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Characteristics of wool fibres from Mule Sheep

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Abstract

A study was conducted to find out if there were any differences in the characteristics of wool fibres from mule sheep in sheep of different ages. Wool samples were taken from 91 North of England Mule Sheep from Seale Hayne Farm in Newton Abbot, Devon. The hypothesis tested was that there are no differences in the characteristics of wool fibres (greasy weight, clean weight, dirt content, mean length and mean diameter) due to the age of the sheep. The age of each sheep was determined by the number of pairs of incisor teeth located on their lower jaw according to Goodwin (1979). Samples were collected with the aid of the farm manager, farm assistant and a lecturer from the University of Plymouth and put into individual bags with the age of each sheep labelled clearly on the bag. Samples were weighed, washed and weighed again to determine greasy weight, clean weight and dirt content. Mean length was determined by measuring the length of two fibres per sample and calculating the mean, and the diameter of a handful of samples was measured by measuring the diameter of 5 fibres per sample and calculating the mean. A one-way unstacked analysis of variance (ANOVA) was used to find any statistically significant differences in different ages, and a Pearson correlation was calculated for greasy and clean weight, and length and diameter. The only significant results returned were for age and length ($p=0.05$) and a strong Pearson Correlation for greasy and clean weight (value of 0.990). Other results found were not statistically significant. These results showed that only the length of the wool fibres in mule sheep is affected by age, and that there is a linear association between greasy weight and clean weight.

Introduction

Mammals use their hair for thermoregulation. It is one of the main components of the integumentary organ system, along with the skin. (Rogers, 1989; Campbell & Reece, 2008) Sheep are covered in wool, a keratin containing protein, which is used by sheep in the process of thermoregulation. Wool is made of about 50% Carbon, 22-25% Oxygen, 16-17% Nitrogen, 7% Hydrogen and 3-4% Sulphur. (Botkin *et al,* 1988) Spöttel and Tänzer carried out extensive studies following on from the research in the 19^{th} and 20^{th} century by H. von Nathusius, de Meijere, Duerden & Ritchie, and Wildman. Research in the 19^{th} and 20^{th} century found that the basic arrangement of hair follicles was groups of, or multiples of 3 with the largest hair – the guard hair – in the middle. Spöttel and Tänzer studied the skin and wool follicles in different breeds of sheep. They distinguished between primary follicles and secondary follicles. Primary follicles possess an erector muscle and a sweat gland, whereas secondary follicles possess neither of these.

The full details of the formation of wool follicles were worked out in 1943 by Carter. (Ryder, 1968) Carter proved that the trio group of three primary follicles starts to develop at around 60 days into foetal development, with the central primary follicle forming first. The two lateral primary follicles then develop around 70 days into foetal development, and the follicle trio groups will usually be all over the body by about 90 days. Following on from this, secondary follicles start to appear in between the primary follicles of the trio groups; this is the secondary stage. By the time the lamb is born, it will usually have three primaries on one side of the follicle, first formed secondaries on the other side, and later formed secondary follicles in between the two. These are 'trio groups' and in sheep these groups show the same positioning in the skin in every region of the body. (Ryder, 1968) There are three cell types in the cortex of wool – orthocortex, mesocortex and paracortex. The highest concentration of cysteine is in the paracortex. In wool, there is a considerable variation in the numbers, and distribution, of these cell types across a transverse-section and along the length of the fibre. This is different to human hair, where there are no differences in the orthocortical and paracortical cells, and their relationship to the crimp or waviness of human hair has never been illustrated. (Plowman *et al,* 2007).

Wool fibres are egg shaped, or 'elliptical' in cross-section, with coarser fibres more elliptical than finer fibres. The axis of each ellipse changes positions along the fibre, associating it with the crimp and the irregular appearance of wool fibres. The diameter of wool also changes along the fibre, with the larger diameters at the root and shaft and the smaller diameter at the tip. This change is due to changes in thickness of the cortex and medulla (Ryder, 1968).

