it is not necessarily helpful to compare alpaca to wool. Alpaca fibers are structurally different from wool fibers, as they have a different configuration of scales than wool fibers. We may be essentially comparing "apples to oranges." The vast majority of Suri alpacas have no crimp whatsoever and that is considered a positive characteristic. While some Suris do express crimped fiber, it is rightly considered a defect. Straight Suri fibers reflect light better than crinkly or crimped fibers. Mohair and Angora, both highly prized for their luster and luxurious softness, also do not exhibit crimp. Vicuna fiber, considered to be the finest natural fiber on the planet, has such extreme high frequency, low amplitude crimp, that it is almost imperceptible to the human eye. So, what is the real story on crimp?

Crimp, in the Huacaya, from the breeder's perspective, is indeed more of an indicator, than a valuable fiber asset in and of itself. The degree to which crimp is expressed, and in what "style," is thought to be determined largely by genetics, although possibly also affected by environmental factors. Crimp does not *necessarily* equate to fineness, but as we will see below, is a strong indicator of both density and fineness. How do we get from a visual expression of crimp to a determination of density and fineness? First, a highly crimped Huacaya fleece is evidence that the fleece is highly organized. Such a fleece will be highly organized by necessity, due to what is happening at skin level. The organization is the result of many fibers growing together in very close proximity, thereby influencing each other to grow together in an organized fashion. The fibers are "pressured" to evolve as a group, moving in unison outward from the skin surface. The pressure that results from dense packing causes the fibers to grow in a crimping, side-to-side fashion, rather than in straight unimpeded lines, vaguely toward the surface. Crimp, therefore, is a visual indicator of many hair follicles producing fibers in close proximity, i.e. density.

Crimp becomes more "defined" (clearer and sharper) as density increases because more and more fibers join the "club" as the hairs leave the skin. The fibers are forced to become one with all the other hairs leaving the skin at the same time. If the animal is not dense, those hairs will tend to dive all about, as there is no pressure to make them perform together. The result is straighter fibers that may tangle or even lie cross-wise, making it difficult to see the skin when

we open the fleece. Consequently, an inability to see the skin clearly upon opening a fleece does not always mean the animal is dense.

In alpacas, whose genetics are related to the vicuña, the llama, and others, there can be a great deal of variability in crimp styles. For reasons of simplicity, however, let's break crimp into two principal styles: high frequency, low amplitude crimp ("zipper" crimp) and low frequency, high amplitude crimp ("French fry" crimp). Fleeces exhibiting high S/P ratios, as assessed through skin biopsies, will tend to exhibit more crimp, which we know generally correlates to finer fiber. According to research done by Cameron Holt, there is a very high correlation between fineness and crimp *frequency*. This really makes perfect sense. A smaller diameter, fine fiber will tend to bend more easily than a thick, coarse fiber. There are always some exceptions – animals that are coarse, but also crimpy, as well as animals that are quite fine, but lack both density and crimp.

Most high frequency, low amplitude "zipper" crimp fleece types are very fine. Many animals with low frequency, high amplitude "French fry" fleeces, however, have also been found to be very fine. According to Dr. Watts, the finer fibers are generally characterized by "deep bold crimp." According to this assessment, the high volume production Huacaya type fleece is that which shows "deep bold crimp," as it is expected to have high density and finer fiber. It has been confirmed by Dr. Sumar of Peru that this style of crimp, along with attention to S/P ratio and follicular density, have been the criteria used for breeding selections in Peru for centuries.

At present, there is no clear consensus among fiber "experts" and/or fleece judges as to whether one style of crimp, Zipper vs. French fry, is always indicative of greater fineness. However, a highly organized fleece exhibiting a *uniform and well-defined crimp* style is generally considered a good indicator of both density and fineness.

From a textile production standpoint, it is not clear that one crimp style is preferable over the other. The majority of crimp disappears in the initial stages of processing, although some people feel that the bolder crimp produces better loft in finished textiles. In processing, one benefit to having crimp in alpaca fiber may be that it adds cohesion to yarn. The overlaying of the individual crimp "speed bumps" catch each other and allow the fibers to go through the drafting process with less drift. High amplitude, or "deeply" crimped fleece, to the extent it contributes to loft in finished yarn, would be particularly appropriate for sweaters or garments that tend to be on the bulky side. If a smoother fabric, with more drape, or a tightly woven fabric is desired, high loft would be counterproductive. Suri fiber does not crimp and is, therefore, a perfect choice for tightly woven textiles.

