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# A REVIEW ON SOME FACTORS AFFECTING WOOL QUALITY PARAMETERS OF SHEEP

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**ABSTRACT**

Wool is a natural fibre with a unique amalgamation of properties that are exploited in garment industry. The wool industry, in particular the production of fine wool, has a notable role in world trade and the price of the wool is dependent on quality. Accordingly, wool characteristics have direct impact on wool prices set by processors and industry. These properties can particularly benefit the wearer of the garment during exercise. There are different factors affecting wool quality parameters both with direct and indirect involvement. The environmental and genetics are the main factors affecting quality and quantity of wool from sheep. Infections related to skin and parasitic infestations have direct influence on the quality of wool. Breed or genotype is one of the main genetic factors that influences the product and productivity as well as quality of wool from sheep that is fleece from different sheep breeds is different in its both physical and chemical characteristics. Hormonal changes in relation to sex of sheep also have effect on the wool quality traits. The main objective of this review was to define and explore key wool characteristics, such as staple length, number of crimp, fibre type, fibre diameter, wool wax and scouring yield in regards to quality and interventions approaches for improving. In most of studies, non-genetic factors such as age, season, shearing period, shearing frequency and nutrition have a significant effect on traits *viz.* staple length, wool wax, scouring yield, fibre diameter and for other traits as well. Conducting a research on wool quality characteristics is an operative way of defining and differentiating the quality of wool. Acquiring knowledge of the wool quality characteristics can help to manage the end use products, consumers comfort and processing intensity. Therefore, an understanding of the factors affecting physical and chemical properties of wool traits is important to improve the quality of wool through genetics and management interventions. This article reviews some important quality attributes of wool for the product and productivity development and value addition.

**Key words:** Fibre diameter, Selection Strategies, Scouring, Staple crimp, Staple length, Wool

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## INTRODUCTION

Wool is an extremely complex protein, evolved over millions of years for the protection of some animals in a great variety of climates and conditions. Wool is produced in the fibre follicle in the skin of the sheep. The differences in wool fibre can be due to the effect of variations in diet, species, breeds and health status of sheep as well as climate change. The wool fibres vary greatly in physical properties *viz.* staple length, number of crimp, fibre type, and fibre diameter as well as on chemical properties like scouring yield and wool wax [1]. It is a versatile product in demand mainly because of its physical characteristics that directly influence wearer comfort [1], processing performance, durability [2] and textile attributes [3].

Processing performance of wool is particularly important as wool buyers explore means of limiting production costs by improving efficiency and profitability through preferential utilization of wool that requires less processing. Physical characteristics of wool differ depending on the genetics, environment and management strategies. These factors are the roots for the differences in quality of wool products which have been producing all over the world [3]. Wool value is intrinsically linked to its characteristics and the ability to meet commercially pre-determined parameters[4]. Routine evaluation and quantification of wool characteristics is undertaken to permit quality and price differentiation at the market level [5].

Wool from sheep and various specialized breeds of livestock *viz.* goats, rabbits, camels and alpacas are often used to manufacture apparel, carpets, draperies, upholstery and blankets besides several industrial uses as insulators for incubators [6]. Coarse quality wool like fleece from Menz sheep [7] can also be used to produce thick fabric for covering floor, hangings arranged in folds and also to produce woolen sheet used as a bed covering, felted products used in saddlery and also as coarse blankets for equines and canines [6]. Hand bags and wall decorations are also some of the items produced from fleece of sheep [6]. The people living in Ethiopia around North Showa and parts of Wollo Zone traditionally spin the fibre of the Menz sheep and weave traditional blanket (Zitet or Banna). The sales proceeds from the woven carpets are a source of income, especially for women. The fleece is also used for weaving of cloaks (Bernos) and rugs [8].

The wool industry, in particular the production of fine wool, has a notable role in world trade because the price of the wool is dependent on quality [9]. The wool quality can be influenced by a variety of factors in a direct and indirect way. Generally, genetic and environmental factors influence the wool quality and quantity [10]. For instance, genotype of animal is an initial determinant factor for the differences in mean and range of diameters of fleece and which sets the size and synthetic capacity of follicles and also the non-genetic factors especially nutrition is responsible for further change in mean and range of the trait [11]. Providing improved nutrition to the animals almost always results in better wool production and increasing in mean diameter of the fibres [12]. Therefore, the objective of this study was to review and provide an insight into the genetic and non- genetic factors affecting some wool quality parameters.