It is said that temporary reduction in nutrients and limiting some dietary amino acids or minerals can reduce fibre diameter and cause temporary changes in the chemical structure of the wool fibre, making it more tender (Botkin *et al,* 1988) and therefore less desirable for purchasers. Tomes *et al* (1979) report that the rate of wool production is determined by the efficiency of conversion of nutrients digested as well as the feed intake. Merino sheep in Australia are selected for breeding by their feed conversion efficiency. Merino rams showed an increase in clean wool production as body weight increased when their feed consumption was increased. However these results also show that there was an increase at a lower rate with the result that feed conversion efficiency was significantly less for large rams than small rams ($p<0.05$) (Tomes *et al,* 1979).

There are three main types of wool; merino, cross-bred and carpet type. Merino wool is fine, crimpy and soft, and has a high number of finer fibres, giving it a high quality number. Cross-bred wool is the wool produced by most sheep in Britain, and despite its name is not always from cross-bred sheep. It has a quality number in the middle region; whereas carpet type wool has the lowest quality number of the three and is coarse with a springy nature. Wool from sheep in Britain is graded on a range of characteristics not just fineness and quality number (Ryder, 1968).

Sheep are bred for their meat and their wool on farms. Wool has its uses, such as in carpets (Gatenby, 1991), tweeds, furnishings, and insulation (Anon., 2004; Anon., 2008). Wool is also used in the fashion industry, but is facing strong competition from other fibres in the knitwear department. Mule sheep generally produce coarse wool**,** which is used for overcoats, blankets and carpets; compared to fine wools which are more valuable, and used for fine hosiery, vests, fine cardigans and babies' garments. (Goodwin, 1979) Generally, white, clean wool is more desirable for buyers due to its capability of being dyed any colour, rather than coloured wool, which is undesirable for commercial manufacturing. However, coloured wool is often used in traditional industries that require wool of different colours for patterns, such as in blankets (Gatenby, 1991).

British wool can have some faults with it, such as genetic or environmental faults, which cannot be avoided by the farmer; however, farmers can avoid the group of faults which are caused by bad husbandry practices or carelessness during shearing. Since the inception of the Wool Marketing Board, prices reductions due to faults in wool have been lowered, and advice has been given as to the avoidance of wool. Ryder reported in 1968 that the "standard of presentation of the British Clip" had improved "immensely in recent years" (Ryder, 1968) due to booklets on shearing and packing wool being produced to aid farmers.

Wool is extremely elastic, so much so that according to Schoenian (2005), it can be bent 30,000 times without danger of breakage or damage to the fibre. The strength of wool, or its 'soundness' is estimated by pulling the fibres until they break. Thin, easily-broken fibres usually come from sheep which are underfed or where the wool is rotted by bacteria or fungi. The 'yield' of wool is the clean fleece weight expressed as a proportion of greasy fleece weight (Gatenby, 1991).

Wool is usually sheared on a clean floor or tarpaulin in order to keep the wool clean and ensure no straw gets caught up in it. (Ryder, 1968) Shearing must be done carefully, although it sounds obvious, common mistakes are to cut the skin of the sheep or to cut the wool some distance away from the skin – this gives shorter length wool, which is less desirable than full length wool. The fleece should always be dry when shorn, and ewes shouldn't be shorn in late pregnancy (Gatenby, 1991).

Skin is also a valuable by-product of the sheep industry, according to Gatenby (1991). The skin of sheep is lighter than that of cattle, and due to this is used to produce light leather for products such as gloves, handbags and the upper soles of shoes. For this purpose, the skin has to be flayed, cured and tanned. The processes of these three steps are outlined below;

- Flaying: the process of removing the skin from the carcass. The skin is pulled off by hand, and fat and flesh from the inner surface scraped off.
- Curing: the process of treating the skin so it can be stored or transported without going ‘bad’. The skin is washed and dried and then a large amount of salt spread over it. This process takes about a month.
- Tanning: Any remaining fat and tissue is removed from the under side of the skin, then hair or wool removed. The skin is then soaked in an acidic solution for one day, and then tanned using chrome or vegetable tannins. After tanning, skin is rinsed in clean water and hung or nailed out to dry. The skins can be dyed at this stage; they are also kneaded to become soft (Gatenby, 1991).