> Note: The carding process will take much of the crimp out of fiber. Once processed, that portion of the crimp does not return. If a processor wants crimp in the fiber for a specific application, she may use a machine that will put crimp back into the fibers. So, from a fiber producer's perspective, crimp is not an important attribute on its own, but rather it is a highly useful indicator of fleece quality. Uniformity of length and uniformity of fineness are important in presenting fleece for sale to textile manufacturers. Crimp definition, crimp frequency, and crimp uniformity provide Huacaya breeders with a visual clue to help assess a fleece. Crimp itself has little value with respect to end products, although it does facilitate fiber processing.

4. The Benefits of Crimp

The following analogy may help in visualizing the value of crimp:

> Picture a large parking lot, with all those slanting yellow lines painted on the blacktop to remind drivers to park within the orderly structure. Now, picture a parking lot without those lines. Drivers can park where they will, in various directions and at varying distances from each other's cars. Which parking lot would hold the greatest number of cars? The one with the yellow lines, right? The structured parking lot (painted yellow lines) will hold the greatest number of cars (think high density). This is efficient. In the alpaca, crimp structure is analogous to the painted yellow lines. Highly-defined crimp is an indication that the fibers are tightly and efficiently packed, as are the cars in a painted, well-defined parking lot. Crimpy, highly organized fibers can be tightly squeezed together, utilizing every bit of space, which is more efficient than a chaotic, fly-away fleece structure. Therefore, the more organized, defined, and uniform the crimp, the greater the density. And, since fine fibers will bend more easily and often than coarse fibers, highly organized crimp structure is also indicative of fineness.

Research corroborates these conclusions, showing that finer fibers tend to exhibit crimp more often than do coarse fibers. Given a highly organized crimp structure, breeders generally may assume a fine and dense fleece. **The value of crimp, therefore, lies in our ability to use it as an indicator of important attributes for producing alpaca fiber for profit – *uniform fineness*, which translates to soft end products, and *density*, which translates to heavy fleece weights and higher yields.**

Crimp Evaluation Checklist:

- Highly defined crimp, in terms of frequency and amplitude, are indicative of a high S/P ratio.
- The tighter and more defined the crimp, the less moisture and dirt will penetrate to the skin
- Crimpy fleece is generally cleaner, because its greater density helps to keep out dirt and debris, as well as insects and moisture. This helps to eliminate problems with fleece rot, that can cause breaks or discoloration of the fiber. Alpacas with little or no crimp tend to be less dense and have open fleeces that are more likely to pick up dirt and vegetable matter.
- Well-crimped fleeces generally have fewer coarse medullated fibers. Variation in crimp along individual fibers can be indicative of a period of sickness, stress, or poor nutrition.

- Curvature is a measure of crimp amplitude. The higher the curvature number, the higher the crimp amplitude. When coupled with a low CV, a high curvature number generally correlates with a low AFD.

- "Bold" crimp usually means low frequency crimp, while "deep" crimp means high amplitude. Deep, bold crimp, therefore, describes a relatively low frequency, high amplitude style.

- "Zipper" crimp is characterized by a high frequency, low amplitude style and it is usually soft, fine, and even. In addition, it tends to reflect more light, making it appear brighter.

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- Alpacas with high frequency, high amplitude crimp are very rare.

- "Deep bold crimp" is considered by some to provide a good balance of fineness and density for sale to commercial markets. However, there are many different styles of fleece that will need to be classed into separate lots according to their differing attributes, including crimp style, staple length, color, and fineness, among others. The variety in end products that can be manufactured as a result of this fleece diversity is advantageous to designers, offering a wide array of options for utilizing alpaca.

- Well-defined crimp indicates fibers of a similar nature and size growing together, into a tight, uniform staple. Uniformity is crucial to the production of valuable fleece.