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## FACTORS AFFECTING WOOL QUALITY PARAMETERS

### Non-genetic factors affecting wool quality

Several non-genetic factors such as; feed, shearing periods, housing of the sheep and quality of the grazing land can significantly affect the wool quality which thus influences the value of the fleece as a whole [13]. The fleece quality traits like average fibre diameter, spinning fineness, staple length, staple strength, fibre curvature/crimp and clean fleece yield are some of the parameters used to distinguish the wool quality and for differentiating the grade [14]. Physical characteristics (staple length, number of crimp, fibre diameter, fibre type and so on) of sheep wool are highly influenced by several environmental factors viz. seasons of shearing, nutrition, production system and other factors [3,15]. The feeding of the sheep determines the rate of wool growth [16]. However, the genotypes of the animals have their own effect on fleece quality and contribute to differentiate the value of the fleece, thus influencing the economics of the fleece itself [17]. For instance, the type of fibre production from two different genotypes of Menz and Merino Sheep are characterized by the coarse wool and fine wool production, respectively with the highest market interest of fibre from Merino Sheep breed [3, 10]. The entire characteristics of fibres are expressed by the wool quality and thus can further be quantified with regards to its processing performance and end use preference [4]. Biological and non-biological agents such as presence of microbes, urine (from the animal or the neighboring animals in the pens) and color of dipping solutions (for the control of ecto-parasites) are the main reason for the development of stains in the wool, besides some breeds tend to produce canary colored wool which is a result of the sweat and sunshine that leads to discoloration of the normal color of the wool [18]. Vegetable contamination and weathering of wool are some other common faults [18]. Fleece impurity is whichever naturally produced by the sheep itself (impure fibres, urine, dung, suint & wool wax), acquired from the environment viz. vegetable matter, mineral matter, animal matter, polypropylene, jute, strings, cigarette filters and others or applied paint brands, pesticides and medications on fleece before and post-harvesting depending on the conditions [19]. Some diseases such as fleece rot and mycotic dermatitis can also lead to damage of the fibres, which of course can influence the overall economics of the sheep farming [18]. The disease fleece rot and Mycotic dermatitis damage the fibre by formation of crust or scabs which bind the wool fibres firmly together. The mycotic dermatitis it characterized by highly variable incidence of infection and a consequence for loss of large income from wool [20]. Copper deficiency in sheep results in the formation of steely wool, diminishes the numbers of crimps and reduced tensile strength [21]. Shearing time and frequency of shearing have their own effect on the wool quality and most of the non-improved fleece producing breeds like Menz are thus shorn only once a year [2, 22]. However, shearing takes place twice annually in some localities of the world especially in globally recognized wool producing sheep breeds like Merino and Rambouillet. Timing of shearing (time and frequency) is one of the key administration judgments for a wool producer. These two choices have a substantial influence on wool quality and quantity produced by keepers as well as the well-being of sheep. The farmers have many different reasons for shearing at a particular time. According to study by Irving [23], as a first reason most of massive sheep farm managers/farmers for their shearing time were that when shearers were available and the second most widespread reason was a

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concern of higher flystrike risk in unshorn sheep run over summer. Time of shearing has been observed to affect staple strength, the location of weakness along the staple, fleece weight, yield and fibre diameter. It also can have important consequences for a flock's nutritional requirements and disease risk. A particular time of shearing that improves one aspect of wool production or animal management often undesirably affects another factor [23], Shearing Frequency is obviously affects the length of the wool staple. Wool processors generally prefer staple length to be between 60 and 90 millimetres. In an attempt to meet market requirements, some producers have altered shearing frequency, such as shearing three times every two years. Because, so many wool traits vary annually such as staple length, staple strength, position of break, vegetable matter and yield and it can make control of these factors difficult [24]. Moreover, according to Dyrmundsson [22], shearing sheep more frequently than once yearly may in some cases assist in increasing annual wool production and enhance the fleece quality.