The average mature sheep has 32 teeth. There are (up to) eight incisors at the front of the lower jaw, premolars and molars at the back of the lower jaw and a toothless pad on the upper jaw; sheep do not have canine teeth. In general, a sheep will grow a pair of incisor teeth for each year of its life. When a sheep is about 4 years old it will have 8 pairs, or a full mouth, of incisor teeth, which will then be gradually lost as the sheep ages further, eventually losing all of their teeth – being referred to as ‘broken mouthed’. These ‘adult’ incisor teeth replace milk incisors that grow at an early age.

The age of a sheep can be determined by looking at how many pairs of incisor teeth are on their lower jaw. Table 1 demonstrates the number of incisor teeth, referred to simply as ‘teeth’ corresponding to the age of the sheep.

Table 1: Table demonstrating age of sheep indicated by number of incisor teeth. (Goodwin, 1979)

Number of incisor teeth (teeth)	**Age of sheep (years)**
0	Up to 1 year – lamb
2	1
4	2
6	3
8	4 and above
Broken mouthed	Aged sheep

A “2 tooth” sheep is referred to as a sheep with one pair of incisor teeth, and therefore would be about 1 year old. A “4 tooth” sheep is referred to as a sheep with two pairs of incisor teeth, and therefore would be about 2 years old, etc.

Due to broken mouthed sheep not being able to eat as much food as younger sheep they are generally unproductive and are usually taken out of the breeding flock (Gatenby, 1991; Goodwin, 1979).

The sheep at Seale Hayne Farm are North of England Mules, bred from a Bluefaced Border Leicester ram and a Swaledale ewe. According to thesheeptrust.org (Anon., 2003), the finest wool of any native breed in the UK comes from the Bluefaced Leicester, it is also one of the highest priced. The wool from Swaledale sheep; a Mountain breed, has a tight undercoat making it suitable only for carpets and coarse tweeds. (Goodwin, 1979) Since the 1960s, it seems the Mule sheep has become more popular for breeding to produce lambs for meat. According to Skinner *et al* (1985) and Lelli (2007), Mule sheep are the most commercially bred ewe in the United Kingdom, bred for their prime lamb in a 3-tier breeding system. This is supported by Tomes *et al* (1979), who state that of the returns from sheep in the UK, only around 10% is from wool.

The aim of this project is to assess the characteristics of the wool fibres from mule ewes from Seale Hayne Farm (Newton Abbot, Devon, England) to see if there are any significant differences between ewes of different ages. Age will be determined by the number of incisor teeth on the bottom jaw of the ewe with the aid of the farm manager. The assessments of the characteristics of the wool will be achieved by measuring the length, greasy weight, clean weight, dirt content and diameter in mule ewes of different ages from 2 tooth up to broken mouthed (lamb up to aged ewe). Length will be measured by measuring the length of two fibres from each sample to determine a mean length for each sample. Greasy and clean weight will be measured using a digital scale to the nearest 0.1g. Dirt content is estimated by calculating the difference between greasy and clean weight. Fibre diameter will be measured using a low power microscope and a graticule; 5 measurements from 5 different fibres will be taken for each sample, and a mean calculated per sample. A one-way unstacked analysis of variance (ANOVA) will be used to find any statistically significant differences between the ages of the sheep for each characteristic. A Pearson correlation will then be used to determine the probability of a relationship between greasy and clean weight and length and diameter, and probability values (p-values) calculated.

Null Hypothesis
There will be no statistically significant differences in the characteristics of the wool fibres from mule sheep due to the age of the sheep.