- In commercial production, uniformity is key, whether it be with respect to color, fiber length, AFD, or crimp style. Larger lots will produce more consistent end products, but only to the extent that fiber characteristics are uniform within the fleeces making up the lots.

A Few More Notes on Crimp:

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- Some very fine alpacas are also blessed with having very long staples. These long staples weigh more than short staples of the same AFD and density. At times, these very long and fine staples may droop, due to their weight, which may cause those fleeces to appear open and less dense.

- There are many styles of crimp, as fiber crimp is a multi-dimensional structure, and crimp is affected by cortical cells, bi-lateral structure, amplitude, frequency, and micron count.

- Style is less important than uniformity, although many breeders prefer high frequency crimp as an indicator of fineness. Some believe it provides more elasticity (stretch).

- Crimp is thought to increase the ability of alpaca fiber to provide thermal insulation, as the additional loft helps trap air within a garment.

- Crimpy fibers are easier to spin and often add loft to garments,
- Crimped fibers are significantly easier to spin than non-crimping fibers for the hand spinner. Hand spinning of crimped fleeces may or may not produce a more regular and uniform yarn. The ability and experience of the spinner has more to do with uniformity of yarn than any other factor.
- Most processors feel that crimp is not a factor in the decision to process using the woolen vs. the worsted methods; rather, length of fiber is the biggest factor in determining which method should be used.
- Some feel that too many crimps per inch interfere with handle. Is there is an optimum crimp frequency?
- Luxurious fabrics that are exceptionally bright seem to result from fleeces with long staples and low curvature.
- More robust and somewhat thicker fibers, with good curvature, are particularly suited to the manufacture of durable outerwear.

5. Luster in Suri

When we open a Suri's fleece or watch a Suri move through a sunlit field, the luster we perceive is the result of light reflecting off the unique structure of Suri fiber. *Luster is the key characteristic that distinguishes the rare, elite Suri fiber from most other natural fibers.*

Suri luster results primarily because of the length, evenness, and uniformity of the individual scales on each fiber shaft. Studies show that the signature sparkling glow in Suri fiber is produced by its flatter, more elliptical shape (as opposed to cylindrical), in addition to the length, evenness, and consistency of scale structure. It has also been suggested that light not only reflects from solid Suri fibers, but penetrates into medullated fibers as well, thereby adding another dimension to its luminosity.

Under a microscope, Suri fiber scales appear fewer and longer than those on Huacaya fibers. While numerous short scales may diffuse reflected light, the fewer and longer Suri scales efficiently reflect significantly more light into a concentrated area, like into your eye. Suri scales are twice the length of those of sheep wool. The larger, uninterrupted fiber surface acts more like a mirror than a prism and reflects the sun's rays effectively and efficiently. While genetics are the biggest factor in achieving luster, a sick or underfed Suri, no matter how well it is genetically predisposed to exhibit luster, will appear chalky and dull. Environmental factors matter. Trace element deficiencies, such as iodine, can inhibit the amount of luster in a fleece.

The Suri Network Study is a work in progress that is focused on defining, analyzing, and measuring Suri Luster. The following elements are being developed, compiled, and/or explored:

- Collection of objective baseline data that can be meaningfully connected to Suri fiber qualities, the most important of which is luster. Data collection methods will include:
  - Skin biopsies
  - Scanning electron microscope examinations
  - Amino acid analysis
  - Histograms
  - Collection of shear weight data
  - Analysis of the effects of washing, processing, and the like.
- Exploration of how to measure luster; how luster is affected by breeding decisions and environmental factors; and how breeders can improve luster.
- Development of a broad spectrum of alpaca fiber samples that includes all colors, in the full range of luster.
- Development of a complete and independent luster evaluation method that can be implemented by a panel of trained alpaca judges.
- Development of a method for performing quantitative measurements for luster in fiber samples.
- Calibration of that automatic system under various conditions.
- Compilation of a series of washed samples from a single fiber source.
- Comparison of data drawn from analysis on washed samples with data drawn from analysis of unwashed samples.