**Genetic factors affecting wool fibre quality**

The rate of wool growth and the maximum rate at which fleece can be obtained from an animal and the variation in traits is basically influenced by the genotype of the animal, the values of which varies both within and between breeds [16]. Physical characteristics (staple length, crimp, fibre type and fibre diameter) are influenced largely on the genetic factors [3]. There are definite differences between breeds of sheep in the capacity to grow wool and in various fleece characteristics [16]. Thus, Merinos, which have a much greater follicle density than Down and Long wool sheep breeds, grow a similar mass of wool but more than the Down wool breeds. Likewise, within a breed, there is considerable variation in the rate of wool growth between strains and individual sheep [16]. Most of the fibre related traits are highly heritable and significant improvement can be made by selection for the desired characteristics. The heritability of wool traits such as greasy or clean wool weight, number of follicles per unit area of skin, secondary to primary follicle ratio, fibre diameter, staple length and crimp frequency vary between 0.3 to 0.6, however higher values for the traits have also been reported [13]. For instance, a study conducted by Malau-Aduli and Holman [25] found a significant interactions effect of sire genetics and nutrition for achieving the desirable spinning fineness of wool in Australian crossbred sheep. According to their findings, highly significant interactions between the sire breed (Texel, Coopworth, White Suffolk, East-Friesian and Dorset) × level of feeding (1 and 2% BW) ($P < 0.0043$) on SF that ranged from $22.7 \pm 0.16$ microns in White Suffolk-sired progeny to $25.1 \pm 0.21$ in East-Friesian crosses. Coopworth-sired sheep supplemented with either canola or lupins at 1% BW recorded the highest spinning fineness. There were significant correlations between SF (spinning fineness) and wool fibre diameter (0.93), CV of fibre diameter (−0.40), wool curvature (−0.12) and wool yield (0.10). This interaction effect of sire genetics and supplementary feed levels were used as a base for selecting a crossbred Australian sheep and the relationships among spinning fineness and other wool traits should be taken into account when designing breeding programmes [25].

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## PHYSICAL WOOL QUALITY PARAMETERS

***Staple length (SL)***

Wool quality and its value are globally determined by the staple length of the fibre [17, 18]. The trait is measured in millimeter (mm). Staple length is linked with fleece processing performance. Wool with long staple length are commercially preferable as they tend to be easier to spin, thus they give fewer stoppages and ultimately can form stronger and more even yarns in comparison to their shorter counterparts [26]. Staple length to a certain degree is influenced both by environmental and genetic factors [27], besides the age and genotype of the sheep [28, 29]. It is a function of the length of the individual fibre and the extent of crimping of the fibre. The trait is also correlated with the growth rate and the duration of growth. The variation if high for the trait is desirable among the carpet wool breeds but low variation is generally observed among the apparel grade wool where high variation is not desirable [30]. Growth of the staple is not uniform throughout the year and at certain times the growth can be high (corresponding to availability of feed) while at other times the reverse is true. Thus, in order to obtain a uniform SL shearing takes place biannually in sheep and much hair producing goat breeds [30]. Use of the end product that is whether it will be used in weaving or knitting too correlates with the SL needed to produce them [31]. Frequency and time of shearing also influences the SL [26] and study by Gelaye *et al.* [15] found that, the staple length of fibre is directly affected by time and frequency of shearing due to when the frequency and time of shearing increase the fibre gets time to grow well and resulted in the production of fibre having long staple length. The trait also varies between sexes with the values being lower among the ewes. The supply of nutrients available to wool follicles during the process of fibre growth may also be influence SL [32]. The SL of the lambs is low presumably due to competition for nutrients between follicles and other tissues responsible for their growth [33]. The values for SL of some sheep breeds are presented in Tables 1.

