Applied Research Project to Improve Alpaca Quilts and Textiles Through Analysis of Parameters Affecting Raw Fibre Production

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FINAL REPORT

The effects of age, location, nutrition, and season on body weight, fiber production, and fiber quality characteristics of penned alpaca males

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SUMMARY

Thirty-six yearling alpaca males (offspring of 9 sires) were identified for this study to determine the effects of age, location, nutrition, and season on body weight,

fiber production, and fiber quality characteristics. Fully quantified components of the fleeces produced by the study animals were used by a collaborator to optimize textile manufacturing processes and develop new products composed of alpaca. In May 2002, half the animals were relocated to research facilities at Olds College, Alberta and the other half to San Angelo, Texas where they remained for the duration of the study. The animals were sheared (yearling fleece) soon after arrival and for the next 4 months were group fed free-choice with local hays and a custom ration for growing alpacas. Body and fleece weights were used to assign the alpacas to three equivalent groups (6 animals per treatment, 3 per rep) at each research location. The animals were then penned (3 animals per pen) and rations at both locations were formulated to provide the same complete diet when fed in equal amounts with the respective locally available hay. Animals were monitored monthly for weight and body condition. The amounts fed were adjusted over a 7-month period to produce a monthly gain of 3% of body weight while maintaining a body condition score of 3 or higher. The nutrition treatments were imposed in March, 2003, and fleeces were shorn for a second time in April, 2003. For the next year, one group was fed at levels established to produce 3% per month gain. Another group was fed 10% less (hay and ration), and a third treatment received 20% less. Animals were weighed and assessed for body condition monthly. Diets were adjusted monthly, and fleeces were shorn and characterized annually.

Changes due to increasing age (one through three years) followed the expected pattern. As the alpacas aged, their body weight, fleece weight, fiber diameter (and associated alpaca grade, SD, spin fineness, along-fiber AFD and SD), staple strength, resistance to compression, total medullated and objectionable fibers, and AFD of medullated fibers all increased. In contrast, fiber production per unit of body weight, CV of fiber, comfort factor, fiber curvature, and staple length showed declines. The body condition score, clean yield, vegetable matter present, flat fibers, SD of fiber diameter of medullated fibers, and position of break in the staple strength test were not affected.

Effects attributable to location were complicated by different diets but at this point our data indicate that when fed similar diets, animals grew faster at the northern location and attained significantly greater body weights. These larger animals produced more fiber that tended to be coarser ($P = 0.06$), more variable in fiber diameter along its length, more heavily medullated, and exhibited higher resistance to compression. In contrast, the Texas fleeces had higher clean yields and comfort factors, and were stronger (tensile strength) than the Alberta fleeces. All other characteristics were unaffected by location.

Young alpaca males fed to gain at moderate rates (2-3% increase in body weight per month) produced more fiber (actual and g/kg BW) that tended to be slightly coarser ($P = 0.1$) and more heavily medullated than animals that received 20% less feed. In all other measured traits, fleeces produced in the three nutrition treatments were very similar. The effects of season on fiber diameter related traits were negligible. Finally, this experiment has permitted documentation of variability in the many traits measured and also the correlation between traits, all of which information should be of considerable use to breeders and manufacturers.

INTRODUCTION

The alpaca *(Vicugna pacos)* is commercially the most important fiber producer of the New World camelidae family. Two breeds of alpaca are recognized; the huacaya and the suri. This study deals exclusively with the more populous, crimpy-fleeced huacayas. Alpacas are indigenous to the Andean highlands of South America. Of the approximately 3.5 million in the world, most (~ 3.0 million) are in Peru with the majority of the remainder being in Chile and Bolivia. These numbers in South America have been fairly static due in part to the lower, more productive altitudes (2600 to 3400 m) being used for sheep and cattle production. In contrast, the population of alpacas in North America has risen from less than 400 in 1984 to around 60,000 today. South American alpacas produce about 90% of the world camelid family's total production of fiber (Pumayalla and Leyva, 1988). Until about 20 years ago, alpacas were considered to be specifically adapted to their native environment. However, successful introductions of the species to Australia, Canada, England, France, New Zealand and the United States, to name but a few countries, have shown that alpacas are more versatile than previously recognized. Husbandry practices, and to a lesser extent production traits, have been documented in their native South American environment (approximate latitude, 5 to 20°S, approximate longitude, 70 to 80°W, altitude range, 2500 to 5000 m). Now that alpacas are being raised in North America as far south as Texas and certainly as far north as Alberta and Alaska, a need has arisen to develop management and diet recommendations for these animals under local conditions. Further, many owners and breeders are anxious to learn the effects of age, location, nutrition, and season on growth, reproduction, and fleece and fiber properties. This study was designed to answer some of these questions for environments represented by that of Olds, Alberta (latitude, 51° 46' N; longitude, 114° 5' W; altitude, 1035 m) and San Angelo, Texas (latitude, 31° 26' N; longitude, 100° 27' W; altitude, 563 m). The study we recently completed is just one part of a larger project in which Custom Woolen Mills, Ltd. of Carstairs, AB, Canada, developed technology to produce high quality yarns and finished products using all grades of domestically produced alpaca. This work is described in a separate section of this report. The research was made possible by a grant from the National Research Council of Canada through their Industrial Research Assistance Program, as well as contributions from the two academic institutions, Olds College and Texas A&M University, and a private alpaca breeder, R&R Alpacas, Ltd.

HYPOTHESIS

Fiber production by alpacas and important processing characteristics of their fiber are affected by animal age, geographic location, nutrition, and season.

OBJECTIVES

1. Determine the effects of age, location, nutrition, and season on the body weight, fiber production, and quality characteristics of penned alpaca males.

2. Provide our textile manufacturer partner with fully characterized samples of alpaca fiber to be used for process optimization and new product development.

LITERATURE REVIEW

In sheep and Angora goats, age, location, nutrition, and season are known to produce effects on fiber diameter, staple length, and medullation (Sumner, 1979 and 1983; Birrell, 1992; Lupton et al., 1996 and 1997). In contrast, for species producing relatively small amounts of down fibers in fleeces composed predominantly of hair (e.g., cashmere goats) down fiber characteristics appear to be less sensitive to nutritional influences (Norton et al., 1990) although some nutritional effects have been noted in high-producing cashmere goats (McGregor, 1996). Because alpacas (like sheep and Angora goats) produce a predominantly single-component fleece, it might be expected that fiber production and some characteristics are amenable to nutritional manipulation. Documented information exists on this topic, but none has been generated addressing alpacas occupying a North American environment. Production of alpacas in the Andes was reviewed comprehensively by Fernandez-Baca (1975) as was their status and distribution (Novoa and Wheeler, 1984). Husbandry practices and genetic resources of alpaca in the Andes were also documented (Calle-Escobar, 1984; Hoffman and Fowler, 1995). However, very little information was presented on the specifics of fiber production and quality characteristics.

Reiner et al. (1987) used castrated male alpacas to estimate forage intake when the animals were free-ranging on high-altitude, native Andean pastures during the dry (winter) and wet (summer) seasons. Organic matter intakes of free-ranging alpacas during the dry and wet seasons were 1.8 and 1.6% of BW, respectively, these intakes being equivalent to 60.5 and 53.7 g DM/kg of metabolic body weight (MBW), respectively. Increased intake in the dry season did not result in increased BW (~ 62.0 kg) because (presumably) more energy was required for maintenance during the winter months. Dietary crude protein of the free-ranging alpacas was 8.1% in the dry season and 12.6% in the wet season. Organic matter intakes of caged alpacas having free access to freshly harvested, immature ryegrass (to simulate wet-season forage) and oat hay (to simulate low quality, dry-season forage) were 1.08 and 1.13% of BW, respectively. However, both groups of animals lost weight on this study and were reported to never having adjusted properly to confinement. Earlier studies with alpacas (Fernandez-Baca and Novoa, 1966; Flores and Valdivia, 1973; San Martin et al., 1982) housed in metabolism cages reported intake on a dry matter (DM) basis ranging from 1.2 to 2.4% of BW. Huasasquiche Schwarz (1974) found in a N balance study that alpacas maintained weight while consuming 2.13 g digestible protein/kg MBW daily. These intake findings all support the statement that alpacas consume less forage than sheep when expressed as a % of body weight. It has been suggested this may be due to slower passage of ingesta (i.e., better utilization of forage) through the gastro-intestinal tract of alpacas compared to sheep (50.3 vs 43.2 h, respectively; Flores and Valdivia, 1973).

Russel et al. (1994) used 12 male alpacas and two levels of nutrition (0.67 and 2.0 of assumed maintenance requirements, i.e., 0.44 MJ ME/kg MBW) in a cross-over designed experiment to establish fiber production during two six-week periods. The effect of the higher level of nutrition was to increase clean fiber production by 25% and fiber growth rate by 20%. The observed small increases in clean yield and average fiber diameter were not significant. The authors concluded that fiber production in alpaca can be positively influenced by nutrition but the effect appears to occur through increased growth in length and not diameter. This is unlike the effects in sheep and Angora goats where increased fiber production due to nutrition are attributed to increased rate of growth in staple length and in fiber diameter such that the ratio staple length: $(\text{fiber diameter})^2$ remains relatively constant. The short durations in which fiber production was measured produced very small increases in clean yield and fiber diameter that were not statistically different. These differences might have become significant if more animals and/or longer times had been used in the experiment. There was no mention whether or not this was a pen or a range study, most likely a pen study.

Newman and Paterson (1994) reported that alpacas fed ad libitum on the North Island of New Zealand had 21% more fiber growth than control alpacas fed at maintenance. Fiber diameters were 25% greater in summer than in winter. Wuliji et al. (2000) reported on production performance, repeatability, and heritability estimates for BW, fleece weight and fiber characteristics of alpacas farmed on the South Island of New Zealand from 1989 to 1994. Mean BW at shearing, greasy fleece weights, clean fleece weights, yield, staple length, resistance to compression, and fiber diameter in adult alpacas were 68.0 kg, 2.16 kg, 2.03 kg, 93.6 %, 9.9 cm, 5.3 kPa, and 31.9 µm, respectively. Seasonal variations in fiber growth and fiber diameter were small to moderate with lowest values in winter. The mid-side fleece site was shown to be appropriate for predicting mean fiber diameter of the bulk of the fleece.

Body weights, rate of gain of growing alpacas, fiber diameters, and clean yields (but not fleece weights) were markedly higher than data previously reported for South American camelids in their native environment. This was attributed to the better feed conditions and less harsh environment of New Zealand versus the native Andean punas. The result is also supported by the observation that alpacas grazing Mediterranean grasslands in Chile were able to maintain similar BW as in the New Zealand environment (Castellaro et al., 1998). Marshall et al. (1981) produced data showing that young female alpacas grazing improved pastures had a dramatic increase in fiber diameter.

Wuliji et al. (2000) also demonstrated that alpaca staple strength was higher than wool of comparable fineness. Given the high medullation levels of alpaca, this is somewhat surprising, but it is in agreement with staple strengths reported for other camelid fibers (Iniguez et al., 1998). In contrast, the resistance to compression of alpaca fibers was lower than that of comparable wool. This was expected given the lower levels of fiber crimp in alpaca.

The coarser fiber diameter reported for New Zealand farmed alpacas, though attributed to improved nutrition and less harsh climate, may also have been confounded by age. Calle-Escobar (1984) reported a difference of 10.5 µm (27.9 vs 38.4 µm) in female alpacas differing in age by 13 years. Briosco (1963) also showed that fiber diameter increased by 10 µm (and staple length decreased by 4 cm) between gelded alpacas of 5 and 15 years of age.

Another interesting aspect of the Wuliji et al. (2000) study was that the observed increase in staple lengths and fiber diameters would be predicted to produce higher fleece weights than those actually observed. Because fleece weights did not increase markedly, the authors concluded that the increase in fiber growth in the better environment resulted in greater fiber volume rather than mass, i.e. the fibers were more heavily medullated. Since this property is difficult to measure in colored fibers and was not measured in this study, this point could only be inferred. However, the conclusion did agree with data published earlier (Wuliji, 1993).

Compared to Romney sheep (Wuliji et al., 1995) the seasonal effect on fiber growth and fiber diameter was very small in the alpacas on New Zealand farms and corresponded mostly to available nutrition. This result was in agreement with those results reported by Marshall et al. in 1981, Newman and Paterson (1994), and Russel and Redden (1997).

MATERIALS AND METHODS

Management

Thirty-six alpaca males (yearlings representing 9 sires) were donated for this study by R&R Alpacas, Ltd., Olds, Alberta. In May 2002, half the alpacas were relocated to San Angelo whereas the other 18 were moved to Olds College. At each location, the alpacas were maintained together in a single pen. The animals were sheared (yearling fleece) soon after arrival and for the next 4 months were group-fed free-choice with local hays (~2 kg/hd/d) and a custom commercially available pelleted ration (Table 1, 225g/hd/d) for growing alpacas. Body and yearling fleece weights were used to assign alpacas to three equivalent treatments (6 animals per treatment, 3 per rep) at each research location. In September, 2002 the animals were penned (3 animals per pen) and rations at both locations were formulated to provide the same complete diet when fed in equal amounts with the respective locally available hay. In Texas, the major roughage component of the diet was sorghum hay (Table 5). The mixed ration (Tables 2 and 5) contained sorghum grain, alfalfa meal, peanut hulls, soybean meal, ammonium chloride, vitamins, minerals (Tables 3 and 4), and a coccidiostat. The primary roughage source in Canada was Timothy hay (Table 10). The mixed ration (Tables 6 and 10) contained oat hulls, wheat mill run, alfalfa, light screenings, ammonium chloride, vitamins, minerals (Tables 7 and 8), and a coccidiostat. The actual complete diet (50% hay, 50% ration, Tables 5 and 12) was designed to contain 13% crude protein, 2% crude fat, 3% crude fiber (30% acid detergent fibers, 47% neutral detergent fibers) and 65% total digestible nutrients. Animals were monitored monthly for weight and body condition (body condition score, BCS, 1-5; 1=excessively thin , 5=obese). The amounts fed were adjusted over a 7-month period to produce a monthly gain of 3% of body weight while maintaining a body condition score of 3 or higher. The nutrition treatments were imposed in March, 2003 and fleeces were shorn a second time in April, 2003. For the next 6 months, one group (nutrition treatment 1) was fed at the level that had been established to produce 3% gain per month (i.e., 1.40% of body weight [BW] of mixed ration and 1.40% hay). The second group (treatment 2) was fed 10% less (1.26% BW hay and ration) and a third group (treatment 3) received 20% less (1.12% BW). Animals were weighed and assessed for body condition monthly and diets were adjusted after each weighing. In November 2003, the amounts fed were changed to 1.23, 1.11, and 0.98% BW, respectively, to reduce weight gains that were higher than desired and to minimize orts, especially in Treatment 1. Fleeces were shorn in May, 2004 and characterized once more.

For the results of this experiment to be meaningful, it was extremely important that a comprehensive health program be maintained at each location. This was achieved with the assistance of the respective project veterinarians and animal nutrition specialists at each location.

Sampling and Shearing

A mid-side sample (~ 5 x 5 cm) was removed from each animal before shearing. The following fleece portions were shorn, weighed, packaged, and measured separately: short leg, long leg, butt, neck, and saddle (see Figure 1). Fleece portions from both sets of animals were tested at the Wool and Mohair Research Lab in Texas and most traits were also measured on the Alberta fleeces at the Natural Fibre Centre in Olds. While the alpacas were immobilized for shearing, their teeth and toenails were trimmed.

Side sample and fleece testing

The side samples were tested using an OFDA2000 instrument that measures average fiber diameter (AFD), standard deviation and coefficient of deviation of fiber diameter (SD and CV), average fiber curvature (AFC) and SD of fiber curvature (SDFC), comfort factor (CF) and average staple length (SL). This instrument also constructs an along-fiber profile of average fiber diameter so that changes throughout the year from tip to base are fully documented with this single test. The samples were used to examine the effects of age and season on fiber diameter – related properties.

The following sub-sampling and testing procedures were conducted on each of the 5 major portions of each fleece. The individual fleece portions were weighed and subsampled (20 staples per component) for staple length and strength testing. Raw and clean fleece weights and staple length measurements were adjusted to a 365-day growth period. Each portion was core sampled (2 x 25 g raw cores; Johnson and Larsen, 1978), and these samples were used to obtain alpaca clean fiber base and vegetable matter base (ASTM, 2000a) and subsequently AFD, SDFD, CVFD, AFC, SDFC, CVFC, total medullation, flat fibers, and objectionable fibers using the OFDA (ASTM 2000c; light colored fleeces [white, cream and light fawn] only). The SL, SDSL, and CVSL were measured and calculated using 20 staples/fleece portion and ASTM Test Method D 1234 (ASTM 2000b). The staple strength (SS), SDSS, CVSS, and position of break (POB) were also measured on 20 staples using the Agritest Staple Breaker (Agritest, 1988a). A subsample of each set of scoured cores was carded and then measured for resistance to compression using the Agritest Resistance to Compression instrument (Agritest, 1988b).

STATISTICAL ANALYSIS

Yearling body and fleece weights were used to assign animals to nutrition treatments (imposed before the start of year 3) such that average values were not different among treatments. However, the same was not true for reps. Experience had taught us that relatively small intact males would likely be bullied by their heavier counterparts if penned together. To avoid this, one rep of each treatment consisted of relatively large animals while the other contained comparatively small ones. Yearling, two- and three-year-old body and fleece characteristics were used to establish the effects of age. Body weights of the two-year-old alpacas and data from their second fleeces were used as covariates in the analyses conducted on the three-year-old body weight and fleece data. Subsequently, data from the third set of fleeces (adjusted by the second year data) were used to establish the effects of nutrition. The effects of age (confounded with year), location and nutrition treatments and their interactions on all measured traits were established using the GLM procedure of SAS (SAS, 1996). Our model used the correct error term for testing treatment and location differences and removed the block effects of the treatments. Another model was used to investigate the effects of sire. The SAS CORR procedure was used to establish correlation coefficients among age and all the measured traits within and across treatments.