Some studies suggest that the brighter or more lustrous the fleece, the softer the handle. Frequently, bright fleeces tend to have a very low curvature metric, as is the case with Suri fiber. Although, as noted previously, the decision to use a "woolen" vs. a "worsted" processing method is generally more dependant on staple length, than on crimp style, some people feel that a low curvature fiber is best suited to the "worsted" method. This is because "woolen" textiles need memory, loft, and a spring-like resistance to compression, which is generally better achieved with a higher curvature fiber. One processing method is not considered better than another; they are just different approaches, with each tending to be better suited to certain fiber characteristics, in particular fiber length.

A point to remember is that not all textile producers are interested in producing finished products that exhibit luster or brightness, as not all end uses are compatible with shine. Furthermore, if a manufacturer wants some brightness or sheen in a particular textile, blending in a synthetic nylon

or another petroleum-based product will often produce the desired result. Very little synthetic material is required to impart sheen to a finished garment. The real beauty of using *natural silk* to manufacture stockings or hose for women is that it makes their legs look terrific without the shine that is produced with nylon. In fact. nylon producers have gone to a lot of trouble to try to design synthetic fibers that do not have *too much* luster. In the synthetic world, very shiny end products are often equated to a gaudy or even a "worn out" look.

Suri fiber, on the other hand, is a natural and inherently lustrous fiber, much more akin to silk than to shiny synthetics. It is that *natural* luster on which Suri breeders must capitalize. When its luster is coupled with density and uniform fleece architecture, Suri fiber can really light up your world!

A Few Points on Suri Luster:

- Some people believe that high luster necessarily correlates to softness because fewer scales (cuticle cells) result in less drag. There is not full agreement on this, however.
- In general, high luster and brightness tend to be exhibited by more uniform fleeces, which will tend to have a softer hand.
- Suri fibers exhibit an elliptical shape in cross-section, as compared to the cylindrical structure of Huacaya fiber. Its elliptical shape, along with its fewer scales, results in the Suri's luster, whereas the Huacaya's cylindrical fiber shape produces the feature we label brightness.
- The wool industry distinguishes three types of luster: silvery, silky, and vitreous. The silvery luster is found in the finest Merino wools, that exhibit a high degree of crimp. The silky luster is present in the long staples of British breeds, like the Lincoln and Leicester. The vitreous luster is found in Mohair and other goat fibers. Von Vergen studies of alpaca fleece mention that Suri fleece exhibits a silky luster, while Huacaya fleece has a silvery luster.

6. Handle

Handle is purely subjective; it is evaluated by feeling the fiber with "the hand," hence the term "handle." The term "handle" is used primarily by breeders, whereas consumers use the term "softness." Fiber handle can be described in many ways, including silky, velvety, buttery, luxurious, and exquisitely soft, among others. Handle is highly related to the uniformity in a fleece or end product.

A soft handling fleece is usually comprised of very uniform fibers, which have a low CV. However, *fineness together with uniformity* will produce the softest handling fleeces of all. Many people feel that flat Suri and low frequency crimp in Huacaya tend to be softer handling than high frequency crimp fleeces. It may be that more "bumps" (high frequency crimp) create more points of contact with fiber scales, making those fleeces seem less soft.

Note: Some believe, scale structure may also be a factor. The height of alpaca scales average about 0.4 microns. Those of sheep average 0.8 high, or twice as high. Alpaca fibers average 9 scales per 100 mm. Sheep measure only 4 scales per 100 mm. According to Weidong Yu, "The measured data showed that the equivalent bending modulus of the alpaca fiber is higher than that of wool fiber, and even the rigidity is 10 times as high as wool, but its friction coefficient is lower than that of wool, which means that the soft handle of alpaca fabrics is mainly due to the smooth surface and low friction coefficient of alpaca fibers in contrast to that of wool fiber."

Handle can be affected by both nutrition and environmental factors. Certain trace element deficiencies can impact handle; for example, a copper deficiency is thought to impart a harsh feel to fleece. Inadequate nutrition, in general, can result in dry, lack-luster fleeces, that lose their softness, whereas a well-nourished fleece will tend to be more "buttery" and soft. Similarly, stress or adverse environmental conditions can negatively impact handle.