Materials and Methods

Wool was collected using standard curved blade scissors from the back of the necks of 103 sheep. Out of these sheep, there were 91 North of England Mule ewes, 10 Dorset ewes and two Charollais Rams. Samples were put into individual bags with the number of teeth for that sheep and individually numbered from one up to the number of samples in that age group. After a sample was taken from each sheep the sheep was marked with a standard wax based sheep marker stick to prevent two samples being taken from the same sheep. The samples were then weighed with a digital scale to the nearest 0.1g and the weights recorded. They were then washed in a solution made of 1 L of warm water with 4 ml of washing up liquid in a bowl, before being rinsed in warm water and then left to dry in their individual bags for approximately 4 weeks with the bag left open at the top. When washing, 10 samples were washed per bowl and then the bowls were rinsed and fresh water and washing up liquid added to them. 250 ml of cold water was added to every bowl after the first 10 samples were washed due to the water being extremely hot and burning my hands. After 4 weeks, 57 of the samples were still wet and so each sample was laid out on their individual bags on a table overnight to dry. This method was following an example from Ryder, 1968. When all samples were dry, each sample was weighed again and the clean weight recorded. From this, a rough value for dirt content was worked out. Clean fleece weight was not calculated, only clean weight of the sample obtained. All samples were weighed at the same time to avoid changes in weight due to moisture content changes. (Ryder, 1968) Other measurements taken were length and diameter. The length of two fibres per sample was measured using a vernier caliper to get an average length for each sample. Diameter was measured from the two 2 tooth mules, ten 4 tooth, 6 tooth and 8 tooth mules, and five broken mouth mules. Measurements were taken from five different fibres from each sample at a x 10 000 magnification on an Olympus low power microscope, then an average diameter worked out**.** From the eyepiece graticule of the microscope, 100 eye piece graticule units = 100 µm (0.1 mm) and so each eyepiece graticule unit measured 0.1 µm (0.001 mm).

Data was analysed by carrying out a one-way unstacked analysis of variance (ANOVA) to find the probability of statistically significant differences between the ages (2 tooth, 4 tooth, 6 tooth, 8 tooth, broken mouthed) for each characteristic (clean weight, greasy weight, length, diameter, dirt content). Next, a Pearson correlation to ascertain the probability of a relationship between greasy and clean weight, and length and diameter was performed and the probability values calculated.

Results

The results obtained are shown in full in Tables 2 to 6. Where no diameter was measured for a sample, the cell has been left blank. For comparisons of length, greasy weight and clean weight with fibre diameter, only samples whose diameter was measured were used.

Using the one-way unstacked ANOVA analysis of variance, statistical significance was found with length only ($p=0.05$). The mean length showed a decrease as age increased. The graph in Figure 1 below shows the decrease in mean length as age increases. The graph also shows a slightly insignificant decrease between 8 tooth and broken mouthed mules. This decrease in length could possibly be due to the fact that during pregnancy, sheep use their energy for foetal growth and lactation rather than wool production and due to this wool production is decreased. (Gatenby, 1991) However this refers to wool production rather than specifically to length. It could also be due to poorer nutrient absorption in older age. There was no significant difference found for clean weight ($p=0.591$), greasy weight ($p=0.787$), dirt content ($p=0.903$) or diameter ($p=0.771$).