RESULTS AND DISCUSSION

Animal health and longevity

Texas

Shortly after arrival in Texas from Alberta, the alpacas were sheared (first fleece). Their health appeared to be excellent upon arrival. However, in August 2002, one of the alpacas (assigned to Treatment 1, Rep 1) became ill and died. Respiratory problem was the diagnosis of the veterinarian. Basically, the animal sat down, refused to eat and drink for several days, then died. In September 2003, a second animal was found dead in his pen. He had previously exhibited no signs of illness and no weight loss. The animals frequently rolled in the dust in their pens, particularly during the heat of the day. The diagnosis was twisted gut. This animal had been assigned to Treatment 1, Rep 2. Replacements for neither of these animals were used in this experiment. Except for the two deaths, no other health problems were experienced during this two-year study.

Alberta

Two animals died in December 2002 and were immediately replaced with animals of similar age, weight, and genetic background from the original donor flock. These animals were assigned to Treatment 2, Reps 1 and 2. Causes of death were blockages in their urethras caused by the omission of ammonium chloride in one batch of the commercially mixed ration. Close to the end of the study, three animals died somewhat mysteriously in May 2004. Despite the security measures taken to safeguard these precious animals, foul play was suspected. The pathologist's report suggested that lead poisoning might have been involved in the deaths. Excessive amounts of lead were not found in the final batch of mixed ration. A major repercussion of these deaths was the omission of three fleeces (Treatment 1, Rep1; Treatment 2, Rep 2; and Treatment 3, Rep 1) from our year 3 analysis.

Feed consumption

Ingredients of the experimental rations and nutrient composition of the rations and hays used in Alberta and Texas are summarized in Tables 1 – 12. Because the protein content of Timothy hay was considerably higher than that of the sorghum-sudan grass hay, adjustments were made in the mixed rations such that the complete diets offered to animals in Alberta and Texas would be similar. Due primarily to the variable composition among batches of the ration purchased from the commercial feed mill in Alberta, the similarity of the two complete diets was not as close as we had originally calculated. A further complexity was that the animals did not always eat all that was offered. Because uneaten hay and ration was weighed back every day, we were able to calculate average consumption at both locations (Table 13).

After the first year's work in which hay and ration consumptions were adjusted to produce ~ 3% per month weight gains in the coming 2-yr-old males, we anticipated that animals in each treatment would eat all the feed that was subsequently offered. This was not the case, so after 6 months we decreased the amount of hay and ration offered.

Age effects

Table 14 summarizes the effects of age on body weight (see also Figures 2-5), body condition score, and the measured major fleece and fiber characteristics for the three sets of fleeces shorn from these male alpacas. There are no real surprises here. The animals increased in body weight and grew progressively more and coarser fiber that contained higher proportions of medullated fibers. Recall that while the third fleeces were being grown, all animals were on restricted feed (designed to produce specific, moderate gains) so reported body weights and fleece weights are not expected to be optimal. A measure of fiber production efficiency, clean fiber produced per unit of body weight, decreased as the animals aged. This may be surprising to some but it is fairly common in other fiber producing species. Although clean yield of the second year fleeces is higher than the other two years, this is more likely an effect of year (confounded with age) and not a true age effect. Fiber curvature (a direct measure of crimp in the fully relaxed fibers) decreased slightly as the fibers coarsened. Note that these levels of fiber curvature, though typical for alpaca, are very low compared to wool from fine-wool sheep, for example. Staple length in the first (or cria) fleece was significantly longer than that in the second and third fleeces. This is not an unusual phenomenon in alpacas. Resistance to compression followed the reverse trend, being mainly influenced by increasing fiber diameter, in this particular case. Staple strength also increased from first to second fleece, but then decreased. Even at the lowest level (first fleeces) it is well above the minimum required for efficient textile processing (~35 N/ktex). Another interesting effect of age is that the proportion of the fleece classified as saddle increases linearly between the first and third fleece (Table 15). Butt and neck portions stay more or less constant and long and short leg both decrease. Each portion of the fleece increases in fiber diameter with age (Table 16) with short leg showing the greatest increase and the butt portion the least. Similarly, medullation shows annual increases in each of the fleece portions (Table 17). Staple length (Table 18) as previously indicated is a different story. For each fleece component, staple length was longest for the first fleece and shortest for the second fleece. Recall, staple length measurements were all adjusted to 365 days.

Effects of treatment and location

We originally designed the diets and the treatments in such a way that the animals maintained at both locations would gain weight at a similar rate, that being 3% per month for the Treatment 1 animals with animals in Treatments 2 and 3 gaining at slower rates. In fact, gains across all three treatments in Texas in the third year of the study averaged 1.9% per month while those in Alberta averaged 2.7% per month (Figure 6). Average monthly rates of gain were 2.6, 3.3, and 2.3% for Treatments 1, 2, and 3, respectively in Alberta (Figure 2) and 2.2, 1.7, and 1.8%, respectively in Texas (Figure 4). As explained earlier, the diets fed to the animals at the two locations were similar in terms of gross chemical composition (% crude protein, % crude fiber, etc.) but differed in terms of actual components and therefore specific proteins, etc. Thus, it is unclear at this point whether the higher rate of gain observed in Alberta was an effect of location, diet, or both. The statistical analysis identified two significant treatment * location interactions (Table 19). In Alberta, Treatment 2 alpacas were heavier than Treatment 3 animals, but not different than Treatment 1. In Texas, there were no significant differences in body weight among any of the treatment groups. Conversely, body condition scores were not different among treatments in Alberta whereas Treatment 2 animals had a lower score than either of the other treatments.

Tables 20 – 47 contain least squares means for each of the characteristics measured presented by treatment, location, and fleece component (including total fleece). Treatment 1 alpacas produced more fiber (greasy [Table 20] and clean [Table 24]) than animals in Treatments 2 and 3. Animals in Alberta produced more (8.6 %, clean) fiber than those in Texas.

Tables 21 and 26 show the mean values of the fractions of different fleece components (greasy and clean, respectively). None of these were affected by treatment but the proportion of short leg fiber was higher in Alberta than Texas (14.0 vs. 9.3%, greasy). This is likely a result of slightly differing shearing techniques at the two locations. Small differences in clean yield (Table 22) were significant, but not very important. Overall, Treatment 2 animals yielded higher than Treatment 1 (92.1 vs 89.5%) and Texas fleeces yielded higher than Alberta fleeces (92.0 vs. 89.6%). Differences in vegetable matter content (Table 23) were only significant for the Butt component, with Treatment 1 containing more vegetable matter than Treatments 2 and 3. It should be noted that attempts were made to remove loose vegetable matter by vacuuming the fleeces just before shearing. Also in the Butt component, Texas fleeces contained considerably more vegetable matter (4.0 vs 1.2) than the Alberta fleeces.

Clean fiber production efficiency (g/kg BW) is presented in Table 25. Overall, production efficiency was highest in Treatment 1. Despite the very different climates, fiber production efficiency was not different between Alberta and Texas. Arithmetically, Treatment 1 produced coarser fibers than treatments 2 and 3 (Table 27). However, the differences (1.7 and 2.1 μm, respectively) were not large enough to be significant. Similarly, location had no effect on fiber diameter. The same trends were noted for alpaca grade (Table 28), SD of fiber diameter (Table 29), CV of fiber diameter (Table 30), and spinning fineness (Table 32). Although the fiber diameter difference between locations was not (quite) significant ($P = 0.06$), the comfort factor difference was (Table 31). Texas fleeces (being arithmetically finer) had a higher comfort factor than Alberta fleeces (53.5 vs 44.0 deg/mm, respectively). Neither treatment nor location produced differences in fiber curvature (Table 33), SD of curvature (Table 34), or along-fiber average fiber diameter (Table 35). A small difference in SD of along-fiber diameter (Table 36) between locations (0.06 μm) proved to be significant (though not particularly important).

Only 15 of the alpacas used in this experiment were either white, cream, or light fawn. Thus, only 15 fleeces were considered in the medullation analysis. Fleeces in Treatment 3 contained less medullated fibers (Table 37) and less objectionable fibers (Table 39) than fleeces from Treatments 1 and 2. Flat fibers (Table 38) were not different among treatments. The same trend was also present in all of the fleece components, although some of the differences were not significant (e.g., short leg total medullation). Alberta fleeces contained more medullated fibers (Table 37) and more objectionable fibers (Table 39) than Texas fleeces. However, the average fiber diameter of these medullated fibers (Table 40) was identical (39.2 μm) between locations and not different among treatments. Overall, SD of fiber diameter of medullated fibers (Table 41) was not affected by treatment or location. Staple lengths among treatments and between locations (Table 42) were very similar and not significantly different. Since differences in greasy and clean fiber production were noted, (among treatments and between locations) it is likely these were caused by the observed differences in fiber diameter rather than the small differences in staple length. It will be recalled that fleece production is proportional to staple length x (average fiber diameter)^2. The SD of staple length (Table 43) was not affected by treatment or location and in fact was quite constant throughout (~ 1.0 cm). Staple strength (Table 44) and SD of staple strength (Table 45) were not affected by treatment. However, staple strength of Texas fleeces was greater (80.3 vs

67.7 N/ktex) than Alberta fleeces. The SD of staple strength (Table 45) and average position of break (Table 46) were not affected by treatment or location. Lastly, treatment did not affect resistance to compression (Table 47) but surprisingly (in view of the identical fiber curvatures and the relative fiber diameter values) Alberta fleeces exhibited higher resistance to compression than Texas fleeces. This observation is hard to explain in light of the direct general relationships between fiber curvature, fiber diameter, and resistance to compression. However, this location difference is real, showing significance in each of the fleece components. It should also be noted that all the reported values for alpaca (~ 6 kPa) indicate the fiber has low resistance to compression (8.0 – 10.9 kPa is classified as medium and 11 – 18 kPa is high resistance to compression).

Variability in traits

Genetic improvement for a particular trait can only be achieved if heritability and variability exist for that trait. Development of breeding objectives and selection programs for any species requires a knowledge of genetic variation and heritability of the economically important traits and an understanding of the relationships among traits (Fogarty, 1995). An additional outcome of this experiment, in which we have measured many traits on numerous alpaca males over a three-year period, is that we have been able to document the variabilities in each trait. When comparing variabilities of traits having different mean values, the coefficient of variation (CV) is the most useful statistic because it is a measure of variability that is independent of the mean. Table 48 lists the CV's for the traits measured during our experiment. With the exception of clean yield (that is uniformly very high), it can be seen that most of the CV's are quite high and the CV's for total medullated fibers are very high. Regarding the relationships among traits, these are listed in Table 49 and represent critical information for a breeder to understand the full implications of selecting for any particular trait. Noteworthy positive correlations are between age and body weight, fleece weight, fiber diameter, alpaca grade, spinning fineness, total medullation, objectionable fibers, fiber diameter of medullated fibers, staple strength, and resistance to compression. Significant negative correlations exist between age and fiber production efficiency, comfort factor, fiber curvature, flat medullated fibers, and staple length. Intuitively most of these appear correct. Table 49 contains the results for the complete permutation of correlations of the traits measured in our study.

Effect of season

Staples removed from side samples were measured using the OFDA2000. This instrument measures fiber diameter from the tip to the base of the staple and produces a classical histogram and a staple profile. Typical profiles for Alberta (Figure 7) and Texas (Figure 8) indicate that no drastic changes in fiber diameter occur during the growing season. It is possible the rate of fiber growth changes with season but this was not measured in this experiment.

CONCLUSIONS

Effects of age, location, nutrition, and season have been reported for two groups of young male alpacas maintained under similar conditions in Alberta and Texas. Changes due to increasing age (one through 3 years) followed the expected pattern. As the alpacas aged, their body weight, fleece weight, fiber diameter (and associated alpaca grade, SD, spin fineness, along-fiber AFD and SD), staple strength, resistance to compression, total medullated and objectionable fibers, and AFD of medullated fibers all increased. In contrast, fiber production per unit of body weight, CV of fiber, comfort factor, fiber curvature, and staple length showed declines. The body condition score, clean yield, vegetable matter present, flat fibers, SD of fiber diameter of medullated fibers and position of break in the staple strength test were not affected.

Effects attributable to location were complicated by different diets but at this point our data indicate that when fed similar diets, animals grew faster at the northern location and attained significantly higher body weights. These larger animals produced more fiber that tended to be coarser ($P = 0.06$), more variable in fiber diameter along its length, more heavily medullated, and exhibited higher resistance to compression. In contrast, the Texas fleeces had higher clean yields and comfort factors, and were stronger than the Alberta fleeces. All other characteristics were unaffected by location.

Young alpaca males fed to gain at moderate rates (2-3% increase in body weight per month) produced more fiber (actual and g/kg BW) that tended to be slightly coarser ($P = 0.1$) and more heavily medullated than animals that received 20% less feed. In all other measured traits, fleeces produced in the three nutrition treatments were very similar. The effects of season on fiber diameter related traits were negligible. Finally, this experiment has permitted documentation of variability in the many traits measured and also the correlation between traits, all of which information should be of considerable use to breeders and manufacturers.

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** Spanish language references accessed only through Wuliji.

Table 1. Nutrient composition of commercial (Unifeed, Alberta) pelleted ration for growing alpacas

Component	Amount
Crude protein (minimum), %	11
Crude fat (minimum), %	7
Crude fiber (maximum), %	10
Calcium, %	0.91
Phosphorus, %	0.63
Iron, ppm	106
Manganese, ppm	43
Zinc, ppm	428
Copper, ppm	6.4
Iodine, ppm	25
Supplemental selenium, ppm	1.4
Vitamin A (minimum), IU/kg	36000
Vitamin D (minimum), IU/kg	5,000
Vitamin E (minimum), IU/kg	1,150

Table 2. Ingredients of experimental ration fed to alpacas in Texas

Ingredients	Percentage by weight
Sorghum grain	25.50
Dehydrated alfalfa meal, 17 %	23.00
Peanut hulls	30.00
Soybean meal, 47 %	11.91
Molasses, cane	5.00
Ammonium chloride	1.00
Mono-dicalcium phosphate	1.50
TAES Alpaca vitamin-mineral premix	2.00
Deccox, 6 % active ingredient	0.092

Table 3. Ingredients of alpaca vitamin-mineral premix in Texas

Ingredients	Percentage by weight
Manganese oxide (MnO)	0.114
Potassium chloride (KCL)	18.532
Salt, feed mixing (NaCL)	72.979
Sulfur, flour (S)	5.008
Zinc oxide (ZnO)	0.641
Molasses, cane	1.500
Vitamin A_{30}	0.732
Vitamin D_{30}	0.099
Vitamin E_{50}	0.396

Table 4. Nutrient composition of alpaca vitamin - mineral premix in Texas

Ingredients	Percentage by weight
Dry matter, %	99.4
Crude protein, %	0.1
Total digestible nutrients, %	1.2
Potassium, %	9.7
Sodium, %	21.2
Sulfur, %	5.0
Iron, ppm	4
Zinc, ppm	5000
Copper, ppm	1
Manganese, ppm	880
Vitamin A, IU/kg	219902
Vitamin D, IU/kg	29700
Vitamin E, IU/kg	1980

Table 5. Average nutrient composition of hay, feed mixture, and complete diet of alpacas in Texas[a]

Item	Sorghum-Sudan grass hay	Feed mixture	Complete diet[b]
Dry matter, %	91.1	89.5	90.3
Crude protein, %	7.6	18.4	13.0
Fat, %	2.1	2.3	2.2
Crude fiber, %	25.7	19.7	22.7
Acid detergent fiber, %	36.6	24.7	30.7
Neutral detergent fiber, %	61.1	33.4	47.3
Total digestible nutrients, %	56.8	73.8	65.3
Calcium, %	0.85	0.84	0.84
Phosphorus, %	0.10	0.63	0.37
Magnesium, %	0.15	0.23	0.19
Potassium, %	1.73	1.57	1.65
Sodium, %	0.01	0.67	0.34
Sulfur, %	0.08	0.30	0.19
Iron, ppm	418	478	448
Zinc, ppm	23	99	61
Copper, ppm	14	12	13
Manganese, ppm	60	52	56
Molybdenum, ppm	0.45	1.80	1.13
Vitamin A, IU/kg	N/A	4879	2440
Vitamin D, IU/kg	N/A	659	330
Vitamin E, IU/kg	N/A	73	37
Decoquinate, ppm	0	62	31

[a] Nutrient values are on a 100% dry matter basis.
[b] The complete diet represents a 1:1 mixture of the hay and feed mixture.