***Staple crimp/Fibre curvature (Number of Crimp)***

Staple crimp evaluates the fibre curvature or natural waviness of the fibre. The trait is evaluated as the number of crimps/waves per unit of length usually per inch [34]. The numbers of crimps usually vary from 1 to 30 per inch, depending on the degree of coarseness of the fibre [35]. Fine wools usually have higher numbers of crimps when compared to their coarse counterparts and crimpiness is correlated with the spinning capacity. A high crimped fibre produces a finer and stronger yarn with less wastage. Uniformity of crimp is associated with fineness and length, and is a sign of superior quality [33]. A study by Thiagarajan and Jayashankar [36] shows, breed, age, season of shearing and sex significantly influence the trait. As also indicated in a study by Yared [29] age and genotype of the sheep significantly influence the staple crimp. For instance, as the study indicates the number of crimp between pure Dorper and Arsi Bale Sheep breed was significantly different due to the genotypic differences for this specific traits and it is because of the fleece from Dorper sheep breed is more wooly comparing with the fleece from Arsi-Bale Sheep breed characterized with hair type of fibre [29]. This is because of the wool has several qualities that distinguish it from hair or fur: it is crimped, it has a different texture, it is elastic, and it grows in staples [37]. Contrary to the findings, Singh *et al*. [28] reported that, age of the sheep did not

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influence ($p<0.05$) the waviness of the wool in Corriedale and South down Sheep. A mineral deficiency such as of Zinc is reported to result in brittle wool and loss of crimp in sheep [38]. Tables (2) show the number of crimp values of some sheep breeds.

### *Fibre type*

The principal reason for the different fleece types is variation in the ratio of secondary to primary (S/P) follicle [39]. However, variation in the density or number of follicles per unit area of skin, arrangement of follicles in the skin and the relative size of the primary and secondary follicles also influence the fleece type. Generally, the fibre types recognized in adult sheep; are wool, hetero, hairy/kemp. Hetero and hairy/kemp fibre types are categorized under the medullated fibres [40]. Medullated fibre are characterized by a central canal containing cell residues and air pockets, running either as continuous or fragmented from along with their length [41]. While the wooly type of fibre is characterized by the absence of medulla [42]. Studies by Yared [28] indicated that both genotype and age of the sheep influenced the fibre type. The maximum rate at which an animal can produce wool/hair and range of variation are influenced by its genotype [16]. There are definite differences between breeds of sheep in the capacity to grow wool and in most of the fleece characteristics [16]. For instance, average proportion of wooly fibre type from Zandi sheep breed (93.7±1.9) is too much varying comparing with Garole sheep breed (18.78±1.85) in % (Table 3) and its good indicator as breed has direct significant effect on fibre type. Within a breed, there is considerable variation in the rate of wool growth between strains and individual sheep [16]. For example, average proportion of 18.78±1.85 and 28.0±1.12 percent of wooly fibre type were reported from Garole sheep breed (Table 3) and it indicates there is a variation in wool growth within breed. The percentages of different fibre types of selected sheep genotypes are presented in Table (3).

### *Fibre diameter (FD)*

Internationally the price of the fleece is determined by fibre diameter. The average width of a single cross section of fleece is called fibre diameter [43]. It is measured in millimicrons (μm) [5, 17]. Fineness of the fibre is correlated with the FD with which a yarn can be spun. The amount or weight of wool that can move through the processing machinery is influenced by the fibre diameter [3, 17]. As a result, finer wools can produce fabrics of characteristically light weight, soft, with superior handle and drape [17]. Genotype of the animal determines the average values and the range of different diameters in fleece, which because of the size of the follicles, and this trait is mainly influenced by genetic factors [10]. According to studies by Thiagarajan [27] and Yared [29] the age of the sheep positively influenced ($p<0.05$) the fibre diameter. In contrast, Singh *et al*. [28] revealed that the age of sheep do not affect fibre diameter of wool. Results of a study by Russel [32] indicated that the wool quality parameter that is fibre diameter is influenced by nutrition available to wool follicle during the process of fibre growth. Moreover, Sahoo and Soren [44] indicated that, sheep placed on a high plane of nutrition tend to have coarser fibre diameter when compared to that of the yearlings. Findings of a study by Reis [45] indicated that very high rates of wool growth could be obtained with moderate energy intakes. Energy frequently appears to be the main dietary factor correlated with wool growth. Length growth rate and diameter of fibres are improved with high energy diet. The observations of Chapman and Ward [12]


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indicated that, the nutrition which has dietary nutrients needs to provide for the sheep to obtain a good quality wool production and such fibres are of consistent diameter. The fibre diameter values for the wool trait of selected sheep breeds are presented in Table 4.