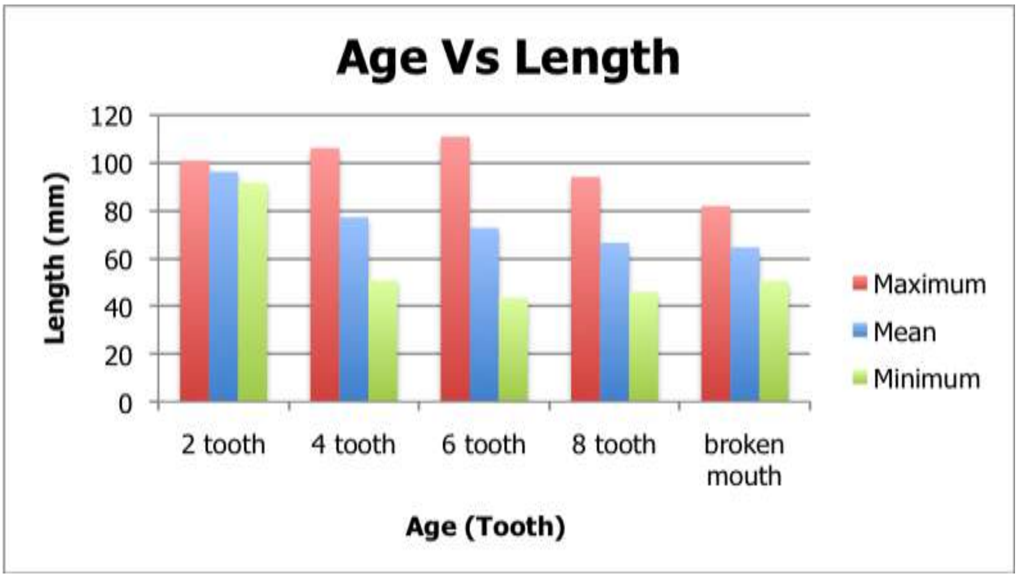

Figure 1: Graph showing the changes in the length of the wool of mule sheep for different ages.

Table 2: Characteristics of wool fibres from 2 tooth mules

Sample No.	Greasy Weight (g)	Clean Weight (g)	Dirt Content (g)	Mean Length (mm)	Mean Diameter (mm)
1	3.4	3.2	0.2	100.95	0.44
2	1.9	1.9	0.3	91.65	0.36

Table 3: Characteristics of wool fibres from 4 tooth mules

Sample No.	Greasy Weight (g)	Clean Weight (g)	Dirt Content (g)	Average Length (mm)	Average Diameter(mm)
1	2.0	1.8	0.2	74.05	-
2	1.8	1.7	0.1	78.80	0.40
3	4.4	4.0	0.4	106.25	0.32
4	2.2	1.9	0.3	63.15	0.32
5	1.6	1.3	0.3	54.10	0.30
6	3.2	2.9	0.3	70.35	0.42
7	2.2	2.0	0.2	61.55	0.34
8	2.7	2.5	0.2	90.95	-
9	3.1	2.7	0.4	83.20	0.44
10	1.4	1.2	0.2	50.80	-
11	2.9	2.5	0.4	75.55	0.36
12	1.4	1.3	0.1	96.40	-
13	2.0	1.8	0.2	80.75	0.30
14	2.3	2.2	0.1	95.90	0.34