Table 6. Ingredients of experimental ration fed to alpacas in Alberta

Ingredient	Percentage by weight
Oat hulls, ground	30.000
Alfalfa suncured pellets	23.000
Beet pulp pellets	15.000
Wheat millrun pellets (cracked kernels)	14.018
Light screenings	10.000
Dicalcium phosphate, 21% bulk	2.1443
Molasses, best	2.000
Ammonium chloride	1.000
Sodium chloride, bulk	0.77169
Salt, Trace Mineral 15-7842	0.70397
1:1 Sheep mineral	0.51744
Dyna K, potassium chloride	0.50938
Magnesium chloride	0.19133
Limestone, glass	0.00649
Deccox, 6% active ingredient	0.1000
Vitamin E – 50,000	0.02236
Vitamin A (45), D, E	0.01500

Table 7. Composition of trace mineral salt used in the Alberta alpaca ration (Unifeed 15-7842)

Ingredient	
Dry matter, %	98
Sodium, %	36
Iron, ppm	1525
Iodine, ppm	100
Zinc, ppm	9000
Manganese, ppm	6000
Selenium, ppm	90
Cobalt, ppm	50

Table 8. Composition of 1:1 sheep mineral used in the Alberta alpaca ration

Item	Amount
Sodium, %	10.0
Sodium chloride, %	25.0
Calcium, %	12.0
Phosphorus, %	12.0
Magnesium, %	0.4
Copper, ppm	50
Zinc, ppm	9000
Iron, ppm	5000
Manganese, ppm	6000
Cobalt, ppm	50
Iodine, ppm	100
Selenium	30
Vitamin A, IU/lb	400000
Vitamin D, IU/lb	50000
Vitamin E, IU/lb	400

Table 9. Vitamin pre-mix used in the experimental alpaca ration in Alberta

Ingredient	
Vitamin A, IU/kg	10000
Vitamin D, IU/kg	1250
Vitamin E, IU/kg	10

Table 10. Calculated and actual average nutrient composition of ration fed to alpacas in Alberta[a]

Item	Calculated Values	Analyzed average
Dry matter, %	91.24	89.90
Crude protein, %	12.30	15.30
Fat, %	1.76	2.13
Crude fiber, %	39.82	26.86
Acid detergent fiber, %	27.50	24.50
Neutral detergent fiber, %	42.73	39.66
Total digestible nutrients, %	62.78	67.39
Calcium, %	0.99	1.44
Phosphorus, %	0.99	0.74
Magnesium, %	0.26	0.27
Potassium, %	1.54	1.28
Sodium, %	0.77	0.64
Sulfur, %	0.22	0.22
Iron, ppm	442.05	448
Zinc, ppm	149.95	143
Copper, ppm	32.89	32
Manganese, ppm	124.52	112
Molybdenum, ppm	---	2.5
Vitamin A, IU/lb	4386	N/A
Vitamin D, IU/lb	591	N/A
Vitamin E, IU/lb	10	N/A
Decoquinate, ppm	62	N/A

[a] Nutrient values are on a 100% dry matter basis.

Table 11. Average nutrient composition of grass hay and feed mixture for alpacas in Alberta[a]

Item	Timothy hay	Feed mixture	Complete diet[b]
Dry matter, %	86.7	89.9	88.3
Crude protein, %	14.4	15.3	14.9
Fat, %	2.9	2.1	2.5
Crude fiber, %	28.0	26.9	27.5
Acid detergent fiber, %	35.2	24.5	29.9
Neutral detergent fiber, %	52.9	39.7	46.3
Total digestible nutrients, %	60.7	67.4	64.1
Calcium, %	1.47	1.44	1.46
Phosphorus, %	0.17	0.74	0.46
Magnesium, %	0.20	0.27	0.24
Potassium, %	1.41	1.28	1.35
Sodium, %	0.02	0.64	0.33
Sulfur, %	0.14	0.22	0.18
Iron, ppm	364	448	406
Zinc, ppm	17	143	80
Copper, ppm	8	32	20
Manganese, ppm	32	112	72
Molybdenum, ppm	1.1	2.5	1.8
Vitamin A, IU/kg	N/A	9669	4835
Vitamin D, IU/kg	N/A	1303	652
Vitamin E, IU/kg	N/A	22	11
Decoquinate, ppm	0	62	31

[a] Nutrient values are on a 100% dry matter basis.
[b] The complete diet represents a 1:1 mixture of the hay and feed mixture.

Table 12. Average nutrient composition of complete diets (50:50 hay : ration) offered to alpacas in Alberta and Texas[a]

Item	Alberta	Texas
Dry matter, %	88.3	90.3
Crude protein, %	14.9	13.0
Fat, %	2.5	2.2
Crude fiber, %	27.5	22.7
Acid detergent fiber, %	29.9	30.7
Neutral detergent fiber, %	46.3	47.3
Total digestible nutrients, %	64.1	65.3
Calcium, %	1.46	0.84
Phosphorus, %	0.46	0.37
Magnesium, %	0.24	0.19
Potassium, %	1.35	1.65
Sodium, %	0.33	0.34
Sulfur, %	0.18	0.19
Iron, ppm	406	448
Zinc, ppm	80	61
Copper, ppm	20	13
Manganese, ppm	72	56
Molybdenum, ppm	1.8	1.13
Vitamin A, IU/kg	4835	2440
Vitamin D, IU/kg	652	330
Vitamin E, IU/kg	11	37
Decoquinate, ppm	31	31

[a] Nutrient values are on a 100% dry matter basis.

Table 13. Percentages (of bodyweight) of hay and ration offered and consumed during production of the third fleece

	Alberta			Texas		
	Treatment			Treatment		
	1	2	3	1	2	3
Hay offered	1.32	1.19	1.05	1.32	1.19	1.05
Hay consumed	1.26	1.17	1.05	1.11	1.07	0.99
Ration offered	1.32	1.19	1.05	1.32	1.19	1.05
Ration consumed	1.05	1.13	1.03	1.26	1.17	1.04
Total consumption	2.31	2.30	2.08	2.37	2.24	2.03

	Rep						Rep					
	1	2	1	2	1	2	1	2	1	2	1	2
Hay offered	1.32	1.32	1.19	1.19	1.05	1.05	1.32	1.32	1.19	1.19	1.05	1.05
Hay consumed	1.29	1.22	1.16	1.18	1.05	1.04	1.13	1.09	1.04	1.10	0.98	1.00
Ration offered	1.32	1.32	1.19	1.19	1.05	1.05	1.32	1.32	1.19	1.19	1.05	1.05
Ration consumed	1.13	0.97	1.15	1.10	1.01	1.05	1.20	1.32	1.15	1.18	1.04	1.04
Average body weight, kg	63.5	81.6	64.9	83.0	73.9	59.4	68.0	78.5	71.2	60.3	72.1	58.5

Table 14. Means (± SD) of body weight, body condition score and fleece traits by age

Item	Age 1			Age 2			Age 3		
Body weight, kg	40.0[c]	±	7.7	58.6[b]	±	9.3	76.3[a]	±	12.4
Body condition score, 1-5	4.2[a]	±	0.5	3.9[b]	±	1.3	4.2[a]	±	0.9
Grease fleece weight, g	2443[b]	±	372	2448[b]	±	426	2910[a]	±	533
Clean alpaca fiber present, %	90.4[b]	±	3.6	95.2[a]	±	2.6	90.9[b]	±	2.6
Vegetable matter present, %	2.3[a]	±	1.2	1.2[c]	±	0.9	1.8[b]	±	1.3
Clean fleece weight, g	2209[b]	±	350	2331[b]	±	416	2640[a]	±	461
Clean fiber production efficiency, g/kg BW	56.6[a]	±	11.4	40.2[b]	±	6.7	35.4[c]	±	6.2
Average fiber diameter, μm	25.3[c]	±	1.7	28.9[b]	±	2.9	33.2[a]	±	4.1
Alpaca grade	3.2[c]	±	0.6	4.4[b]	±	0.9	5.3[a]	±	1.0
SD of fiber diameter, μm	6.9[c]	±	0.7	7.6[b]	±	0.9	8.4[a]	±	1.0
CV of fiber diameter, %	27.1[a]	±	1.8	26.1[a,b]	±	2.8	25.4[b]	±	2.8
Comfort factor, %	79.7[a]	±	6.7	64.6[b]	±	13.0	48.9[c]	±	17.9
Spinning fineness, μm	26.1[c]	±	1.9	29.6[b]	±	2.8	33.7[a]	±	3.8
Average fiber curvature, deg/mm	34.2[a]	±	4.4	33.9[a]	±	5.1	29.7[b]	±	5.8
SD of fiber curvature, deg/mm	28.1[a]	±	3.8	26.4[b]	±	3.7	22.8[c]	±	4.5
Along-fiber average fiber diameter, μm	25.0[c]	±	1.6	28.6[b]	±	2.9	32.9[a]	±	4.0
SD of along-fiber diameter, μm	0.62[b]	±	0.07	0.64[a]	±	0.07	0.65[a]	±	0.07
Total medullation, per 10,000 fibers	1444[c]	±	587	2180[b]	±	1216	2897[a]	±	1613
Flat fibers, per 10,000 fibers	53[b]	±	22	97[a]	±	42	11[c]	±	8
Objectionable fibers, per 10,000 fibers	242[c]	±	104	408[b]	±	288	585[a]	±	484
Average fiber diameter of medullated fibers, μm	33.4[c]	±	2.0	36.2[b]	±	2.6	39.2[a]	±	2.9
SD of fiber diameter of medullated fibers, μm	8.2	±	1.2	8.2	±	1.5	9.2	±	1.7
Average staple length, cm	12.5[a]	±	1.4	9.2[c]	±	1.4	10.8[b]	±	1.1
SD of staple length, cm	1.6[a]	±	0.3	1.2[b]	±	0.3	1.1[b]	±	0.3
Average staple strength, N/ktex	61.1[c]	±	12.2	89.7[a]	±	11.3	74.1[b]	±	10.1
SD of staple strength, N/ktex	13.9[b]	±	3.0	21.7[a]	±	6.0	14.1[b]	±	4.2
Position of break	0.45	±	0.05	0.43	±	0.08	0.46	±	0.06
Average resistance to compression, kPa	5.0[b]	±	0.7	5.6[a]	±	0.5	5.9[a]	±	1.0

[a,b,c] Means within a row with different superscripts differ ($P < 0.05$).

Table 15. Effect of age on the fraction of each alpaca fleece component, clean %

Fleece component	Age 1			Age 2			Age 3		
Butt	8.2[b]	±	1.9	11.3[a]	±	3.0	11.7[a]	±	2.2
Long leg	26.8[a]	±	4.1	21.8[b]	±	5.0	20.8[b]	±	2.7
Neck	19.9[b]	±	3.0	21.0[a]	±	3.0	19.9[b]	±	2.5
Saddle	24.5[c]	±	7.0	30.5[b]	±	6.0	35.7[a]	±	4.3
Short leg	20.7[a]	±	3.5	15.4[b]	±	5.4	11.9[c]	±	5.0

[a,b,c] Means within a row that do not share a common superscript differ ($P < 0.05$).

Table 16. Effect of age on the average fiber diameter (μm) of each alpaca fleece component

Fleece component	Age 1	Age 2	Age 3
Butt	$23.6^c \pm 1.8$	$26.2^b \pm 3.3$	$28.5^a \pm 4.2$
Long leg	$25.8^c \pm 2.4$	$30.9^b \pm 3.8$	$35.9^a \pm 5.1$
Neck	$23.4^c \pm 2.4$	$28.2^b \pm 3.3$	$33.0^a \pm 4.7$
Saddle	$22.7^c \pm 1.7$	$25.4^b \pm 2.9$	$28.5^a \pm 3.7$
Short leg	$30.0^c \pm 2.9$	$37.6^b \pm 5.1$	$48.4^a \pm 7.1$
Total	$25.3^c \pm 1.7$	$28.9^b \pm 2.9$	$33.2^a \pm 4.1$

^{a,b,c} Means within a row that do not share a common superscript differ ($P < 0.05$).

Table 17. Effect of age on the medullated fiber content (per 10,000) of each alpaca fleece component

Fleece component	Age 1			Age 2			Age 3		
Butt	1573[c]	±	903	2148[b]	±	1313	2903[a]	±	1607
Long leg	1730[c]	±	696	2554[b]	±	1699	3248[a]	±	2047
Neck	1376[c]	±	787	2582[b]	±	1610	3413[a]	±	2327
Saddle	1230[b]	±	775	1447[b]	±	774	2262[a]	±	1200
Short leg	1397[c]	±	587	2354[b]	±	1386	2837[a]	±	2069
Total	1444[c]	±	587	2180[b]	±	1216	2897[a]	±	1613

[a,b,c] Means within a row that do not share a common superscript differ ($P < 0.05$).

Table 18. Effect of age on the staple length (cm) of each alpaca fleece component

Fleece component	Age 1	Age 2	Age 3
Butt	14.5[a] ± 1.6	10.3[c] ± 1.8	12.0[b] ± 1.6
Long leg	13.8[a] ± 1.7	9.1[c] ± 2.2	10.1[b] ± 1.4
Neck	9.7[a] ± 1.3	7.5[c] ± 1.1	8.9[b] ± 1.3
Saddle	14.8[a] ± 1.6	10.8[c] ± 1.6	12.5[b] ± 1.4
Short leg	9.9[a] ± 1.5	7.4[c] ± 1.7	8.5[b] ± 1.0
Total	12.5[a] ± 1.4	9.2[c] ± 1.4	10.8[b] ± 1.1

[a,b,c] Means within a row that do not share a common superscript differ ($P < 0.05$).

Table 19. Least squares means of liveweight and body condition score for the significant treatment * location interactions

	Location						
	Alberta			Texas			
	Treatment						
Variables	1	2	3	1	2	3	P
Body weight, kg	78.3[a,b]	83.6[a]	76.4[b]	75.5	70.9	72.6	0.0482
Body condition score	4.9	4.9	4.9	3.9[a]	3.1[b]	3.7[a]	0.0771

[a,b] Treatment means within a location are different if they have different superscripts ($P < 0.05$).

Table 20. Least squares means of adjusted grease fleece weight (g) by treatment and location

	Treatment				Location		
Fleece component	1	2	3	P	Alberta	Texas	P
Butt	344	331	336	0.9614	354	321	0.5486
Long leg	696	585	530	0.1593	595	613	0.8538
Neck	669[a]	564[b]	542[b]	0.0115	630[a]	554[b]	0.0204
Saddle	1153[a]	1003[b]	992[b]	0.0283	1111[a]	987[b]	0.0368
Short leg	384[a]	347[a,b]	310[b]	0.0190	435[a]	259[b]	0.0021
Total	3246[a]	2806[b]	2730[b]	0.0049	3079[a]	2776[b]	0.0092

[a,b] Fleece component means within treatment or location row having different superscripts differ ($P < 0.05$).

Table 21. Least squares means of fraction of greasy fleece (%) by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	10.7	11.2	12.5	0.4283	11.3	12.1	0.6731
Long leg	21.3	20.8	19.5	0.5149	19.8	21.3	0.5549
Neck	20.8	20.1	19.8	0.7532	20.4	20.1	0.8078
Saddle	35.5	35.6	36.8	0.5528	35.6	36.3	0.7092
Short leg	11.7	11.8	11.4	0.5548	14.0[a]	9.3[b]	0.0022
Total	100.0	100.0	100.0	0.4790	100.0	100.0	0.4085

[a,b] Fleece component means within location row having different superscripts differ ($P < 0.05$).

Table 22. Least squares means of clean alpaca fiber present (%) by treatment and location

Fleece component	Treatment 1	Treatment 2	Treatment 3	Treatment P	Location Alberta	Location Texas	Location P
Butt	88.4[b]	90.6[a]	89.7[a,b]	0.0176	89.4	90.0	0.3195
Long leg	91.3[b]	93.3[a]	92.3[a,b]	0.0537	90.5[b]	94.1[a]	0.0007
Neck	89.2	91.0	89.9	0.2210	88.9[b]	91.1[a]	0.0292
Saddle	88.5	90.4	90.5	0.2177	88.9	90.7	0.1203
Short leg	93.4[b]	95.8[a]	94.3[a,b]	0.0400	92.3[b]	96.6[a]	0.0005
Total	89.5[b]	92.1[a]	90.7[a,b]	0.0270	89.6[b]	92.0[a]	0.0081

[a,b] Fleece component means within treatment or location row having different superscripts differ ($P < 0.05$).

Table 23. Least squares means of vegetable matter present (%) by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	3.3[a]	2.4[b]	2.1[b]	0.0210	1.2[b]	4.0[a]	0.0005
Long leg	0.4	0.8	0.4	0.6052	0.4	0.6	0.7233
Neck	2.5	2.0	1.7	0.7385	1.4	2.8	0.1744
Saddle	3.3	2.5	1.8	0.1545	1.9	3.2	0.2198
Short leg	0.4	0.3	0.3	0.4898	0.3	0.4	0.3340
Total	2.1	1.7	1.5	0.2138	1.2	2.3	0.0997

[a,b] Fleece component means within treatment or location row having different superscripts differ ($P < 0.05$).

Table 24. Least squares means of adjusted clean fleece weight (g) by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	305	300	302	0.9950	315	289	0.5885
Long leg	633	543	490	0.1729	537	574	0.6733
Neck	596[a]	515[b]	484[b]	0.0090	558[a]	505[b]	0.0313
Saddle	1013[a]	914[a,b]	896[b]	0.0911	981	901	0.1149
Short leg	356[a]	330[a]	290[b]	0.0181	401[a]	250[b]	0.0025
Total	2904[a]	2587[b]	2472[b]	0.0119	2764[a]	2544[b]	0.0308

[a,b] Fleece component means within treatment or location having different superscripts differ ($P < 0.05$).

Table 25. Least squares means of clean fiber production efficiency (g/kg BW) by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	4.0	4.1	4.1	0.9449	3.9	4.2	0.6962
Long leg	8.4	7.3	6.7	0.2036	6.7	8.3	0.1606
Neck	7.8	6.9	6.7	0.1473	7.1	7.1	0.9535
Saddle	13.2	12.3	12.3	0.2207	12.4	12.8	0.5576
Short leg	4.6	4.3	3.9	0.1431	4.7	3.8	0.1378
Total	38.2[a]	34.3[b]	34.0[b]	0.0234	34.9	36.1	0.2216

[a,b] Fleece component means within treatment row having different superscripts differ ($P < 0.05$).