## CHEMICAL WOOL QUALITY PARAMETERS

### *Scouring yield (SY)*

The process of separation of dirt, grease and foreign matter from greasy wool is known as scouring [46]. Differences in grazing location, strains of foreign origin, quality of wool, time of shearing and sampling time are some sources influencing the scouring yield content [47]. Estimation of scouring yield is an important criterion for assessment of market price of the wool and this measure is used to determining the price of the greasy wool and it may be one of the oldest bases used for this purpose [47]. The estimation of scouring yield is carried out depending on the proportion of the weight of wool before and after scouring. As the study indicates, the total amount of contaminants present in greasy wool is around 35% to 40% of the total fleece weight [48]**.** The principal objectives of wool scouring are to remove all wool contaminants at maximum efficiency, with efficient energy utilisation and with minimum impact on the environment [49]. For instance, the colour of greasy Merino wool can vary from near white through to shades of cream and yellow, with intense yellow discolouration in greasy wool known as 'canary stain'. Yellow discolouration results from chemical reactions occurring within the fleece under the influence of moisture, temperature and bacterial activity. Due to moisture and bacterial activity at skin level inducing fleece rot, other discolourations can often occur. Discolouration can range from red, orange, pink, violet and blue as well as the more usual discolourations of yellow, grey, brown and green [50]. Frequency and time of shearing influences fleece characteristics, particularly by discoloration of the wool. However, double shearing of the sheep may help to minimize the same [51]. A study by Yared [29] showed that, genotype and age influenced the SY, respectively. The results were however, contradicted by the observation of Qureshi *et al*. [47] and Singh *et al*. [28] who indicated that, the genotype has no effect on the scouring yield. Moreover, results of studies by Qureshi *et al*. [47] indicated that the difference due to year of shearing and sex has no significant effect on the scouring yield. The wool wax and suint content are determined and expressed as a percentage of the clean dry wool and there is a moderate and negative correlation between the scouring yield and the wool wax [52]. The value presented in Table (5) indicates the scouring yield value of some sheep breeds.

### *Wool wax/Alcoholic extractable matter*

Wool grease and suint are secretions from the sebaceous and sudoriferous (suint) glands within the skin, which mingle, forming yolk in the follicle shafts and coat the developing fibre [52]. Studies by Daly and Carter [53] indicated, grease production and nutritional intake was positively related. Both nutritional intake and fleece weight are positively correlated to suint production [52]. Studies indicated that the rams produced more grease than ewes and there is reduction of grease content in wool of lambs from one month to 7or 10 months [54], which may be attributed to the physiological difference between the sheep. Wax yield is significantly influenced by year, as studied

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by Arora and Singh [55] in Merino and Dorset x Deccani. Similarly, Tomar *et al*. [56] and Arora and Singh [55] indicated that, season also has a significant effect on greasy fleece yield of Bharat Merino breed of sheep. Influence of non-genetic factors has also been reported by Tomar *et al*. [56]. According to Yared [29], there was a significant difference in the content of wool wax among different genotypes (Arsi Bale and their crosses with Dorper) and also the significant differences in wool wax from different age groups of Menz Sheep [7]. High wax content was also found to be a barrier to fleece rot [57] and *Dermatophilus dermatonomus* infection [54]. Sheep tolerant to these infections had higher wool wax content. Table (5) shows wool wax content of some sheep breeds.