Table 4: Characteristics of wool fibres from 6 tooth mules

Sample No.	Greasy weight (g)	Clean weight (g)	Dirt content (g)	Mean Fibre Length (mm)	Mean Fibre Diameter (mm)
1	1.9	1.7	0.2	56.20	0.30
2	3.1	2.9	0.2	86.85	-
3	2.7	2.5	0.2	91.00	-
4	1.5	1.4	0.1	75.00	-
5	2.4	2.2	0.2	102.50	0.38
6	2.4	2.1	0.3	71.80	-
7	1.8	1.5	0.3	52.05	-
8	1.7	1.6	0.1	96.65	-
9	1.6	1.4	0.2	75.05	-
10	1.4	1.2	0.2	67.45	-
11	3.0	2.7	0.3	58.20	-
12	1.6	1.4	0.2	87.60	-
13	1.6	1.4	0.2	77.50	0.36
14	3.5	3.2	0.3	65.65	-
15	2.3	2.0	0.3	90.00	-
16	2.7	2.4	0.3	53.60	-
17	2.3	2.0	0.3	77.95	-
18	2.7	2.3	0.4	59.40	-
19	1.1	0.9	0.2	43.65	-
20	2.0	1.8	0.2	78.70	-
21	2.5	2.2	0.3	77.90	-
22	2.6	2.2	0.4	46.85	0.46
23	2.5	2.2	0.3	65.95	-
24	1.7	1.5	0.2	73.75	0.38
25	2.5	2.3	0.2	65.95	-
26	2.8	2.5	0.3	83.70	-
28	2.1	1.9	0.2	94.90	-
27	1.3	1.2	0.1	78.85	0.34
29	2.9	2.7	0.2	70.30	-
30	1.3	1.1	0.2	65.10	0.38
31	1.4	1.2	0.2	66.40	-
32	2.8	2.5	0.3	90.75	-
33	2.0	1.7	0.3	90.20	-
34	2.3	2.2	0.1	58.50	-
35	2.9	2.6	0.3	82.90	-
36	1.3	1.2	0.1	78.20	-
37	3.4	3.0	0.4	93.50	0.32
38	3.5	3.1	0.4	70.50	-
39	2.0	1.8	0.2	105.85	0.42
40	2.3	1.8	0.5	43.45	-
41	0.8	0.6	0.2	47.05	-
42	1.8	1.6	0.2	59.90	-
43	3.0	2.7	0.3	71.90	-
44	1.7	1.5	0.2	75.10	-
45	2.9	2.5	0.4	53.85	-
46	2.0	1.6	0.4	69.25	-

47	3.2	3.0	0.2	111.00	-
48	2.1	2.0	0.1	86.60	0.36
49	2.7	2.4	0.3	49.45	-
50	2.0	1.8	0.2	69.55	-
51	2.4	2.1	0.3	59.70	-
52	3.2	2.8	0.4	60.25	-
53	1.3	1.1	0.2	79.15	-
54	1.2	1.0	0.2	62.70	-
55	2.2	2.1	0.1	77.80	-

Table 5: Characteristics of wool fibres from 8 tooth mules

Sample No.	Greasy weight (g)	Clean weight (g)	Dirt content (g)	Mean Length (mm)	Mean Fibre Diameter (mm)
1	2.7	2.4	0.3	61.50	0.30
2	1.4	1.2	0.2	61.75	-
3	1.7	1.6	0.1	61.70	0.36
4	3.3	3.0	0.3	75.70	0.40
5	2.6	2.4	0.2	70.45	-
6	2.3	2.1	0.2	60.90	0.42
7	1.9	1.8	0.1	46.05	0.36
8	2.2	2.0	0.2	83.65	0.40
9	2.3	2.1	0.2	56.10	0.44
10	2.0	1.6	0.4	70.85	-
11	2.1	2.0	0.1	57.40	0.30
12	2.3	1.9	0.4	63.75	-
13	2.4	2.3	0.1	73.55	0.38
14	1.6	1.3	0.3	61.25	0.30
15	2.7	2.5	0.2	94.15	-

Table 6: Characteristics of wool fibres from broken mouthed mules

Sample No.	Greasy Weight (g)	Clean Weight (g)	Dirt Content (g)	Mean Length (mm)	Mean Fibre Diameter (mm)
1	2.6	2.4	0.2	62.45	0.34
2	2.5	2.3	0.2	50.65	0.42
3	2.6	2.3	0.3	81.95	0.40
4	2.2	2.0	0.2	60.00	0.34
5	2.3	2.1	0.2	68.20	0.34

The Pearson correlation for greasy weight and clean weight gives a significant value of 0.990 whereas the correlation of length and diameter only gives a value of 0.107. However, the p-value for greasy and clean weight is p=0.000 whereas the p-value for length and diameter is p=0.536. This shows a stronger linear association for greasy and clean weight than length and diameter due to the Pearson correlation being nearer to 1 than that of length and diameter. However, due to the clean weight being obtained after washing the wool after to the measurement of greasy weight, the data may not be hugely significant.