Table 26. Least squares means of fraction of clean fleece (%) by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	10.6	11.6	12.4	0.4156	11.3	11.7	0.8425
Long leg	21.7	21.1	19.8	0.5151	19.9	21.7	0.4781
Neck	20.7	19.9	19.6	0.6972	20.2	19.9	0.8079
Saddle	34.9	35.3	36.6	0.4477	35.1	36.0	0.6462
Short leg	12.2	12.3	11.7	0.3112	14.6[a]	9.5[b]	0.0008
Total	100.0	100.0	100.0	---	100.0	100.0	---

[a,b] Fleece component means within location row having different superscripts differ ($P < 0.05$).

Table 27. Least squares means of average fiber diameter (μm) by treatment and location

Fleece component	Treatment 1	Treatment 2	Treatment 3	Treatment P	Location Alberta	Location Texas	Location P
Butt	29.8	28.8	27.0	0.1560	30.5[a]	26.6[b]	0.0102
Long leg	37.3	35.3	35.4	0.6645	36.0	36.0	0.9776
Neck	34.7	32.5	32.1	0.1844	34.1	32.1	0.1055
Saddle	28.6	28.1	28.6	0.8159	29.1	27.7	0.1107
Short leg	51.0	47.7	47.7	0.4255	47.9	49.7	0.4917
Total	34.6	32.9	32.5	0.1292	34.2	32.4	0.0620

[a,b] Fleece component means within location row having different superscripts differ ($P < 0.05$).

Table 28. Least squares means of alpaca grade by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	4.7	4.5	4.1	0.3025	5.1[a]	3.7[b]	0.0054
Long leg	6.4	6.0	6.1	0.7461	6.2	6.2	0.8603
Neck	6.2[a]	5.4[b]	5.4[a,b]	0.0815	5.8	5.5	0.2830
Saddle	4.3	4.2	4.5	0.7341	4.6	4.0	0.0897
Short leg	6.9	7.0	6.7	0.3047	6.9	6.8	0.8335
Total	5.6	5.2	5.2	0.2901	5.6	5.0	0.0595

[a,b] Fleece component means within treatment or location row having different superscripts differ ($P < 0.05$).

Table 29. Least squares means of SD of fiber diameter (μm) by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	7.1	6.9	6.1	0.2399	7.0	6.4	0.3015
Long leg	11.0	10.0	9.7	0.4028	9.4	11.1	0.0994
Neck	8.1	7.8	7.2	0.1921	7.9	7.5	0.4274
Saddle	6.9	7.0	7.0	0.9804	7.1	6.9	0.7684
Short leg	12.1	12.4	12.6	0.8987	12.7	12.1	0.5810
Total	8.7	8.5	8.2	0.6060	8.6	8.3	0.5644

Table 30. Least squares means of CV of fiber diameter (%) by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	23.9	24.1	23.0	0.5964	23.4	23.9	0.7040
Long leg	30.0	28.1	27.8	0.5234	26.6	30.7	0.0528
Neck	23.5	24.0	22.6	0.1808	22.9	23.8	0.1833
Saddle	23.9	24.9	25.2	0.8024	24.5	24.9	0.8197
Short leg	24.6	25.6	26.9	0.3485	26.6	24.8	0.1818
Total	25.2	25.7	25.3	0.8758	25.1	25.7	0.5222

Table 31. Least squares means of comfort factor (%) by treatment and location

Fleece component	Treatment 1	Treatment 2	Treatment 3	Treatment P	Location Alberta	Location Texas	Location P
Butt	60.8	64.4	74.5	0.1563	54.6	78.6	0.0045
Long leg	31.2	37.7	37.4	0.7574	32.7	38.3	0.5077
Neck	34.4	46.1	47.1	0.2092	38.6	46.5	0.2042
Saddle	68.0	69.6	65.7	0.7314	63.5	72.1	0.0967
Short leg	4.0	7.0	13.6	0.3835	10.4	6.1	0.4856
Total	44.2	50.2	51.9	0.2433	44.0[b]	53.5[a]	0.0408

[a,b] Fleece component means within location row having different superscripts differ ($P < 0.05$).

Table 32. Least squares means of spinning fineness (μm) by treatment and location

Fleece component	Treatment 1	Treatment 2	Treatment 3	Treatment P	Location Alberta	Location Texas	Location P
Butt	29.9	28.8	26.8	0.1818	30.3[a]	26.6[b]	0.0248
Long leg	39.6	36.9	36.7	0.5301	36.9	38.6	0.4829
Neck	34.3	32.6	31.8	0.2257	34.2[a]	31.6[b]	0.0493
Saddle	28.6	28.4	28.8	0.9366	29.4	27.9	0.1778
Short leg	50.9	48.6	48.9	0.6835	49.7	49.3	0.8908
Total	35.1	33.5	33.0	0.3098	34.7	33.0	0.1385

[a,b] Fleece component means within location row having different superscripts differ ($P < 0.05$).

Table 33. Least squares means of average fiber curvature (deg/mm) by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	33.0	34.3	33.6	0.6667	33.0	34.3	0.3146
Long leg	26.3	28.2	27.3	0.7014	28.3	26.3	0.3292
Neck	28.0[b]	31.0[a]	30.6[a]	0.0594	28.5[b]	31.2[a]	0.0331
Saddle	33.0	33.5	33.1	0.9127	33.4	33.0	0.7630
Short leg	17.8	19.8	20.6	0.5373	20.4	18.4	0.4619
Total	28.4	30.2	30.2	0.2593	29.6	29.6	0.9568

[a,b] Fleece component means within treatment or location row having different superscripts differ ($P < 0.05$).

Table 34. Least squares means of SD of fiber curvature (deg/mm) by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	25.5	25.6	26.7	0.6684	26.9	25.0	0.1572
Long leg	21.2	22.6	21.9	0.6679	23.4	20.4	0.0548
Neck	22.5	23.4	25.1	0.1386	23.6	23.7	0.9168
Saddle	23.6	22.2	25.4	0.5048	25.4	22.1	0.1660
Short leg	15.8	18.0	18.5	0.2293	19.8[a]	15.1[b]	0.0092
Total	22.0	22.5	24.1	0.3170	24.1	21.6	0.0578

[a,b] Fleece component means within location row having different superscripts differ ($P < 0.05$).

Table 35. Least squares means of along-fiber average fiber diameter (μm) by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	29.7	28.6	26.8	0.1286	30.3[a]	26.4[b]	0.0088
Long leg	36.9	35.0	35.2	0.6529	35.7	35.7	0.9763
Neck	34.6	32.1	31.7	0.1514	33.8	31.8	0.1208
Saddle	28.4	27.8	28.3	0.7507	28.9	27.5	0.0933
Short leg	50.4	47.1	46.9	0.4119	47.2	49.0	0.4658
Total	34.4	32.5	32.1	0.0986	33.9	32.1	0.0584

[a,b] Fleece component means within location row having different superscripts differ ($P < 0.05$).

Table 36. Least squares means of SD of along-fiber diameter (µm) by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	0.63	0.64	0.62	0.5152	0.66[a]	0.60[b]	0.0288
Long leg	0.64	0.67	0.67	0.1778	0.69[a]	0.63[b]	0.0086
Neck	0.66	0.66	0.69	0.5321	0.69	0.64	0.0571
Saddle	0.61	0.61	0.62	0.6636	0.65[a]	0.58[b]	0.0050
Short leg	0.73	0.74	0.73	0.9799	0.76	0.71	0.2235
Total	0.65	0.66	0.66	0.5577	0.68[a]	0.62[b]	0.0011

[a,b] Fleece component means within location row having different superscripts differ ($P < 0.05$).

Table 37. Means of total medullation (per 10,000) by treatment and location

	Treatment (N)				Location (N)		
Fleece component	1 (4)	2 (3)	3 (8)	P	Alberta (10)	Texas (5)	P
Butt	4101[a]	3737[a]	2038[b]	< 0.05	3156	2399	> 0.05
Long leg	4092[a]	5145[a]	2115[b]	< 0.05	3619[a]	2508[b]	< 0.05
Neck	4876[a]	5114[a]	2044[b]	< 0.05	3635	2970	> 0.05
Saddle	2530[a,b]	2814[a]	1868[b]	< 0.05	2290	2190	> 0.05
Short leg	3233	3588	2358	> 0.05	3259	1994	> 0.05
Total	3756[a]	4202[a]	1978[b]	< 0.05	3124[a]	2442[b]	< 0.05

[a,b] Fleece component means within treatment or location row having different superscripts differ ($P < 0.05$).

Table 38. Means of flat fibers (per 10,000) by treatment and location

Fleece component	Treatment (N) 1 (4)	2 (3)	3 (8)	P	Location (N) Alberta (10)	Texas (5)	P
Butt	3.5	3.7	2.4	> 0.05	2.4	4.0	> 0.05
Long leg	16.3	9.8	3.0	> 0.05	4.3[b]	21.8[a]	< 0.05
Neck	1.0	0.0	4.9	> 0.05	1.0[b]	6.6[a]	< 0.05
Saddle	0.8	1.7	3.3	> 0.05	2.2	2.4	> 0.05
Short leg	54.0	27.7	126.3	> 0.05	36.6	188.6	> 0.05
Total	11.3	6.3	14.1	> 0.05	8.2	19.1	> 0.05

[a,b] Fleece component means within location row having different superscripts differ ($P < 0.05$).

Table 39. Means of objectionable fibers (per 10,000) by treatment and location

Fleece component	Treatment (N) 1 (4)	2 (3)	3 (8)	P	Location (N) Alberta (10)	Texas (5)	P
Butt	627[a]	678[a]	239[b]	< 0.05	513[a]	264[b]	< 0.05
Long leg	1015[a,b]	1647[a]	288[b]	< 0.05	891	480	> 0.05
Neck	1384[a]	1331[a]	314[b]	< 0.05	947[a]	514[b]	< 0.05
Saddle	459	433	251	> 0.05	353	340	> 0.05
Short leg	774	822	425	> 0.05	726	340	> 0.05
Total	869[a]	998[a]	288[b]	< 0.05	674[a]	407[b]	< 0.05

[a,b] Fleece component means within treatment or location row having different superscripts differ ($P < 0.05$).

Table 40. Means of medullated fibers average fiber diameter (µm) by treatment and location

Fleece component	Treatment (N) 1 (4)	2 (3)	3 (8)	P	Location (N) Alberta (10)	Texas (5)	P
Butt	33.1	33.5	32.0	> 0.05	32.7	32.3	> 0.05
Long leg	41.4	40.5	41.9	> 0.05	39.8[b]	44.8[a]	< 0.05
Neck	40.2	40.0	37.1	> 0.05	38.0	39.5	> 0.05
Saddle	33.4	35.5	34.4	> 0.05	34.9	33.1	> 0.05
Short leg	58.1	52.2	54.7	> 0.05	51.6[b]	62.1[a]	< 0.05
Total	40.0	40.1	38.5	> 0.05	39.2	39.2	> 0.05

[a,b] Fleece component means within location row having different superscripts differ ($P < 0.05$).

Table 41. Means of SD of fiber diameter of medullated fibers (μm) by treatment and location

Fleece component	Treatment (N) 1 (4)	2 (3)	3 (8)	P	Location (N) Alberta (10)	Texas (5)	P
Butt	6.8	5.6	7.1	> 0.05	6.6	7.0	> 0.05
Long leg	11.3	9.2	11.4	> 0.05	9.4[b]	13.9[a]	< 0.05
Neck	8.2	7.0	7.9	> 0.05	7.2[b]	9.1[a]	< 0.05
Saddle	6.4	7.0	8.4	> 0.05	7.6	7.3	> 0.05
Short leg	13.9[a,b]	12.6[b]	16.5[a]	< 0.05	12.8[b]	19.5[a]	< 0.05
Total	8.9	8.4	9.7	> 0.05	8.9	9.9	> 0.05

[a,b] Fleece component means within treatment or location row having different superscripts differ ($P < 0.05$).

Table 42. Least squares means of average staple length (cm) by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	11.2	10.6	10.2	0.2572	10.4	10.9	0.4536
Long leg	8.9	8.7	9.2	0.6125	9.3	8.7	0.4374
Neck	8.3	7.8	7.6	0.1379	7.8	8.0	0.3480
Saddle	11.1	10.7	11.3	0.2399	11.1	11.0	0.6310
Short leg	7.9	7.3	7.4	0.4709	7.7	7.4	0.6580
Total	9.8	9.3	9.6	0.3310	9.4	9.7	0.4944

Table 43. Least squares means of SD of staple length (cm) by treatment and location

	Treatment				Location		
Fleece component	1	2	3	P	Alberta	Texas	P
Butt	0.9	1.2	1.2	0.2509	1.1	1.1	0.7506
Long leg	0.9	1.2	1.4	0.1311	1.3	1.1	0.4017
Neck	1.2	1.1	0.9	0.0702	1.1	1.1	0.7657
Saddle	0.9	0.9	0.8	0.9127	0.9	0.8	0.6603
Short leg	1.0	0.9	1.1	0.5068	1.1	0.9	0.2473
Total	1.0	1.0	1.0	0.9877	1.1	1.0	0.5747

Table 44. Least squares means of average staple strength (N/ktex) by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	79.2	71.7	72.0	0.2975	70.8	77.8	0.1299
Long leg	78.0	80.3	74.4	0.4924	71.6[b]	83.5[a]	0.0296
Neck	77.7	78.6	76.4	0.9415	68.9[b]	86.2[a]	0.0188
Saddle	71.7	73.2	70.0	0.7800	67.0[b]	76.2[a]	0.0671
Short leg	77.0	80.4	68.9	0.1390	71.4	79.4	0.1237
Total	75.6	75.1	71.3	0.4040	67.7[b]	80.3[a]	0.0072

[a,b] Fleece component means within location row having different superscripts differ ($P < 0.05$).

Table 45. Least squares means of SD of staple strength (N/ktex) by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	11.3	15.5	10.6	0.1589	12.2	12.7	0.7836
Long leg	13.8	14.6	14.7	0.9465	12.2	16.6	0.1149
Neck	18.0	16.0	14.4	0.5540	15.2	17.0	0.5119
Saddle	15.0	13.9	9.8	0.4524	10.1	15.7	0.0987
Short leg	15.1	16.5	18.3	0.3692	17.0	16.3	0.6842
Total	14.9	14.8	13.0	0.6905	12.9	15.6	0.2040

Table 46. Least squares means of position of break by treatment and location

Fleece component	Treatment				Location		
	1	2	3	P	Alberta	Texas	P
Butt	0.46	0.44	0.45	0.9119	0.46	0.44	0.7478
Long leg	0.46	0.43	0.43	0.6770	0.44	0.44	0.7979
Neck	0.47	0.43	0.45	0.4189	0.46	0.44	0.4935
Saddle	0.49	0.46	0.46	0.5573	0.47	0.47	0.9893
Short leg	0.45	0.43	0.44	0.7222	0.46[a]	0.41[b]	0.0463
Total	0.48	0.44	0.45	0.4356	0.46	0.45	0.6385

[a,b] Fleece component means within location row having different superscripts differ ($P < 0.05$).

Table 47. Least squares means of resistance to compression (kPa) by treatment and location

Fleece component	Treatment 1	Treatment 2	Treatment 3	Treatment P	Location Alberta	Location Texas	Location P
Butt	5.4	5.8	5.7	0.3393	6.6[a]	4.8[b]	0.0005
Long leg	6.2	6.0	6.0	0.5487	6.8[a]	5.4[b]	0.0008
Neck	6.2	6.1	6.3	0.8023	6.9[a]	5.4[b]	0.0016
Saddle	5.8[a]	5.5[b]	5.7[a,b]	0.0815	6.4[a]	5.0[b]	0.0001
Short leg	6.7	7.0	6.6	0.4045	7.4[a]	6.1[b]	0.0053
Total	6.0	5.9	5.9	0.2395	6.7[a]	5.2[b]	0.0001

[a,b] Fleece component means within treatment or location row having different superscripts differ ($P < 0.05$).