## INTERVENTION TO IMPROVE THE QUALITY OF WOOL

### Selection Strategy

Genetic selection is one of the breeding programmes which can be used as an intervention method to improve the wool quality parameters [58]. Estimation of genetic parameters is one of the preliminary stages to start up an optimum design for selection programmes [59]. The estimated genetic parameters of wool quality traits revealed that, there is a substantial moderate to high direct genetic effect on the wool quality traits and consequently wool quality traits are very suitable and possible for employing genetic selection programmes for better genetic progress. However, the genetic correlations among wool traits as well as between wool and other production and or reproduction traits should be considered [9]. Most of the study indicates that the selection programme are currently depending on the wool quality trait and wool weight traits. Among wool quality trait, the fibre diameter, staple length, staple strength, standard deviation of fibre diameter, coefficient variation of fibre diameter, yield and crimp frequency are widely involving in selection programme and also greasy fleece weight and clean fleece weight are considered in selection program for wool weight traits [9]. The selection strategy is the means by which the breeding objective is achieved. While there is a range of strategies, all of them involve a comparison of the individual's performance relative to the average performance of the unselected group. The criteria used at selection to indicate the individual's performance should be genetically related to the traits in the breeding objective. These criteria may be direct or indirect indicators [60]. The study by Valera [61] indicated that selection based on only single wool trait was not an advisable strategy for better genetic progress of wool characteristics. The results also showed that, it is possible to improve wool and growth traits at the same time by considering a multiple wool traits in selection program as a best strategy [61].

### Improving the management

The quality of wool is influenced by several management factors viz. system of management, feeding, sampling period, season and methods of shearing are some of the determinant factors which can influence on the amount of clean fleece that can be obtained from the sheep and its quality [7]. For instance, proper wool growth requires all the important nutrients like amino acids, carbohydrates, minerals and vitamins, and providing adequate nutrition increases both the length and diameter of the wool fibre [32]. Generally, many physiological (pregnancy, reproduction, sex, and so on), and environmental (husbandry system, nutrition, housing) factors influence the quality and quantity of wool produced from sheep farms. These factors need to be managed to optimize wool production and quality. Among the management strategies - time of shearing, season of shearing, disease control, timing of cull sales, feeding, grazing management and reproduction management - are the factors need that to be improved for better wool quality [62]. Early spring is typically the time of year for sheep fibre shearing. This relieves the sheep of their year-old coats in time to keep them cool and comfortable, and gives them plenty of time to grow a coat that's long and heavy for the winter. Shearing may begin in March unless the weather is particularly mild, in which case producers sometimes begin shearing toward the end of February. Shearing timing has a lot to do with the lambing season, too. Shearing pregnant sheep about a month before their lambs are due encourages ewes to take shelter, so their lambs aren't born outside. Shearing also stimulates ewes to eat more just before lambing, which provides nutrients to ewe sheep and her lamb, establishes a more hygienic environment for the lamb to be born in, and clears the way for easy nursing once the lamb has arrived [63]. Therefore, improving the management practices of sheep husbandry is a possible strategy for better quality wool production [62]. In addition to these, post-harvest processing factors are a determinant factor of marketing price and the acceptability of the wool commodity in the market. Production of wool in the garment depends on the possible quality control of wool fibre after harvest. The quality of wool has a direct influence on the market value chain of wool production [64]. The possible post-harvesting process of wool are sorting, washing, carding and spinning. All these post-harvest processing steps are dependent on the quality of raw wool mainly on the proportion of impurities and diameter of wool [64].

## CONCLUSION

This review indicated that physical and chemical characteristics of wool quality parameters are dependent on both genetic and non-genetic factors. Nutrition, shearing frequency, shearing season/time, type of housing in which the sheep are living are the major non-genetic factors affecting the quality of wool production and in regarding to genetics; breed type and blood level of different crossbred sheep are the main factors for production different quality of wool. In addition to this, the physiological conditions viz. age, sex, pregnancy and mothering (feeding of lambs) are also other factors affecting the wool quality parameters. Thus, conducting research on wool quality characteristics is an operative way of defining and differentiating the quality of wool. Having knowledge of the wool quality characteristics can help to manage the end use products, consumers comfort and processing intensity. Accordingly, wool characteristics have direct impact on wool prices set by processors and industry. Therefore, understanding about the factors affecting physical and chemical properties of wool traits is important to improve the quality of wool through selection and management interventions. Among the selection strategies, the selection program based on the multiple wool traits are the advisable and recommended strategies for better product of wool traits in terms of quality and quantity. Production of wool in the garment is depending on the possible quality control of wool fibre and it determines the marketing price and the acceptability of the wool commodity in the market.