Although thick primary fibers and guard hair will adversely affect handle, a relatively coarse alpaca may still feel soft if its fleece is highly uniform. It may be that an alpaca with an AFD of 23 microns, high luster, and very uniform fleece will feel as soft to the hand as an animal with a 15-micron Vicuña type fleece. Clearly it is a combination of many factors that influence handle; however, the most significant factor is the interplay of fineness and uniformity.

7. Consistency or Uniformity

Uniformity and consistency are frequently found in highly organized fleeces, and highly organized fleeces are often very fine. Generally, a finer fleece, in terms of AFD, has fewer thick primaries. Uniformity frequently produces a soft, silky feel. While no relationship between fineness and frequency or style of crimp has been established, good definition of crimp is usually related to uniformity. Fleeces with well-defined crimp structure throughout, tend to be finer than those that lack well expressed crimp

Many breeders particularly value an alpaca that exhibits a very low Coefficient of Variation (CV) in its histogram. In fact, low CV is sometimes felt to be a more important indicator in choosing breeding stock than the AFD (average fineness) value. In truth, it is the interplay of these two values that is particularly telling. What breeders really want is to produce stock that exhibits both low AFD and low CV. In other word, breeders hope to produce alpacas that have *uniformly fine* fiber, not just a low average fineness. Consistency has tremendous implications for the quality and value of finished yarns and textiles.

When evaluating the measurements provided by a histogram, many breeders and fleece experts focus on the "coefficient of variation" (CV), rather than the standard deviation (SD). SD values increase as AFD (also known as the "mean fiber diameter" or "MFD") increases. The CV is a more precise gauge of uniformity because it expresses the ratio of SD to AFD, which some testing labs report as a percentage (SD expressed as a percentage of AFD). The formula used is: CV = (SD ÷ AFD) x 100. Therefore, where AFD is 16.0 and SD is 3.0, CV = (3.0 ÷ 16.0) x 100

= 19 %. Fleeces that have CVs lower than 20% are very uniform, with the very best animals, in terms of fleece consistency, having CVs in the mid- to low-teens.

The following two histograms illustrate the usefulness of focusing on CV, rather than SD when gauging uniformity. These two alpacas have very different AFD and SD values, but they have nearly identical CVs. This tells us that, despite the highly different SD numbers, *the two alpacas are almost equally consistent, even though one is much finer overall.*

Alpaca #1: AFD: 21.0 microns; SD: 4.4 microns; CV: 21.1%; >30 microns: 2.7%.

Alpaca #2: AFD: 36.6 microns; SD: 7.9 microns; CV: 21.5%; >30 microns: 83.1%.

Consistency and uniformity do not apply only to fiber diameter. They are also considerations when it comes to color and fiber length. Textile producers need fiber of equal length in order to produce good end products. As previously discussed, variable length fibers contribute to a "prickle factor" for the consumer. With respect to color, commercial textile manufacturers generally require that there be no color "contamination" – white must be white, with no other colors mixed in, black must be black, and so on. Nonetheless, a good market has developed for fleeces that exhibit a combination of colored fibers, as do most fawn and gray alpacas. When well blended, these color combinations produce unique and valued results. Some processors may, in fact, blend pure black alpaca with white alpaca to achieve a nice mix that appears gray in the finished product. As our herds of colored alpacas grow, so too will the markets for a wide variety of uniquely natural colors.

8. Alpaca Fiber Strength

A strong fiber makes a strong thread and, in turn, produces a strong garment that will wear well. Fiber strength has two measureable components: tensile strength and shear strength. Alpaca fiber is naturally strong in terms of both components.

Holes in socks are caused by failure of shear strength, due to repeated pressure applied perpendicular to the fiber. Well-made alpaca socks are less likely to develop holes because alpaca fiber has inherently high shear strength. Holes in suits, dresses, and similar garments are usually caused by failures in tensile strength, where the force applied is parallel to the fiber. Again, properly processed alpaca fiber, that includes no short or damaged fibers, will tend to resist these wear and tear issues more than most other natural fibers.