Table 48. Summary of age, location, and treatment effects on alpaca characteristics

Age	
Increases with increasing age	BW, ADJGFW, ADJCFW, AFD, AG, SDFD, SF, AFAFD, SDAFFD, TM, OF, MEDAFD, ASS (2 > 3 > 1), SDSS, R2C
Decreases with increasing age	ADJCFLW, CVFD, CF, AFC, SDFC, ADJASL, ADJSDSL
Unaffected by age	BCS, CAFP, VMP, FF, MEDSDFD, POB
Location	
AB > TX	BW, BCS, ADJGFW, ADJCFW, SDAFFD, TM, OF, R2C
AB < TX	CAFP, CF, ASS
AB = TX	VMP, ADJCFLW, AFD (P = 0.06), AG (P = 0.06), SDFD, CVFD, SF, AFC, SDFC (P = 0.06), AFAFD (P = 0.06), FF, MEDAFD, MEDSDFD, ASL, SDSL, SDSS, POB
Treatment	
1 > 2 = 3	ADJGFW, ADJCFW, ADJCFLW
1 = 2 > 3 = 1	BW (AB), TM, OF
1 = 2 = 3	BW (TX), BCS, CAFP, VMP, AFD (P = 0.1), AG, SDFD, CVFD, SF, CF, AFC, SDFC, AFAFD (P = 0.1), SDAFFD, FF, MEDAFD, MEDSDFD, ASL, SDSL, ASS, SDSS, POB, R2C

Key to abbreviations for characteristics measured and calculated on alpacas (Tables 48 and 50)

BW, body weight, kg
BCS, body condition score (1-5)
ADJGFW, adjusted (to 365 d) grease fleece weight, g
ADJGFLW, adjusted greasy fiber production per unit of body weight, g/kg
LSY, lab scoured yield, %
VMP, vegetable matter present, %
CAFP, clean alpaca fiber present, %
ADJCFW, adjusted (to 365 days) clean fleece weight, g
ADJCFLW, adjusted clean fiber production per unit of body weight, g/kg
AFD, average fiber diameter, microns
AG, alpaca grade (1-7)
SDFD, standard deviation of fiber diameter, microns
CVFD, coefficient of variation of fiber diameter, %
CF, comfort factor, %
SF, spinning fineness, microns
AFC, average fiber curvature, deg/mm
SDFC, standard deviation of fiber curvature, deg/mm
CVFC, coefficient of variation of fiber curvature, %
AFAFD, along-fiber average fiber diameter, microns
SDAFFD, standard deviation of along-fiber fiber diameter, microns
CVAFFD, coefficient of variation of along-fiber fiber diameter, %
TM, total medullation, per 10,000 fibers
FF, flat fibers, per 10,000 fibers
OF, objectionable fibers, per 10,0000 fibers
MEDAFD, average fiber diameter of medullated fibers, microns
MEDSDFD, standard deviation of fiber diameter of medullated fibers, microns
MEDCVFD, coefficient of variation of fiber diameter of medullated fibers, %
ADJASL, adjusted (to 365 d) average staple length, cm
ADJSDSL, adjusted (to 365 d) standard deviation of staple length, cm
ADJCVSL, adjusted (to 365 d) coefficient of variation of staple length, %
ASS, average staple strength, N/ktex
SDSS, standard deviation of staple strength, N/ktex
CVSS, coefficient of variation of staple strength, %
POB, position of break, fraction of length from tip
R2C, resistance to compression, kPa

Table 49. Mean values and variability of alpaca traits (total fleece, all years)

Item	Mean	SD	CV
Body weight, kg	58.0	17.8	30.8
Body condition score, 1-5	4.1	1.0	23.7
Grease fleece weight, g	2588.3	490.4	18.9
Clean alpaca fiber present, %	92.2	3.7	4.0
Vegetable matter present, %	1.8	1.2	70.9
Clean fleece weight, g	2383.9	443.3	18.6
Clean fiber production efficiency, g/kg BW	44.4	12.4	27.9
Average fiber diameter, µm	29.0	4.4	15.1
Alpaca grade	4.3	1.2	27.6
SD of fiber diameter, µm	7.6	1.1	14.1
CV of fiber diameter, %	26.2	2.6	9.8
Comfort factor, %	65.0	18.0	27.7
Spinning fineness, µm	29.6	4.2	14.3
Average fiber curvature, deg/mm	32.7	5.5	16.7
SD of fiber curvature, deg/mm	25.9	4.5	17.5
Along-fiber average fiber diameter, µm	28.7	4.3	15.1
SD of along-fiber diameter, µm	0.6	0.1	11.7
Total medullation, per 10,000 fibers	2146	1307	60.9
Flat fibers, per 10,000 fibers	57.4	45.3	78.9
Objectionable fibers, per 10,000 fibers	404.4	343.1	84.8
Average fiber diameter of medullated fibers, µm	36.1	3.4	9.4
SD of fiber diameter of medullated fibers, µm	8.5	1.5	17.6
Average staple length, cm	11.2	2.3	21.0
SD of staple length, cm	1.3	0.3	26.3
Average staple strength, N/ktex	75.0	16.4	21.8
SD of staple strength, N/ktex	16.7	5.8	35.0
Position of break	0.45	0.06	14.6
Average resistance to compression, kPa	5.5	0.8	15.0

Table 50. Pearson correlation coefficients between alpaca traits

	AGE	BW	BCS	ADJGFW	ADJGFLW	LSY	VMP	CAFP	ADJCFW	ADJCFLW	AFD	AG
AGE	1.00000	0.83477	0.01920	0.38992	-0.67158	-0.01166	-0.18555	0.05353	0.39820	-0.69815	0.72774	0.70233
	0.0	0.0001	0.8466	0.0001	0.0001	0.9084	0.0646	0.5968	0.0001	0.0001	0.0001	0.0001
	107	104	104	100	100	100	100	100	100	100	100	100
BW	0.83477	1.00000	0.25295	0.52591	-0.75519	0.12312	-0.30448	0.21176	0.57283	-0.76593	0.77320	0.77633
	0.0001	0.0	0.0092	0.0001	0.0001	0.2200	0.0020	0.0335	0.0001	0.0001	0.0001	0.0001
	104	105	105	101	101	101	101	101	101	101	101	101
BCS	0.01920	0.25295	1. 00000	0.24465	-0.04952	-0.11029	-0.42349	0.04642	0.26033	-0.04034	0.16167	0.19443
	0.8466	0.0092	0.0	0.0137	0.6229	0.2722	0.0001	0.6448	0.0086	0.6887	0.1063	0.0514
	104	105	105	101	101	101	101	101	101	101	101	101
ADJGFW	0.38992	0.52591	0.24465	1. 00000	0.08137	-0.19002	-0.00081	-0.16719	0.97743	0.07154	0.59190	0.59722
	0.0001	0.0001	0.0137	0.0	0.4185	0.0570	0.9936	0.0947	0.0001	0.4771	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
ADJGFLW	-0.67158	-0.75519	-0.04952	0.08137	1.00000	-0.38629	0.33970	-0.45562	-0.00755	0.99016	-0.46870	-0.48149
	0.0001	0.0001	0.6229	0.4185	0.0	0.0001	0.0005	0.0001	0.9402	0.0001	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
LSY	-0.01166	0.12312	-0.11029	-0.19002	-0.38629	1. 00000	-0.18135	0.94275	0.00771	-0.26899	0.08902	0.13040
	0.9084	0.2200	0.2722	0.0570	0.0001	0.0	0.0695	0.0001	0.9390	0.0065	0.3760	0.1937
	100	101	101	101	101	101	101	101	101	101	101	101
VMP	-0.18555	-0.30448	-0.42349	-0.00081	0.33970	-0.18135	1. 00000	-0.49893	-0.10502	0.28463	-0.26692	-0.32415
	0.0646	0.0020	0.0001	0.9936	0.0005	0.0695	0.0	0.0001	0.2960	0.0039	0.0070	0.0009
	100	101	101	101	101	101	101	101	101	101	101	101
CAFP	0.05353	0.21176	0.04642	-0.16719	-0.45562	0.94275	-0.49893	1. 00000	0.04241	-0.33357	0.16897	0.22484
	0.5968	0.0335	0.6448	0.0947	0.0001	0.0001	0.0001	0.0	0.6737	0.0007	0.0912	0.0238
	100	101	101	101	101	101	101	101	101	101	101	101
ADJCFW	0.39820	0.57283	0.26033	0.97743	-0.00755	0.00771	-0.10502	0.04241	1.00000	0.00894	0.63004	0.64759
	0.0001	0.0001	0.0086	0.0001	0.9402	0.9390	0.2960	0.6737	0.0	0.9293	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
ADJCFLW	-0.69815	-0.76593	-0.04034	0.07154	0.99016	-0.26899	0.28463	-0.33357	0.00894	1.00000	-0.46752	-0.47296
	0.0001	0.0001	0.6887	0.4771	0.0001	0.0065	0.0039	0.0007	0.9293	0.0	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
AFD	0.72774	0.77320	0.16167	0.59190	-0.46870	0.08902	-0.26692	0.16897	0.63004	-0.46752	1. 00000	0.98010
	0.0001	0.0001	0.1063	0.0001	0.0001	0.3760	0.0070	0.0912	0.0001	0.0001	0.0	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
AG	0.70233	0.77633	0.19443	0.59722	-0.48149	0.13040	-0.32415	0.22484	0.64759	-0.47296	0.98010	1. 00000
	0.0001	0.0001	0.0514	0.0001	0.0001	0.1937	0.0009	0.0238	0.0001	0.0001	0.0001	0.0
	100	101	101	101	101	101	101	101	101	101	101	101
SDFD	0.57248	0.55155	-0.07321	0.43387	-0.37116	0.04588	-0.06252	0.06164	0.44483	-0.38015	0.77162	0.73965
	0.0001	0.0001	0.4669	0.0001	0.0001	0.6487	0.5345	0.5403	0.0001	0.0001	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
CVFD	-0.27460	-0.37378	-0.33839	-0.27511	0.17630	-0.12654	0.30715	-0.21567	-0.32689	0.15508	-0.40383	-0.42533
	0.0057	0.0001	0.0005	0.0054	0.0778	0.2073	0.0018	0.0303	0.0008	0.1215	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
CF	-0.68728	-0.74488	-0.18339	-0.58563	0.43974	-0.06354	0.30217	-0.15847	-0.62178	0.43853	-0.98590	-0.97438
	0.0001	0.0001	0.0664	0.0001	0.0001	0.5278	0.0021	0.1135	0.0001	0.0001	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
SF	0.72396	0.75239	0.11026	0.57861	-0.46582	0.08168	-0.22611	0.14866	0.61144	-0.46726	0.98681	0.96304
	0.0001	0.0001	0.2723	0.0001	0.0001	0.4168	0.0230	0.1379	0.0001	0.0001	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
AFC	-0.30964	-0.38140	0.09347	-0.39764	0.17243	0.02096	-0.02832	0.02808	-0.39170	0.18739	-0.59544	-0.59262
	0.0017	0.0001	0.3525	0.0001	0.0847	0.8352	0.7786	0.7804	0.0001	0.0606	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
SDFC	-0.45555	-0.50493	0.01035	-0.40747	0.31090	-0.00625	0.01132	-0.00934	-0.40910	0.32996	-0.64563	-0.64651
	0.0001	0.0001	0.9182	0.0001	0.0016	0.9506	0.9105	0.9261	0.0001	0.0008	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
CVFC	-0.29000	-0.26435	-0.18141	-0.04976	0.27206	-0.04543	0.09378	-0.07184	-0.06469	0.28083	-0.14613	-0.15676
	0.0034	0.0076	0.0694	0.6212	0.0059	0.6519	0.3509	0.4753	0.5204	0.0044	0.1448	0.1175
	100	101	101	101	101	101	101	101	101	101	101	101
AFAFD	0.73048	0.77728	0.17438	0.59222	-0.47072	0.08349	-0.27111	0.16552	0.62967	-0.47001	0.99952	0.98007
	0.0001	0.0001	0.0811	0.0001	0.0001	0.4065	0.0061	0.0981	0.0001	0.0001	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
SDAFFD	0.20498	0.21962	0.13910	0.43396	0.07526	0.07049	-0.15213	0.11371	0.47150	0.10497	0.33481	0.33493
	0.0408	0.0273	0.1654	0.0001	0.4545	0.4836	0.1288	0.2575	0.0001	0.2961	0.0006	0.0006
	100	101	101	101	101	101	101	101	101	101	101	101
CVAFFD	-0.51372	-0.56544	-0.06001	-0.22391	0.52556	-0.07684	0.15272	-0.11950	-0.24145	0.54161	-0.67298	-0.67124
	0.0001	0.0001	0.5511	0.0244	0.0001	0.4450	0.1273	0.2339	0.0150	0.0001	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
TM	0.44410	0.38689	0.25689	0.48249	-0.15079	-0.13382	-0.10651	-0.08472	0.46747	-0.16096	0.71328	0.70936
	0.0011	0.0050	0.0688	0.0003	0.2909	0.3492	0.4569	0.5545	0.0005	0.2592	0.0001	0.0001
	51	51	51	51	51	51	51	51	51	51	51	51

Table 50. Pearson correlation coefficients between alpaca traits (continued)

	AGE	BW	BCS	ADJGFW	ADJGFLW	LSY	VMP	CAFP	ADJCFW	ADJCFLW	AFD	AG
FF	-0.34010	-0.24480	-0.09774	-0.03324	0.14444	0.58022	-0.19128	0.59017	0.10067	0.21877	0.00796	0.08483
	0.0146	0.0834	0.4950	0.8169	0.3119	0.0001	0.1787	0.0001	0.4821	0.1230	0.9558	0.5539
	51	51	51	51	51	51	51	51	51	51	51	51
OF	0.39933	0.32132	0.27313	0.44141	-0.11636	-0.17065	-0.17698	-0.09398	0.42454	-0.12645	0.70401	0.68175
	0.0037	0.0215	0.0525	0.0012	0.4161	0.2312	0.2141	0.5119	0.0019	0.3766	0.0001	0.0001
	51	51	51	51	51	51	51	51	51	51	51	51
MEDAFD	0.68734	0.70004	0.26429	0.50345	-0.42908	-0.02460	-0.15495	0.03062	0.51572	-0.43209	0.90946	0.87900
	0.0001	0.0001	0.0609	0.0002	0.0017	0.8639	0.2776	0.8311	0.0001	0.0015	0.0001	0.0001
	51	51	51	51	51	51	51	51	51	51	51	51
MEDSDFD	0.25633	0.09281	-0.18575	-0.01762	-0.09683	-0.23075	0.13737	-0.25563	-0.07100	-0.12515	0.03605	-0.02519
	0.0694	0.5171	0.1919	0.9023	0.4991	0.1033	0.3364	0.0702	0.6205	0.3815	0.8017	0.8607
	51	51	51	51	51	51	51	51	51	51	51	51
MEDCVFD	-0.14749	-0.31210	-0.30208	-0.31708	0.15623	-0.27330	0.18222	-0.30942	-0.38503	0.12521	-0.48273	-0.53394
	0.3017	0.0258	0.0312	0.0234	0.2736	0.0523	0.2006	0.0271	0.0053	0.3813	0.0003	0.0001
	51	51	51	51	51	51	51	51	51	51	51	51
ADJASL	-0.74011	-0.56625	0.30753	-0.07455	0.62622	-0.23821	0.14778	-0.26004	-0.12444	0.62464	-0.53969	-0.52428
	0.0001	0.0001	0.0018	0.4587	0.0001	0.0164	0.1403	0.0086	0.2150	0.0001	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
ADJSDSL	-0.71132	-0.64826	-0.04417	-0.16288	0.65580	-0.14173	0.21940	-0.19931	-0.20025	0.66360	-0.60667	-0.61327
	0.0001	0.0001	0.6609	0.1036	0.0001	0.1574	0.0275	0.0457	0.0447	0.0001	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
ADJCVSL	-0.40963	-0.44383	-0.33844	-0.19876	0.35671	0.05529	0.14868	-0.00170	-0.19734	0.37621	-0.43433	-0.44355
	0.0001	0.0001	0.0005	0.0463	0.0003	0.5829	0.1378	0.9866	0.0479	0.0001	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101
ASS	0.34299	0.26724	-0.19055	-0.03253	-0.34893	0.43748	-0.23854	0.46642	0.06634	-0.31114	0.26579	0.30822
	0.0005	0.0069	0.0563	0.7468	0.0003	0.0001	0.0163	0.0001	0.5098	0.0015	0.0072	0.0017
	100	101	101	101	101	101	101	101	101	101	101	101
SDSS	0.04506	-0.00477	-0.32779	-0.21070	-0.17445	0.33396	-0.16801	0.35128	-0.13716	-0.14237	-0.00126	0.02865
	0.6562	0.9622	0.0008	0.0344	0.0810	0.0006	0.0931	0.0003	0.1714	0.1555	0.9900	0.7761
	100	101	101	101	101	101	101	101	101	101	101	101
CVSS	-0.26328	-0.26321	-0.25006	-0.28292	0.08871	0.02829	0.01421	0.02011	-0.27939	0.09339	-0.30538	-0.31224
	0.0081	0.0078	0.011 7	0.0041	0.3777	0.7789	0.8879	0.8418	0.0047	0.3529	0.0019	0.0015
	100	101	101	101	101	101	101	101	101	101	101	101
POB	0.02319	-0.03151	-0.03217	-0.00110	0.09560	-0.11289	0.01414	-0.10428	-0.02482	0.09496	-0.00762	-0.01940
	0.8188	0.7544	0.7495	0.9913	0.3416	0.2610	0.8884	0.2994	0.8054	0.3449	0.9397	0.8473
	100	101	101	101	101	101	101	101	101	101	101	101
R2C	0.47829	0.50538	0.27254	0.33823	-0.33095	0.09346	-0.36344	0.20561	0.38449	-0.31024	0.58374	0.58132
	0.0001	0.0001	0.0058	0.0005	0.0007	0.3526	0.0002	0.0391	0.0001	0.0016	0.0001	0.0001
	100	101	101	101	101	101	101	101	101	101	101	101

Table 50. Pearson correlation coefficients between alpaca traits (continued)