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**Table 1: Average staple length values of some sheep breeds in centimetre**

| Breed | Mean ± SE | Reference |
|---|---|---|
| Menz | 5.66±0.10 | [7] |
| Menz (Rams) | 6.22±0.39 | [7] |
| Menz (Ewes) | 5.07±0.19 | [7] |
| Bannur | 3.17 ± 0.06 | [36] |
| Corriedale X Bannur | 2.87 ± 0.06 | [36] |
| Corriedale | 4.75±0.16 | [28] |
| Poll Dorset | 4.04±0.51 | [28] |
| South Down | 2.80±0.27 | [28] |
| Arsi-Bale | 6.40±0.05 | [29] |
| Dorper | 2.28±0.05 | [29] |
| Dorper x Arsi Bale (50:50) | 4.12±0.06 | [29] |
| Dorper x Arsi Bale (75:25) | 3.33±0.07 | [29] |
| Balochi | 6.8±2.5 | [10] |
| Buchi | 7.1±1.3 | [10] |
| Lohi | 7.5±1.5 | [10] |
| Salt Range | 5.6±2.0 | [10] |
| Sipli | 7.4±1.8 | [10] |
| Poonchi | 7.89±0.67 | [47] |
| Poonchi X Rambouillet | 8.88±0.05 | [47] |
| Rambuillet | 9.00±0.48 | [47] |
| Hamadani | 11.9±1.77 | [65] |
| Mengali | 6.25±1.12 | [9] |

Source: Gelaye Gebisa [69]

**Table 2: Average number of crimp per inch of some sheep breeds**

| Breed | Mean ± SE | Reference |
|---|---|---|
| Menz | 3.82±0.05 | [7] |
| Menz (Rams) | 4.14±0.29 | [7] |
| Menz(Ewes) | 3.78±0.12 | [7] |
| Arsi Bale | 1.45 ± 0.06 | [29] |
| Corriedale | 2.89±0.08 | [28] |
| Dorper | 11.30 ± 0.06 | [29] |
| Dorper x Arsi Bale (50:50) | 5.64 ± 0.08 | [29] |
| Dorper x Arsi Bale (75:25) | 7.84 ± 0.07 | [29] |
| Garole | 2.21±0.04 | [66] |
| Hamadani | 1.65± 0.43 | [65] |
| Poll Dorset | 3.22±0.51 | [28] |
| South Down | 3.46±0.53 | [28] |

Source: Gelaye Gebisa [69]

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**Table 3: Fibre type (percentages of hairy, hetero and wooly) of some sheep breeds**

| Breed | Fibre type (Mean ± SE) | | | Reference |
|---|---|---|---|---|
| | Hairy | Hetero | Wooly | |
| Menz | 27.61±0.86 | 31.37±2.03 | 41.01±2.23 | [7] |
| Menz (Rams) | 25.83±2.87 | 37.17±10.53 | 37.00±10.22 | [7] |
| Menz (Ewes) | 28.29±1.92 | 31.00±4.63 | 40.71±5.46 | [7] |
| Afshari | 8.7±0.5 | 14.0±0.5 | 77.1±0.8 | [68] |
| Balouchi | 1.2±0.2 | 6.1±0.5 | 92.7±0.6 | [68] |
| Dorper | 18.15±1.64 | 34.00±1.09 | 65.36±0.59 | [29] |
| Dorper x Arsi Bale (50:50) | 22.35±1.52 | 20.35±1.45 | 57.38±0.55 | [29] |
| Dorper x Arsi Bale (75:25) | 18.15±1.64 | 34.00±1.09 | 65.36±0.59 | [29] |
| Garole | 59.0±2.0 | 13±0.88 | 28.0±1.12 | [66] |
| Hamadani | 59.4±4.37 | 1.1±0.66 | 36.7±5.14 | [65] |
| Lori | 1.0±0.5 | 7.4±1.1 | 91.6±1.5 | [68] |
| Mehrabani | 9.5±0.9 | 5.5±0.7 | 84.8±1.4 | [68] |
| Naeini | 4.38 | 5.93 | 89.53 | [68] |
| Zandi | 0.8±0.3 | 6.1±1.9 | 93.7±1.9 | [9] |