Discussion

Following an investigation, a significant difference was found only with the length of the wool fibres in relation to age. The mean length of the wool fibres decreased with an increase in age, as shown by the graph in Figure 1. The decrease of fibre length as age increased is possibly due to the fact that sheep of 1 to 3 years old (2 tooth to 6 tooth) use their energy during pregnancy for foetal growth, lactation, and their own nutrition **–** wool growth is likely to be 'put on hold' during pregnancy and the suckling stage.

Seasonal variations could possibly be another factor for these results. It is reported by Ryder (1968) that wool grown in the summer is usually coarser and longer than wool grown in winter, due to changes in light and temperature. It is believed that dilation of the blood vessels in the skin is caused by higher temperatures, thus increasing the flow of nutrients to the follicles, causing increased wool production that is longer and coarser than in winter. This was previously studied by Ferguson *et al* (1949), who found that even on a constant diet, sheep will have changes in their wool growth with seasonal changes such as temperature; proving that Ryder was right by saying that poor nutrition during winter is a contributing factor. Siddiqui *et al* (2001) support these findings by showing that growth of wool increased; but length and diameter did not, in response to changes in diet composition.

Wool follicles and their glands are nourished by the blood system in sheep. A higher temperature increases the flow of nutrients to the follicles, dilating the blood vessels and influencing the growth of the wool. Sheep are generally shorn in warm, sunny weather due to the belief that the wool rises in warm weather and the sebaceous sweat glands produce a fluid known commonly as 'yolk' (Goodwin, 1979). Sheep in Southern England are generally shorn in late May to early June for this reason. The wool samples for this research were taken in November 2008, in relatively cold weather. The weather could have been an influence on the lack of significant differences in the characteristics; clean weight, greasy weight, dirt content and diameter, due to the wool not having grown in copious amounts since it was last shorn.

According to Black (1990), when individual fibres of a fleece lose their natural crimp and become straight, stiff and wire-like, this is an indication of lowered blood copper. Zinc also has a relationship with wool, along with skin, hair and feathers. (Black, 1990) Poor nutrition during the winter could also have been a factor on the results obtained. Another factor that affects wool growth and could have had an effect on the results is the frequency of shearing. McGregor & Butler (2008) showed the effects of shearing frequency on the fleeces of Angora goats, where increasing the frequency of shearing resulted in "linear changes in most fleece attributes".

Conclusion

This study has found that out of clean weight, greasy weight, dirt content, length and diameter, only the length of wool fibres differs with age in mule sheep (p=0.05). No significant differences were found for clean weight (p=0.591), greasy weight (p=0.787), dirt content (p=0.903) or diameter (p=0.771). A strong linear association was found between greasy weight and clean weight (Pearson Correlation value of 0.990) but not for length and diameter (Pearson Correlation value of 0.107).

To improve the research, further study could be undertaken including a higher number of sheep from the age groups 2 tooth, 4 tooth, 8 tooth and broken mouthed. This would give a fairer estimation of the differences in characteristics of the wool fibres in mules of different ages. For example, 20 samples could be obtained from each age group, and their characteristics measured as done in this study. The same statistics could be used, but more accurate p-values and Pearson Correlation values would possibly be obtained.

Another way to improve on this research method would be on the washing and drying process. Ryder (1968) recommends washing a handful of wool inside a net bag in four different tubs with decreasing volumes of detergents and washing soda, decreasing temperature, and a constant volume of water. The wool is then spin dried for 3 to 5 minutes and then spread out in an oven to dry at 100 °c for 2 hours. Ryder also recommends that samples be weighed when dry in an airtight container if possible. This prevents moisture uptake from the atmosphere being included in the measurements of clean weight. For even more accurate measurements, the sample could be weighed in a humidity cabinet or a room kept at 20 °c at a relative humidity of 65 % (Ryder, 1968).

Other factors that could have affected the results are when the sheep were last shorn and frequency of shearing. The diet of the sheep would also have been a major factor in the results obtained. As reported by McGregor & Butler (2008), Siddiqui *et al* (2001) and Ferguson *et al* (1949) shearing and diet are major factors in the growth and quality of wool fibres.

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