	SDFD	CVFD	CF	SF	AFC	SDFC	CVFC	AFAFD	SDAFFD	CVAFFD	TM	FF
AGE	0.57248	-0.27460	-0.68728	0.72396	-0.30964	-0.45555	-0.29000	0.73048	0.20498	-0.51372	0.44410	-0.34010
	0.0001	0.0057	0.0001	0.0001	0.0017	0.0001	0.0034	0.0001	0.0408	0.0001	0.0011	0.0146
	100	100	100	100	100	100	100	100	100	100	51	51
BW	0.55155	-0.37378	-0.74488	0.75239	-0.38140	-0.50493	-0.26435	0.77728	0.21962	-0.56544	0.38689	-0.24480
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0076	0.0001	0.0273	0.0001	0.0050	0.0834
	101	101	101	101	101	101	101	101	101	101	51	51
BCS	-0.07321	-0.33839	-0.18339	0.11026	0.09347	0.01035	-0.18141	0.17438	0.13910	-0.06001	0.25689	-0.09774
	0.4669	0.0005	0.0664	0.2723	0.3525	0.9182	0.0694	0.0811	0.1654	0.5511	0.0688	0.4950
	101	101	101	101	101	101	101	101	101	101	51	51
ADJGFW	0.43387	-0.27511	-0.58563	0.57861	-0.39764	-0.40747	-0.04976	0.59222	0.43396	-0.22391	0.48249	-0.03324
	0.0001	0.0054	0.0001	0.0001	0.0001	0.0001	0.6212	0.0001	0.0001	0.0244	0.0003	0.8169
	101	101	101	101	101	101	101	101	101	101	51	51
ADJGFLW	-0.37116	0.17630	0.43974	-0.46582	0.17243	0.31090	0.27206	-0.47072	0.07526	0.52556	-0.15079	0.14444
	0.0001	0.0778	0.0001	0.0001	0.0847	0.0016	0.0059	0.0001	0.4545	0.0001	0.2909	0.3119
	101	101	101	101	101	101	101	101	101	101	51	51
LSY	0.04588	-0.12654	-0.06354	0.08168	0.02096	-0.00625	-0.04543	0.08349	0.07049	-0.07684	-0.13382	0.58022
	0.6487	0.2073	0.5278	0.4168	0.8352	0.9506	0.6519	0.4065	0.4836	0.4450	0.3492	0.0001
	101	101	101	101	101	101	101	101	101	101	51	51
VMP	-0.06252	0.30715	0.30217	-0.22611	-0.02832	0.01132	0.09378	-0.27111	-0.15213	0.15272	-0.10651	-0.19128
	0.5345	0.0018	0.0021	0.0230	0.7786	0.9105	0.3509	0.0061	0.1288	0.1273	0.4569	0.1787
	101	101	101	101	101	101	101	101	101	101	51	51
CAFP	0.06164	-0.21567	-0.15847	0.14866	0.02808	-0.00934	-0.07184	0.16552	0.11371	-0.11950	-0.08472	0.59017
	0.5403	0.0303	0.1135	0.1379	0.7804	0.9261	0.4753	0.0981	0.2575	0.2339	0.5545	0.0001
	101	101	101	101	101	101	101	101	101	101	51	51
ADJCFW	0.44483	-0.32689	-0.62178	0.61144	-0.39170	-0.40910	-0.06469	0.62967	0.47150	-0.24145	0.46747	0.10067
	0.0001	0.0008	0.0001	0.0001	0.0001	0.0001	0.5204	0.0001	0.0001	0.0150	0.0005	0.4821
	101	101	101	101	101	101	101	101	101	101	51	51
ADJCFLW	-0.38015	0.15508	0.43853	-0.46726	0.18739	0.32996	0.28083	-0.47001	0.10497	0.54161	-0.16096	0.21877
	0.0001	0.1215	0.0001	0.0001	0.0606	0.0008	0.0044	0.0001	0.2961	0.0001	0.2592	0.1230
	101	101	101	101	101	101	101	101	101	101	51	51
AFD	0.77162	-0.40383	-0.98590	0.98681	-0.59544	-0.64563	-0.14613	0.99952	0.33481	-0.67298	0.71328	0.00796
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.1448	0.0001	0.0006	0.0001	0.0001	0.9558
	101	101	101	101	101	101	101	101	101	101	51	51
AG	0.73965	-0.42533	-0.97438	0.96304	-0.59262	-0.64651	-0.15676	0.98007	0.33493	-0.67124	0.70936	0.08483
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.1175	0.0001	0.0006	0.0001	0.0001	0.5539
	101	101	101	101	101	101	101	101	101	101	51	51
SDFD	1.00000	0.26231	-0.74490	0.86420	-0.59112	-0.56099	0.04069	0.76407	0.17282	-0.56678	0.58941	-0.01923
	0.0	0.0081	0.0001	0.0001	0.0001	0.0001	0.6862	0.0001	0.0840	0.0001	0.0001	0.8935
	101	101	101	101	101	101	101	101	101	101	51	51
CVFD	0.26231	1. 00000	0.40734	-0.25260	0.07670	0.18048	0.25095	-0.41340	-0.26321	0.20477	-0.25044	-0.04910
	0.0081	0.0	0.0001	0.0108	0.4459	0.0709	0.0114	0.0001	0.0078	0.0400	0.0763	0.7322
	101	101	101	101	101	101	101	101	101	101	51	51
CF	-0.74490	0.40734	1. 00000	-0.96888	0.56335	0.62981	0.18301	-0.98535	-0.33246	0.66103	-0.72574	-0.07553
	0.0001	0.0001	0.0	0.0001	0.0001	0.0001	0.0670	0.0001	0.0007	0.0001	0.0001	0.5983
	101	101	101	101	101	101	101	101	101	101	51	51
SF	0.86420	-0.25260	-0.96888	1. 00000	-0.61900	-0.65202	-0.10682	0.98456	0.30860	-0.67635	0.71558	0.00095
	0.0001	0.0108	0.0001	0.0	0.0001	0.0001	0.2877	0.0001	0.0017	0.0001	0.0001	0.9947
	101	101	101	101	101	101	101	101	101	101	51	51
AFC	-0.59112	0.07670	0.56335	-0.61900	1. 00000	0.88053	-0.12910	-0.58755	0.14187	0.67041	-0.41130	-0.06457
	0.0001	0.4459	0.0001	0.0001	0.0	0.0001	0.1982	0.0001	0.1570	0.0001	0.0027	0.6526
	101	101	101	101	101	101	101	101	101	101	51	51
SDFC	-0.56099	0.18048	0.62981	-0.65202	0.88053	1.00000	0.35113	-0.64040	0.19868	0.76868	-0.64660	-0.18081
	0.0001	0.0709	0.0001	0.0001	0.0001	0.0	0.0003	0.0001	0.0464	0.0001	0.0001	0.2042
	101	101	101	101	101	101	101	101	101	101	51	51
CVFC	0.04069	0.25095	0.18301	-0.10682	-0.12910	0.35113	1. 00000	-0.15083	0.14727	0.26582	-0.32948	-0.22309
	0.6862	0.0114	0.0670	0.2877	0.1982	0.0003	0.0	0.1322	0.1417	0.0072	0.0182	0.1156
	101	101	101	101	101	101	101	101	101	101	51	51
AFAFD	0.76407	-0.41340	-0.98535	0.98456	-0.58755	-0.64040	-0.15083	1.00000	0.33298	-0.67430	0.71092	-0.00168
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.1322	0.0	0.0007	0.0001	0.0001	0.9907
	101	101	101	101	101	101	101	101	101	101	51	51
SDAFFD	0.17282	-0.26321	-0.33246	0.30860	0.14187	0.19868	0.14727	0.33298	1. 00000	0.45515	0.16147	0.02407
	0.0840	0.0078	0.0007	0.0017	0.1570	0.0464	0.1417	0.0007	0.0	0.0001	0.2576	0.8669
	101	101	101	101	101	101	101	101	101	101	51	51
CVAFFD	-0.56678	0.20477	0.66103	-0.67635	0.67041	0.76868	0.26582	-0.67430	0.45515	1.00000	-0.63763	-0.05069
	0.0001	0.0400	0.0001	0.0001	0.0001	0.0001	0.0072	0.0001	0.0001	0.0	0.0001	0.7239
	101	101	101	101	101	101	101	101	101	101	51	51
TM	0.58941	-0.25044	-0.72574	0.71558	-0.41130	-0.64660	-0.32948	0.71092	0.16147	-0.63763	1.00000	0.13480
	0.0001	0.0763	0.0001	0.0001	0.0027	0.0001	0.0182	0.0001	0.2576	0.0001	0.0	0.3456
	51	51	51	51	51	51	51	51	51	51	51	51

Table 50. Pearson correlation coefficients between alpaca traits (continued)

	SDFD	CVFD	CF	SF	AFC	SDFC	CVFC	AFAFD	SDAFFD	CVAFFD	TM	FF
FF	-0.01923	-0.04910	-0.07553	0.00095	-0.06457	-0.18081	-0.22309	-0.00168	0.02407	-0.05069	0.13480	1.00000
	0.8935	0.7322	0.5983	0.9947	0.6526	0.2042	0.1156	0.9907	0.8669	0.7239	0.3456	0.0
	51	51	51	51	51	51	51	51	51	51	51	51
OF	0.63556	-0.17761	-0.71089	0.71837	-0.42238	-0.60417	-0.24673	0.70117	0.22721	-0.57220	0.94563	0.10324
	0.0001	0.2125	0.0001	0.0001	0.0020	0.0001	0.0809	0.0001	0.1088	0.0001	0.0001	0.4709
	51	51	51	51	51	51	51	51	51	51	51	51
MEDAFD	0.78646	-0.31185	-0.88223	0.92333	-0.62672	-0.67903	0.03608	0.90966	0.53616	-0.61836	0.44533	-0.00535
	0.0001	0.0259	0.0001	0.0001	0.0001	0.0001	0.8016	0.0001	0.0001	0.0001	0.0011	0.9703
	51	51	51	51	51	51	51	51	51	51	51	51
MEDSDFD	0.27989	0.29058	0.03140	0.09676	-0.00388	0.20486	0.38870	0.03614	0.33019	0.21299	-0.40498	-0.30484
	0.0467	0.0386	0.8268	0.4994	0.9784	0.1493	0.0048	0.8012	0.0180	0.1335	0.0032	0.0296
	51	51	51	51	51	51	51	51	51	51	51	51
MEDCVFD	-0.16289	0.48295	0.52673	-0.42862	0.38253	0.60519	0.33182	-0.48199	0.03100	0.57878	-0.64732	-0.29983
	0.2534	0.0003	0.0001	0.0017	0.0056	0.0001	0.0174	0.0003	0.8290	0.0001	0.0001	0.0326
	51	51	51	51	51	51	51	51	51	51	51	51
ADJASL	-0.52400	0.05635	0.51909	-0.56107	0.10088	0.19905	0.16041	-0.53608	-0.23374	0.31550	-0.30799	0.08079
	0.0001	0.5757	0.0001	0.0001	0.3155	0.0460	0.1091	0.0001	0.0186	0.0013	0.0279	0.5730
	101	101	101	101	101	101	101	101	101	101	51	51
ADJSDSL	-0.48755	0.21416	0.58494	-0.60450	0.22740	0.33328	0.21784	-0.60951	-0.16159	0.44854	-0.33715	0.25307
	0.0001	0.0315	0.0001	0.0001	0.0222	0.0007	0.0286	0.0001	0.1064	0.0001	0.0155	0.0732
	101	101	101	101	101	101	101	101	101	101	51	51
ADJCVSL	-0.26377	0.27700	0.41783	-0.41055	0.23519	0.32790	0.22339	-0.44257	-0.05095	0.37883	-0.23999	0.32311
	0.0077	0.0050	0.0001	0.0001	0.0179	0.0008	0.0247	0.0001	0.6129	0.0001	0.0898	0.0207
	101	101	101	101	101	101	101	101	101	101	51	51
ASS	0.19225	-0.15179	-0.26480	0.25865	-0.08396	-0.18821	-0.20144	0.26520	0.02362	-0.25527	0.18536	0.42758
	0.0541	0 . 1297	0.0074	0.0090	0.4039	0.0595	0.0434	0.0074	0.8146	0.0100	0.1928	0.0018
	101	101	101	101	101	101	101	101	101	101	51	51
SDSS	-0.02197	-0.03508	-0.03022	-0.00649	0.02064	-0.00614	-0.06123	-0.00357	-0.03235	-0.03971	-0.01381	0.59684
	0.8274	0.7276	0.7642	0.9486	0.8377	0.9514	0.5430	0.971 7	0.7481	0.6934	0.9234	0.0001
	101	101	101	101	101	101	101	101	101	101	51	51
CVSS	-0.22099	0.15665	0.27412	-0.29720	0.13543	0.20688	0.12745	-0.30826	-0.09309	0.22865	-0.32981	0.24368
	0.0264	0.1177	0.0055	0.0025	0.1769	0.0379	0.2041	0.0017	0.3545	0.0215	0.0181	0.0849
	101	101	101	101	101	101	101	101	101	101	51	51
POB	-0.06128	-0.06194	0.00464	-0.02218	0.09081	0.10435	0.03563	-0.00476	0.11737	0.12136	-0.09502	-0.18700
	0.5427	0.5383	0.9633	0.8258	0.3665	0.2990	0.7235	0.9623	0.2424	0.2267	0.5072	0.1888
	101	101	101	101	101	101	101	101	101	101	51	51
R2C	0.31113	-0.41115	-0.61057	0.54188	0.08719	0.03814	-0.06771	0.58754	0.51085	-0.15119	0.56148	-0.12778
	0.0015	0.0001	0.0001	0.0001	0.3860	0.7049	0 . 5011	0.0001	0.0001	0.1312	0.0001	0.3715
	101	101	101	101	101	101	101	101	101	101	51	51

Table 50. Pearson correlation coefficients between alpaca traits (continued)

	OF	MEDAFD	MEDSDFD	MEDCVFD	ADJASL	ADJSDSL	ADJCVSL	ASS	SDSS	CVSS	POB	R2C
AGE	0.39933	0.68734	0.25633	-0.14749	-0.74011	-0.71132	-0.40963	0.34299	0.04506	-0.26328	0.02319	0.47829
	0.0037	0.0001	0.0694	0.3017	0.0001	0.0001	0.0001	0.0005	0.6562	0.0081	0.8188	0.0001
	51	51	51	51	100	100	100	100	100	100	100	100
BW	0.32132	0.70004	0.09281	-0.31210	-0.56625	-0.64826	-0.44383	0.26724	-0.00477	-0.26321	-0.03151	0.50538
	0.0215	0.0001	0.5171	0.0258	0.0001	0.0001	0.0001	0.0069	0.9622	0.0078	0.7544	0.0001
	51	51	51	51	101	101	101	101	101	101	101	101
BCS	0.27313	0.26429	-0.18575	-0.30208	0.30753	-0.04417	-0.33844	-0.19055	-0.32779	-0.25006	-0.03217	0.27254
	0.0525	0.0609	0.1919	0.0312	0.0018	0.6609	0.0005	0.0563	0.0008	0.0117	0.7495	0.0058
	51	51	51	51	101	101	101	101	101	101	101	101
ADJGFW	0.44141	0.50345	-0.01762	-0.31708	-0.07455	-0.16288	-0.19876	-0.03253	-0.21070	-0.28292	-0.00110	0.33823
	0.0012	0.0002	0.9023	0.0234	0.4587	0.1036	0.0463	0.7468	0.0344	0.0041	0.9913	0.0005
	51	51	51	51	101	101	101	101	101	101	101	101
ADJGFLW	-0.11636	-0.42908	-0.09683	0.15623	0.62622	0.65580	0.35671	-0.34893	-0.17445	0.08871	0.09560	-0.33095
	0.4161	0 . 0017	0.4991	0.2736	0.0001	0.0001	0.0003	0.0003	0.0810	0.3777	0.3416	0.0007
	51	51	51	51	101	101	101	101	101	101	101	101
LSY	-0.17065	-0.02460	-0.23075	-0.27330	-0.23821	-0.14173	0.05529	0.43748	0.33396	0.02829	-0.11289	0.09346
	0.2312	0.8639	0.1033	0.0523	0.0164	0.1574	0.5829	0.0001	0.0006	0.7789	0.2610	0.3526
	51	51	51	51	101	101	101	101	101	101	101	101
VMP	-0.17698	-0.15495	0.13737	0.18222	0.14778	0.21940	0.14868	-0.23854	-0.16801	0.01421	0.01414	-0.36344
	0.2141	0.2776	0.3364	0.2006	0.1403	0.0275	0.1378	0.0163	0.0931	0.8879	0.8884	0.0002
	51	51	51	51	101	101	101	101	101	101	101	101
CAFP	-0.09398	0.03062	-0.25563	-0.30942	-0.26004	-0.19931	-0.00170	0.46642	0.35128	0.02011	-0.10428	0.20561
	0.5119	0.8311	0.0702	0.0271	0.0086	0.0457	0.9866	0.0001	0.0003	0.8418	0.2994	0.0391
	51	51	51	51	101	101	101	101	101	101	101	101
ADJCFW	0.42454	0.51572	-0.07100	-0.38503	-0.12444	-0.20025	-0.19734	0.06634	-0.13716	-0.27939	-0.02482	0.38449
	0.0019	0.0001	0.6205	0.0053	0.2150	0.0447	0.0479	0.5098	0.1714	0.0047	0.8054	0.0001
	51	51	51	51	101	101	101	101	101	101	101	101
ADJCFLW	-0.12645	-0.43209	-0.12515	0.12521	0.62464	0.66360	0.37621	-0.31114	-0.14237	0.09339	0.09496	-0.31024
	0.3766	0.0015	0.3815	0.3813	0.0001	0.0001	0.0001	0.0015	0.1555	0.3529	0.3449	0.0016
	51	51	51	51	101	101	101	101	101	101	101	101
AFD	0.70401	0.90946	0.03605	-0.48273	-0.53969	-0.60667	-0.43433	0.26579	-0.00126	-0.30538	-0.00762	0.58374
	0.0001	0.0001	0.8017	0.0003	0.0001	0.0001	0.0001	0.0072	0.9900	0.0019	0.9397	0.0001
	51	51	51	51	101	101	101	101	101	101	101	101
AG	0.68175	0.87900	-0.02519	-0.53394	-0.52428	-0.61327	-0.44355	0.30822	0.02865	-0.31224	-0.01940	0.58132
	0.0001	0.0001	0.8607	0.0001	0.0001	0.0001	0.0001	0.0017	0.77 61	0.0015	0.8473	0.0001
	51	51	51	51	101	101	101	101	101	101	101	101
SDFD	0.63556	0.78646	0.27989	-0.16289	-0.52400	-0.48755	-0.26377	0.19225	-0.02197	-0.22099	-0.06128	0.31113
	0.0001	0.0001	0.0467	0.2534	0.0001	0.0001	0.0077	0.0541	0.8274	0.0264	0.5427	0.0015
	51	51	51	51	101	101	101	101	101	101	101	101
CVFD	-0.17761	-0.31185	0.29058	0.48295	0.05635	0.21416	0.27700	-0.15179	-0.03508	0.15665	-0.06194	-0.41115
	0.2125	0.0259	0.0386	0.0003	0.5757	0.0315	0.0050	0.1297	0.7276	0.1177	0.5383	0.0001
	51	51	51	51	101	101	101	101	101	101	101	101
CF	-0.71089	-0.88223	0.03140	0.52673	0.51909	0.58494	0.41783	-0.26480	-0.03022	0.27412	0.00464	-0.61057
	0.0001	0.0001	0.8268	0.0001	0.0001	0.0001	0.0001	0.0074	0.7642	0.0055	0.9633	0.0001
	51	51	51	51	101	101	101	101	101	101	101	101
SF	0.71837	0.92333	0.09676	-0.42862	-0.56107	-0.60450	-0.41055	0.25865	-0.00649	-0.29720	-0.02218	0.54188
	0.0001	0.0001	0.4994	0.0017	0.0001	0.0001	0.0001	0.0090	0.9486	0.0025	0.8258	0.0001
	51	51	51	51	101	101	101	101	101	101	101	101
AFC	-0.42238	-0.62672	-0.00388	0.38253	0.10088	0.22740	0.23519	-0.08396	0.02064	0.13543	0.09081	0.08719
	0.0020	0.0001	0.9784	0.0056	0.3155	0.0222	0.0179	0.4039	0.8377	0.1769	0.3665	0.3860
	51	51	51	51	101	101	101	101	101	101	101	101
SDFC	-0.60417	-0.67903	0.20486	0.60519	0.19905	0.33328	0.32790	-0.18821	-0.00614	0.20688	0.10435	0.03814
	0.0001	0.0001	0.1493	0.0001	0.0460	0.0007	0.0008	0.0595	0.9514	0.0379	0.2990	0.7049
	51	51	51	51	101	101	101	101	101	101	101	101
CVFC	-0.24673	0.03608	0.38870	0.33182	0.16041	0.21784	0.22339	-0.20144	-0.06123	0.12745	0.03563	-0.06771
	0.0809	0.8016	0.0048	0.0174	0.1091	0.0286	0.0247	0.0434	0.5430	0.2041	0.7235	0.5011
	51	51	51	51	101	101	101	101	101	101	101	101
AFAFD	0.70117	0.90966	0.03614	-0.48199	-0.53608	-0.60951	-0.44257	0.26520	-0.00357	-0.30826	-0.00476	0.58754
	0.0001	0.0001	0.8012	0.0003	0.0001	0.0001	0.0001	0.0074	0 . 971 7	0.0017	0.9623	0.0001
	51	51	51	51	101	101	101	101	101	101	101	101
SDAFFD	0.22721	0.53616	0.33019	0.03100	-0.23374	-0.16159	-0.05095	0.02362	-0.03235	-0.09309	0.11737	0.51085
	0.1088	0.0001	0.0180	0.8290	0.0186	0.1064	0.6129	0.8146	0.7481	0.3545	0.2424	0.0001
	51	51	51	51	101	101	101	101	101	101	101	101
CVAFFD	-0.57220	-0.61836	0.21299	0.57878	0.31550	0.44854	0.37883	-0.25527	-0.03971	0.22865	0.12136	-0.15119
	0.0001	0.0001	0.1335	0.0001	0.0013	0.0001	0.0001	0.0100	0.6934	0.0215	0.2267	0.1312
	51	51	51	51	101	101	101	101	101	101	101	101
TM	0.94563	0.44533	-0.40498	-0.64732	-0.30799	-0.33715	-0.23999	0.18536	-0.01381	-0.32981	-0.09502	0.56148
	0.0001	0.0011	0.0032	0.0001	0.0279	0.0155	0.0898	0.1928	0.9234	0.0181	0.5072	0.0001
	51	51	51	51	51	51	51	51	51	51	51	51