Source: Gelaye Gebisa [69]

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**Table 4: Average Fibre diameter in microns µm (wooly, hetero and hairy) of some sheep breeds**

| Breed | Fibre diameter (Mean ± SE) | | | | References |
|---|---|---|---|---|---|
| | Hairy | Hetero | Wooly | Mean | |
| Menz | 73.90±2.20 | 34.59±1.65 | 24.46±0.37 | | [7] |
| Menz (Ewes) | 89.38±4.55 | 40.74±4.87 | 26.54±0.70 | | [7] |
| Menz (Rams) | 61.68±5.10 | 31.68±5.00 | 25.97±1.22 | | [7] |
| Arsi Bale | 111.13±2.70 | 42.72±3.99 | 13.22±0.08 | | [29] |
| Bannur | - | - | - | 57.13 ± 0.30 | [27] |
| Corriedale | - | - | - | 26.30±0.55 | [28] |
| Dorper | 128.12±2.88 | 108.98±4.26 | 25.65±0.08 | | [29] |
| Dorper x Arsi Bale (50:50) | 111.71±3.78 | 69.26±5.59 | 18.71±0.11 | | [29] |
| Dorper x Arsi Bale (75:25) | 132.75±4.06 | 92.80±6.01 | 21.61±0.12 | | [29] |
| Garole | 127.45±8.05 | 71.6±6.05 | 36±4.85 | 78.35±6.32 | [66] |
| Garole(ewe) | 121.5 ± 7.2 | 83.0 ± 5.9 | 31.2 ± 4.3 | | [66] |
| Garole(ram) | 133.4 ± 8.9 | 60.2 ± 6.2 | 40.8 ± 5.4 | | [66] |
| Hamadani | - | - | - | 37.2±1.62 | [65] |
| Hamadani(ewe) | | | | 37.2±1.59 | [65] |
| Hamadani(ram) | | | | 37.8±1.88 | [65] |
| Mehrabani | | | | 42.1±1.2 | [67] |
| Poll Dorset | - | - | - | 25.18±1.28 | [28] |
| Poonchi | | | | 27.93±0.58 | [47] |
| Poonchi x Rambouillet | | | | 26.36±0.83 | [47] |
| Rambouillet | | | | 20.02±0.66 | [47] |
| South Down | - | - | - | 20.64±0.60 | [28] |

Source: Gelaye Gebisa [69]

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**Table 5: Scouring yield and wool wax of some breeds of sheep**

| Breed | Chemical quality parameters | | Reference |
|---|---|---|---|
| | SY(Mean ± SE) | WW(Mean ± SE) | |
| Menz | 68.68±0.74 | 8.47±0.18 | [7] |
| Menz (Rams) | 62.56±1.81 | 10.91±0.56 | [7] |
| Menz (Ewes) | 64.99±1.40 | 9.72±0.27 | [7] |
| Afshari | 64.4±1 | | [67] |
| Arsi-Bale sheep | 58.69±0.09 | 6.86±0.08 | [29] |
| Balouchi | 75.6±1.3 | | [67] |
| Dorper | 70.84±0.10 | 13.87±0.07 | [29] |
| Dorper x Arsi Bale Sheep (50:50) | 64.72±0.11 | 9.45±0.10 | [29] |
| Dorper x Arsi Bale Sheep (75:25) | 67.73±0.13 | 10.96±0.11 | [29] |
| Garole | 84.6±3.0 | 5.86±1.6 | [66] |
| Lori | 74.0±1.8 | | [67] |
| Mehrabani | 76.5±1.3 | | [67] |
| Poonchi | 71.08 ±0.37 | | [47] |
| Poonchi x Rambuillet | 68.14±0.60 | | [47] |
| Rambuillet | 69.78 ±0.52 | | [47] |
| Zandi | 63.2±1.6 | | [67] |

WW= Wool Wax, SY= Scouring Yield. Source: Gelaye Gebisa [69]

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