As a result of its natural strength and durability, alpaca fiber may be spun lightly to produce end products that are lightweight, but nonetheless durable. The natural strength of alpaca fiber may be compromised, however, in animals that have suffered stress, illness, or inadequate nutrition. Fiber from these animals is more likely to be "tender" and susceptible to breaking during processing. Producing strong alpaca fiber for the textile industry is dependant upon good herd management techniques.

9. Staples, Staple Length, and Bundling

A staple is defined as a cluster or group of fibers that naturally grow together, as one unit, within the fleece. The number of fibers within a staple, or Suri lock, may vary significantly between animals. Staple length affects overall fiber weight, as longer staples, when compared to shorter staples of like density, diameter, and crimp style, generally will be heavier. To measure actual fiber length, crimpy fibers must be stretched to full capacity. Staple length is an attribute for which alpaca owners should selectively breed. It should be measured at each shearing and those animals not performing well should be culled from the breeding program in order to increase overall productivity of the herd.

> Note: According to Dr. Jim Watts, the Huacaya alpaca has, on average, a fiber length to staple length ratio of about 1.1 to 1.0, which means fiber length is 10% greater than the staple length, with the best measured individual being about 1.35 to 1.0 (meaning fiber length is 35% greater than the staple length).

Uniformity of fiber length is critical in processing, because mixing fibers of markedly variable lengths results in an inferior end product that tends to feel prickly to the wearer and tends also to "pill" more easily. A fabric that "pills" develops tight little balls of fiber on its surface as a result of abrasion, washing, and normal wear. Pilling occurs when short and/or weak broken fibers migrate out of the twist that was created in the fabric's yarn during processing. Although they are given a uniform twist in processing, the two lengths of fiber behave differently and, as the fabric relaxes, the shorter fibers begin to release. Uniformity in fiber length helps to prevent this.

Many processors prefer that overall fiber length be at least 3 inches. Required fiber length is manufacturer-specific, however, and some will process shorter fibers. CanCAM, for example, uses fiber in the 1.75” to 3.75” range in their woolen process. The Alpaca Blanket Project currently uses fiber falling within the 2.0” to 5.0”range, which meets the woolen processing requirements of Pendleton Woolen Mills.

The longest fibers are generally processed using the worsted system, which produces the finest fabrics. Less twist is required in the worsted process, which results in a softer fabric. Shorter fibers generally are processed using the woolen system and are twisted more tightly to add durability. The twist also helps to hold the shorter fibers securely together, which helps to reduce pilling. Unfortunately, the tighter twists necessary to process shorter fibers using the woolen method tend to result in fabrics that do not feel as soft as worsted fabrics.

The term bundling is often used to describe fleece that exhibits well formed, uniform, and discreet staple groups. Bundling "matchsticks," for example, describe tiny, micro-staples, which in turn cling together to form larger staples. Bundling is indicative of a dense fleece and results from the evenness of follicle size and consistency of follicle shape in the skin.

G. Module Summary

We can see from our discussion above that there is no single attribute that stands alone in its importance for assessing the quality and desirability of an alpaca's fleece. While the mantra, "fineness is everything" is often heard and micron counts extolled above all attributes, what is fineness without uniformity, brightness, strong healthy fibers, and substantial fleece weight? Many attributes must combine in order to produce what we might call our "Golden Fleece."

The key to maximizing fleece value is to work toward *a balance* of desirable traits:

- A **fine** fleece also should be **uniform**. Fleeces with low-micron secondary fibers won't feel soft if thick primary fibers are mixed in; the fleece as a whole will be devalued.
- **Long, dense staples** are great, but only if they are comprised of strong, **healthy fibers**.
- A silky, low-micron black fleece that is "contaminated" with white fibers, offers fewer options for commercial production than one that is **consistent in color**.
- Fleeces should be relatively **clean**. An otherwise "perfect" fleece that is full of burrs and debris will be of little to no commercial value.

The next module will delve deeper into methods for measuring and evaluating the quality of our product. In particular, we will dig into histograms and skin biopsies to develop a better understanding of how we can use those tools to help us evaluate our current herds, as well as our breeding programs and goals. Objective measurements will be invaluable as we make breeding decisions that will move us toward our goal of maximizing profit from the production of alpaca fiber.