Table 50. Pearson correlation coefficients between alpaca traits (continued)

	OF	MEDAFD	MEDSDFD	MEDCVFD	ADJASL	ADJSDSL	ADJCVSL	ASS	SDSS	CVSS	POB	R2C
FF	0.10324	-0.00535	-0.30484	-0.29983	0.08079	0.25307	0.32311	0.42758	0.59684	0.24368	-0.18700	-0.12778
	0.4709	0.9703	0.0296	0.0326	0.5730	0.0732	0.0207	0.0018	0.0001	0.0849	0.1888	0.3715
	51	51	51	51	51	51	51	51	51	51	51	51
OF	1.00000	0.48728	-0.25470	-0.50585	-0.28534	-0.28119	-0.17981	0.11283	-0.03328	-0.25815	-0.10141	0.54584
	0.0	0.0003	0.0713	0.0002	0.0424	0.0456	0.2067	0.4305	0.8167	0.0674	0.4789	0.0001
	51	51	51	51	51	51	51	51	51	51	51	51
MEDAFD	0.48728	1.00000	0.31364	-0.24848	-0.49850	-0.51371	-0.33022	0.12770	0.00553	-0.22956	-0.06140	0.63572
	0.0003	0.0	0.0250	0.0787	0.0002	0.0001	0.0180	0.3719	0.9693	0.1051	0.6686	0.0001
	51	51	51	51	51	51	51	51	51	51	51	51
MEDSDFD	-0.25470	0.31364	1. 00000	0.83237	-0.27636	-0.11330	0.03172	-0.14895	-0.23415	-0.11230	0.15993	-0.01084
	0.0713	0.0250	0.0	0.0001	0.0496	0.4286	0.8251	0.2969	0.0982	0.4327	0.2623	0.9398
	51	51	51	51	51	51	51	51	51	51	51	51
MEDCVFD	-0.50585	-0.24848	0.83237	1.00000	0.02000	0.20619	0.23923	-0.23943	-0.21418	0.06682	0.19273	-0.35396
	0.0002	0.0787	0.0001	0.0	0.8892	0.1466	0.0909	0.0906	0.1312	0.6413	0.17 54	0.0108
	51	51	51	51	51	51	51	51	51	51	51	51
ADJASL	-0.28534	-0.49850	-0.27636	0.02000	1.00000	0.66977	0.11615	-0.46757	-0.26389	0.11110	-0.05581	-0.48400
	0.0424	0.0002	0.0496	0.8892	0.0	0.0001	0.2474	0.0001	0.0077	0.2687	0.5793	0.0001
	51	51	51	51	101	101	101	101	101	101	101	101
ADJSDSL	-0.28119	-0.51371	-0.11330	0.20619	0.66977	1. 00000	0.79086	-0.35619	-0.07257	0.24505	0.02762	-0.41043
	0.0456	0.0001	0.4286	0.1466	0.0001	0.0	0.0001	0.0003	0.4708	0.0135	0.7840	0.0001
	51	51	51	51	101	101	101	101	101	101	101	101
ADJCVSL	-0.17981	-0.33022	0.03172	0.23923	0.11615	0.79086	1.00000	-0.11647	0.17138	0.33103	0.06622	-0.19269
	0.2067	0.0180	0.8251	0.0909	0.2474	0.0001	0.0	0.2461	0.0866	0.0007	0.5106	0.0535
	51	51	51	51	101	101	101	101	101	101	101	101
ASS	0.11283	0.12770	-0.14895	-0.23943	-0.46757	-0.35619	-0.11647	1.00000	0.60709	-0.17019	-0.21119	0.13566
	0.4305	0.3719	0.2969	0.0906	0.0001	0.0003	0.2461	0.0	0.0001	0.0888	0.0340	0.1762
	51	51	51	51	101	101	101	101	101	101	101	101
SDSS	-0.03328	0.00553	-0.23415	-0.21418	-0.26389	-0.07257	0.17138	0.60709	1.00000	0.64238	-0.16476	-0.02317
	0.8167	0.9693	0.0982	0.1312	0.0077	0.4708	0.0866	0.0001	0.0	0.0001	0.0997	0.8181
	51	51	51	51	101	101	101	101	101	101	101	101
CVSS	-0.25815	-0.22956	-0.11230	0.06682	0.11110	0.24505	0.33103	-0.17019	0.64238	1.00000	0.01537	-0.22617
	0.0674	0.1051	0.4327	0.6413	0.2687	0.0135	0.0007	0.0888	0.0001	0.0	0.8788	0.0230
	51	51	51	51	101	101	101	101	101	101	101	101
POB	-0.10141	-0.06140	0.15993	0.19273	-0.05581	0.02762	0.06622	-0.21119	-0.16476	0.01537	1.00000	0.06882
	0.4789	0.6686	0.2623	0.1754	0.5793	0.7840	0.5106	0.0340	0.0997	0.8788	0.0	0.4941
	51	51	51	51	101	101	101	101	101	101	101	101
R2C	0.54584	0.63572	-0.01084	-0.35396	-0.48400	-0.41043	-0.19269	0.13566	-0.02317	-0.22617	0.06882	1. 00000
	0.0001	0.0001	0.9398	0.0108	0.0001	0.0001	0.0535	0.1762	0.8181	0.0230	0.4941	0.0
	51	51	51	51	101	101	101	101	101	101	101	101

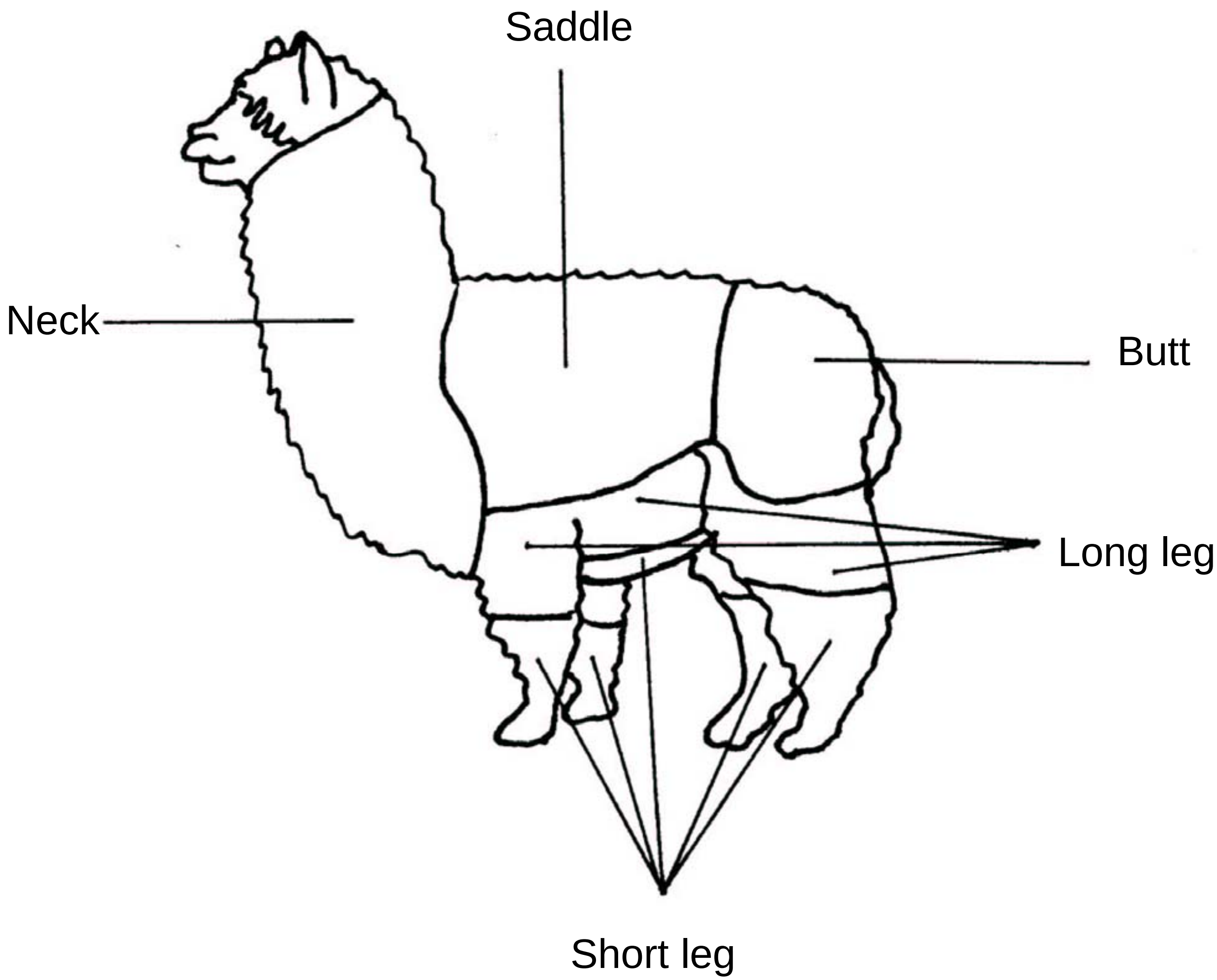

Figure 1. Five fleece components by which alpacas were shorn and tested

Figure 2. Average weight versus month for alpacas on three treatments in Alberta

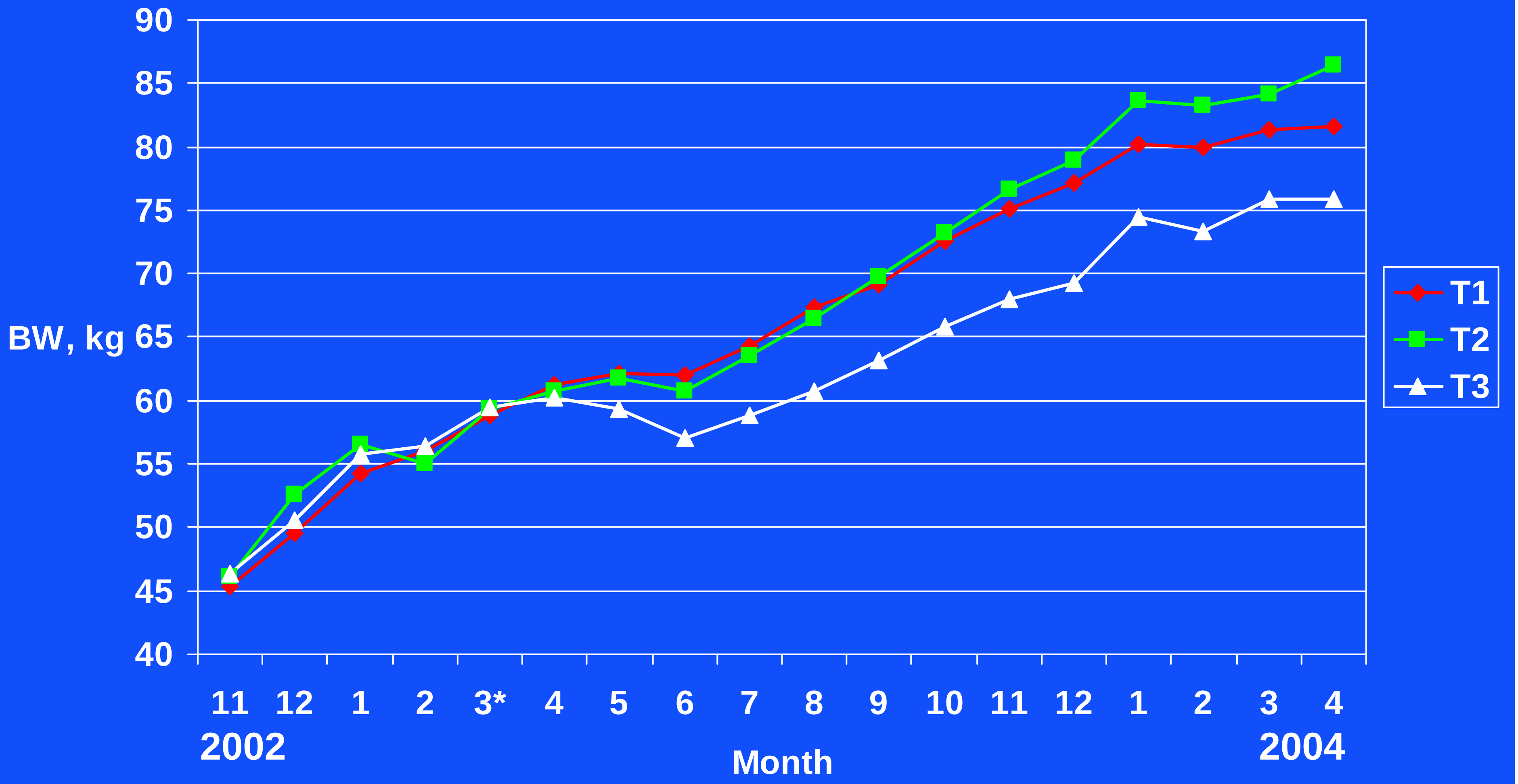

Figure 3. Average weight versus month for alpacas on three treatments in Alberta

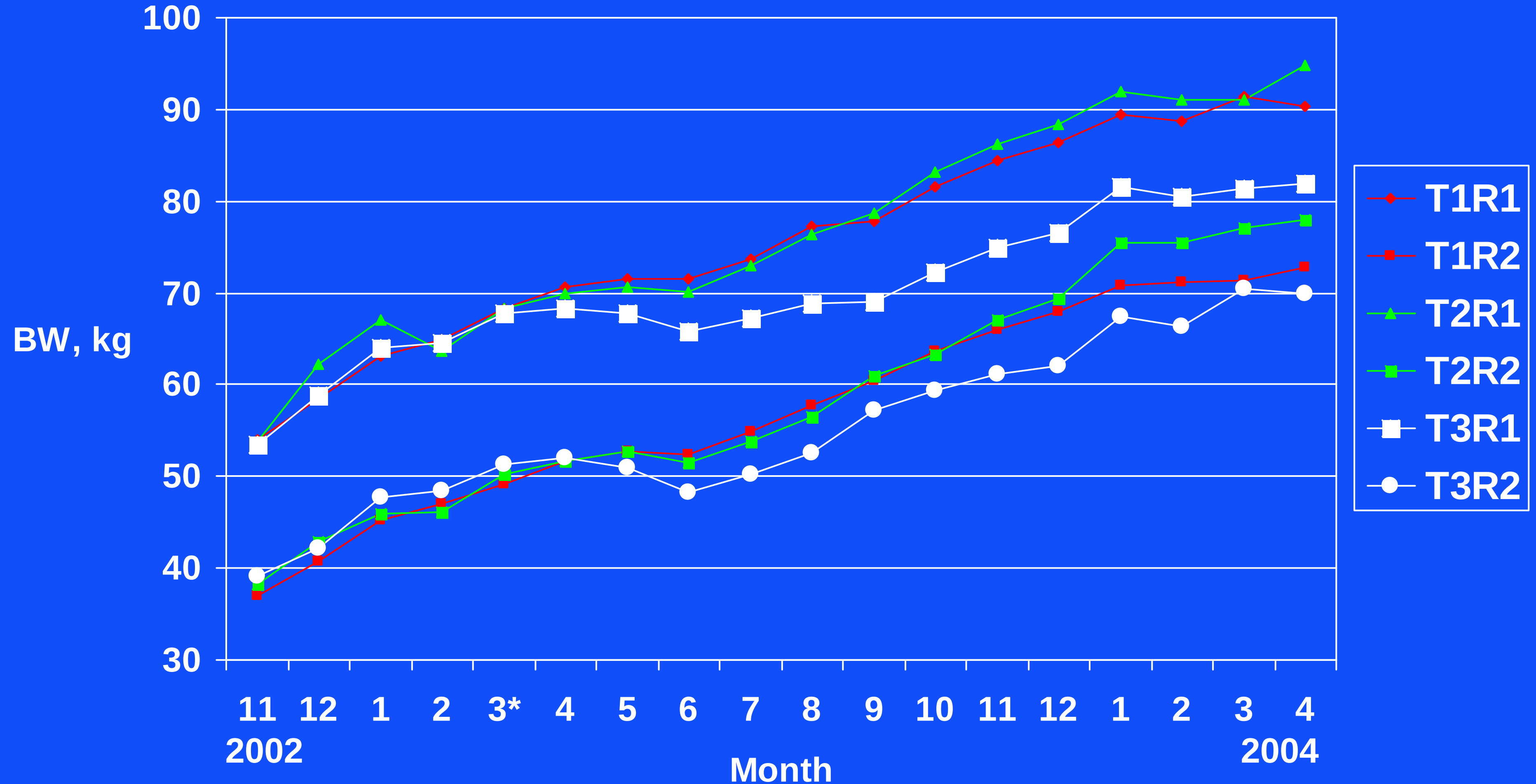

Figure 4. Average weight versus month for alpacas on three treatments in Texas

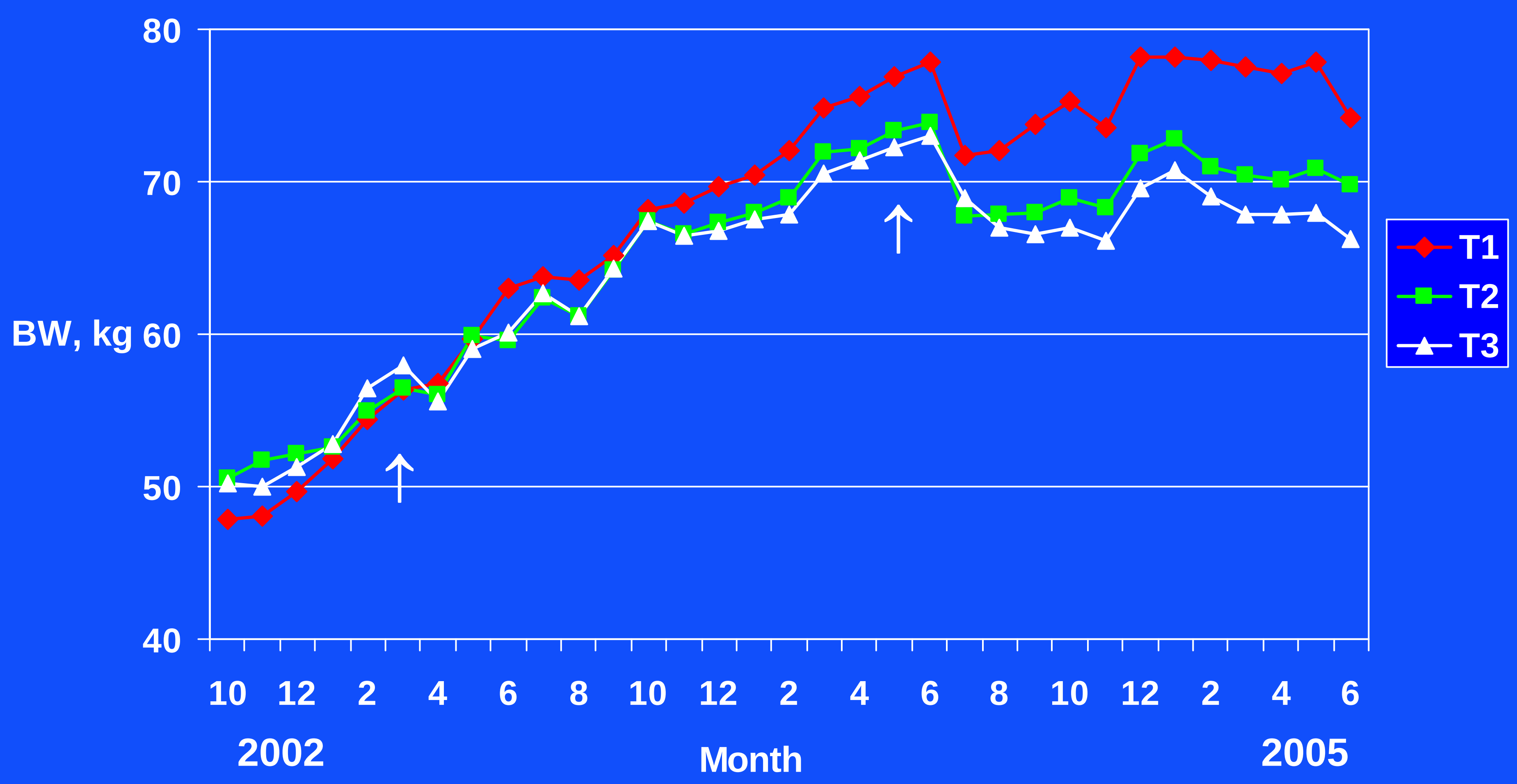

Figure 5. Average weight versus month for alpacas on three treatments in Texas

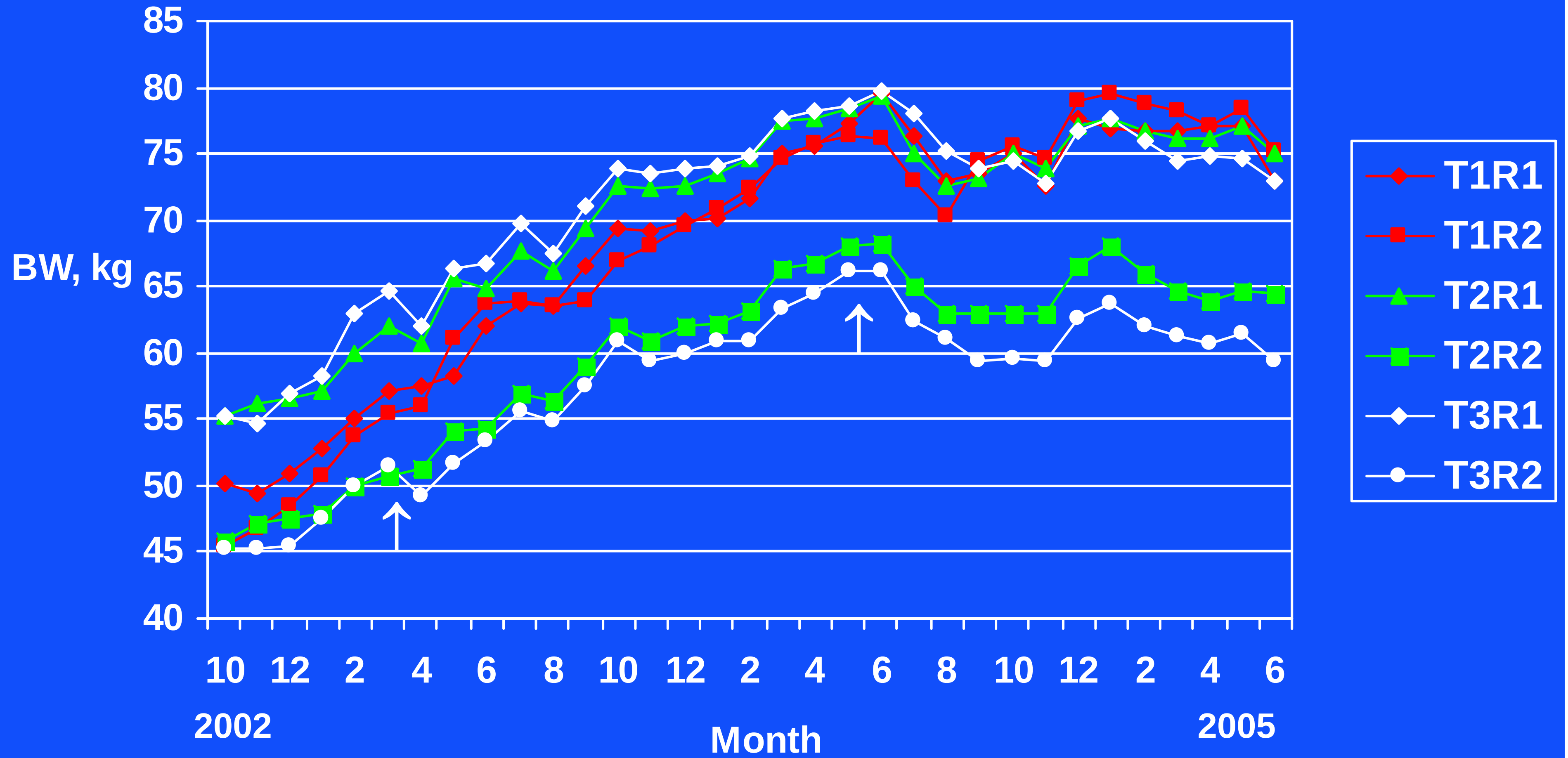

Figure 6. Average weight of alpacas in Alberta and Texas

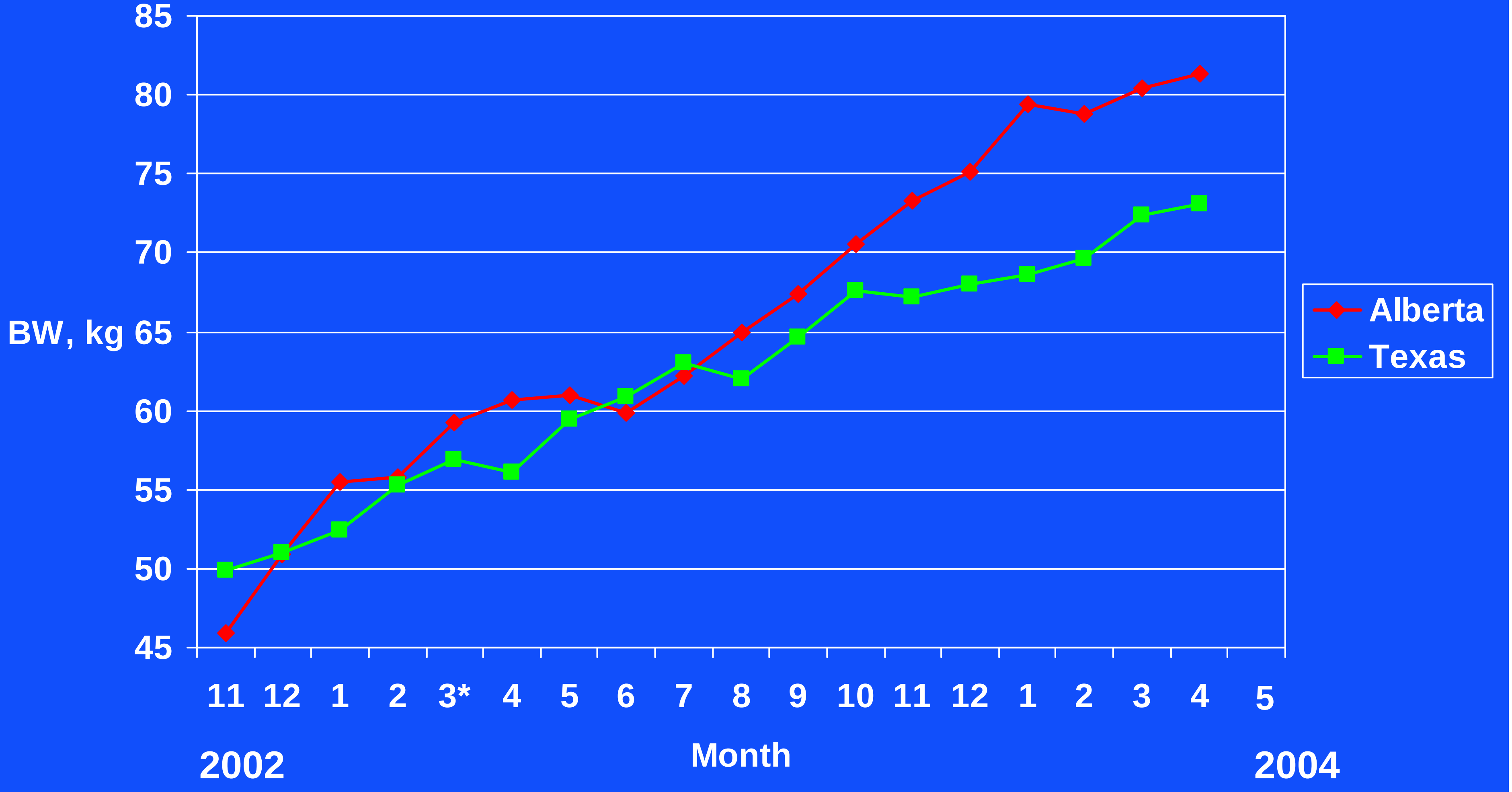

Figure 7. Histogram and typical staple profile for Alberta alpaca

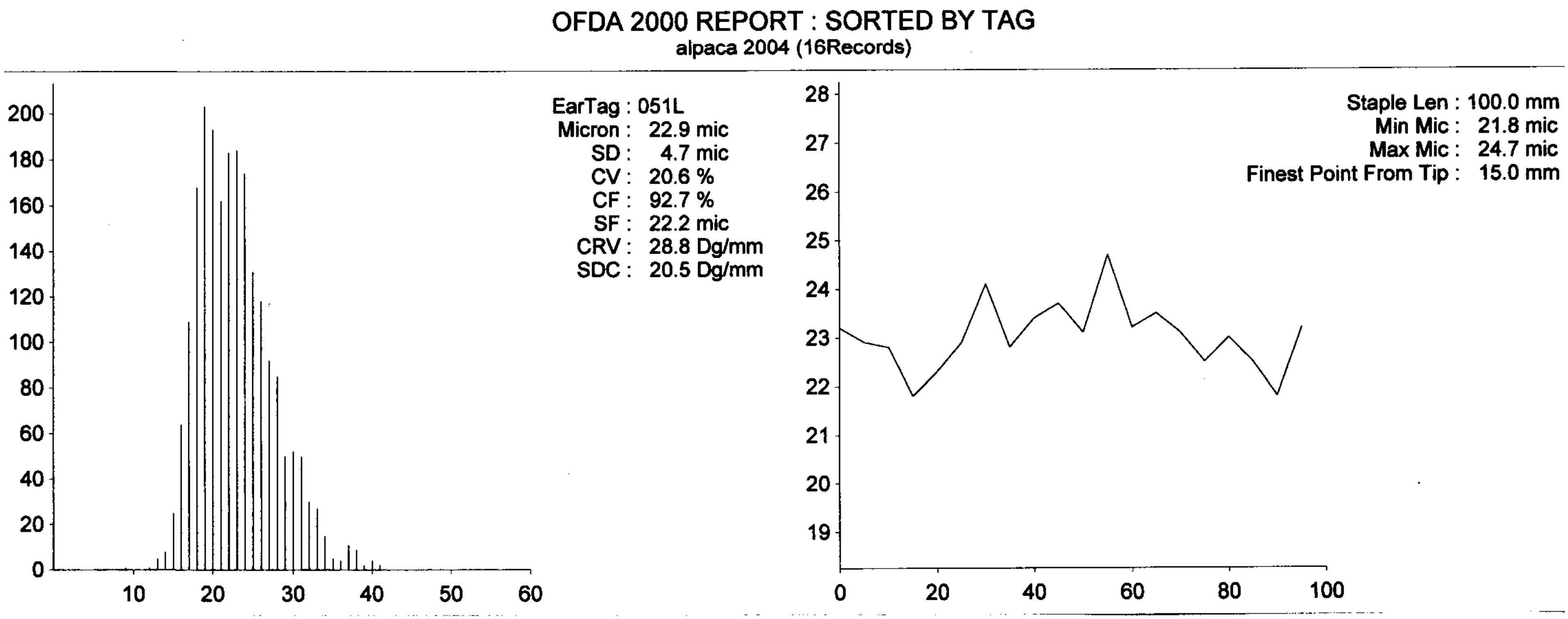

Figure 8. Histogram and typical staple profile for Texas alpaca