**CHAPTER 12: WOOL SCIENCE AND TECHNOLOGY**

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**Terminologies**

* **Apparel Wool:** Suitable for clothing fabrics.
* **Blood:** Denotes fineness; "more blood" means finer wool.
* **Braid:** Long, coarse, lustrous wool.
* **Breech Wool:** Coarse hair on lower hind legs, lowest quality.
* **Burr**: Vegetable matter present in wool is known as burr.
* **Carbonization:** The process of chemical treatment of wool, removing burrs with sulfuric acid.
* **Carpet:** Coarse wool for carpets, rugs.
* **Cotted:** Matted fibers.
* **Cotty wool:** This type of wool is obtained from animals grazing in barren and rocky pastures, representing a poor-grade wool that tends to be matted or felted.
* **Count:** It is an index of thickness or diameter of yarn.
* **Crimp:** Natural waviness in fibers; distinct crimp, fine wools have more.
* **Dead wool:** Wool sourced from deceased animals, resulting in a lower grade.
* **Fellmongering:** The process of removal of wool fibres from sheep skin through use of chemical applications (sodium sulphide) or administration (10-14 mg of thallium) for artificial moult in sheep 10-16 days post administration.
* **Felting:** It is defined as the ability of textile material to undergo irreversible increase in bulk density when subjected to friction and pressure under suitable physical conditions.
* **Fibre Length**: Length of the fibre in stretched condition.
* **Fibrion:** Silk protein is known as fibrion.
* **Fleece Wool:** Single sheep's shorn grease wool.
* **Fur/Hair:** Referring to non-human hair, this term is occasionally used to describe an animal's body hair as a complete coat, also known as pelage. Structurally similar to hair, fur comprises a cuticle, cortex, and medulla.
* **Greasy wool:** Shorn wool with grease and wax etc. before removal of impurities.
* **Handle:** It is measure of fine-ness. A subjective assessment of diameter of hair with respect to its tactile qualities. Feel of wool; softness, fineness, length.
* **Hank:** It is a definite length of yarn or thread which is measure of quality of wool in worsted system. 560-yard wool yarn unit.
* **Hogget wool:** Wool obtained from sheep aged 12 to 14 months during their first shearing is known as hogget wool. This wool displays fine, soft, resilient, and mature fibers, possessing good strength suitable for use in warps.
* **Kemp:** A coarse and brittle wool fibre. It has an irregular medulla, Chalky, weak fiber; undesirable.
* **Keratin:** The wool protein is known as keratin. It contains sulphur.
* **Keratinization:** Hardening of previously soft plastic fibrous protein.
* **Lamb’s wool:** The initial fleece sheared from a lamb aged approximately 6 to 8 months is referred to as lamb's wool or first clip wool. This type of wool boasts exceptional fineness and incredibly soft fibers.
* **Lanolin/ Wool wax:** Refined yolk or wool grease. Secretions of the sebaceous glands of the skin.
* **Lea:** It is a measure of length and is 1/7 th of Hank. 1 Lea- 1000 grains & 1 Hank- 7 Lea.
* **Lock:** A group of fibres clinging together in fleece.
* **Mohair:** Derived from Angora goats, mohair is a natural fiber with a diameter ranging from approximately 25 to 45 microns. Renowned for its resilience and durability, mohair exhibits a high lustre and sheen. Unlike wool, it possesses scales that are underdeveloped, preventing it from felting. Similar to wool, mohair does not contain a medulla.
* **New wool/Virgin wool:** Wool that has not undergone previous manufacturing processes is termed new wool or virgin wool. It may encompass pulled, dead, or other varieties of wool that could be of inferior quality.
* **Noils:** Short, defective fibers from combing.
* **Pelt:** Sheep skin with wool.
* **Pulled wool:** Wool obtained from slaughtered animals, characterized by its inferior quality, with the roots of fibers typically damaged.
* **Raw Wool:** Grease wool before scouring.
* **Recycle wool:** Old woolen items are disassembled to obtain wool fibers, which are then transformed back into yarn through the recycling process.
* **Reprocessed wool:** Wool that undergoes remanufacturing from unused wool materials.
* **Rooing:** Plucking of fleece of indigenous sheep having double coat under going partial moult or loosening of the fibre.
* **Scale:** A cuticle of flattened cells protecting the cortex of fibres.
* **Scouring:** Washing treatment of wool with detergent (sodium carbonate) or removal of impurities from raw wool to obtain clean wool yield.
* **Second Cuts:** Short pieces from previous shear stroke.
* **Secondary/ Primary Ratio**: It is the ration of secondary to primary follicle obtained by dividing the total number of secondaries by total number of primaries in a unit area of skin.
* **Shearing/ Clipping:** Removal of fleece from the body of sheep either with a pair of scissors or by electric shearers.
* **Skirting:** Removal of objectionable parts and stains from body of fleece after shearing.
* **Sorting:** Classifying wool within a fleece.
* **Staple Length:** Length of a wool fibre without disturbing its natural waviness.
* **Suint:** Secretions of the sudoriferous glands of the skin. It is mostly alkaline in nature having potassium salts.
* **Sweating:** The process of removal of wool by bacterial digestion of pre-keratinous region of fibre root or by application of depilatory agent to the under surface of pelt.
* **Tag locks:** The torn, ragged, or discolored portions of a fleece are referred to as tag locks.
* **Virgin Wool:** Used for fabric first time; not reprocessed.
* **Warp:** The longitudinal section of fabrics which is arranged in a sheety form for the purpose of interlacing with the longitudinal section of the fabrics in a particular mode.
* **Weaving:** The technology in which two series of threads are used to produce a fabric running longitudinally and the other lattidinally.
* **Wether wool:** Wool derived from sheep older than 14 months, often containing soil and dust.
* **Wool Yolk:** Wool wax with suint- a water soluble material in raw wool is known as yolk. It is more in finer wool and increases in winters
* **Wool:** A naturally occurring, cylindrical animal fiber known for its hygroscopic properties, crimped texture, elasticity, and cluster growth. Composed primarily of proteins, wool is non-inflammable and lacks a medulla, consisting structurally of a cortex and cuticle.

**Refresher points**

* Wool is categorized into **fine, medium, and coarse types** based on fiber diameter, with **Australia** being the top producer globally.
* Australia produces **641.0 M kg** of wool annually, followed by **New Zealand with 190 M kg** and **China with 160 M kg**.
* India's raw wool production remains constant at **40-55 m kg**, primarily used for apparel, carpet, and other textiles.
* **Australia dominates apparel wool production**, contributing 90% of fine-grade wool used in the sector.
* **New Zealand leads in carpet wool production**, contributing 47.9% of total world wool, mainly for carpets and furnishings.
* Other wools like camel, goat, mohair, and Pashmina have unique applications, with small quantities but significant impact.
* Major wool exporters include **Australia, New Zealand, South Africa, Argentina, and Uruguay**.
* **China, Japan, France, and UK are prominent wool importers**, with China and Japan importing around 30% of raw wool.
* India has diverse sheep breeds producing wool of varying fineness **(25-60 μ)** and primarily uses wool for **carpets and textiles**.
* India produces about **45 M kg of raw wool**, with **5% apparel grade**, **85% carpet grade**, and **10% coarse grade (2007)**.
* Raw wool production in India for the year 2022-23 was **41 thousand tonnes**, valued at **1003 crores** (2023).
* **Khadi sector and village industries utilize 15 m kg of wool**, while organized sectors and carpet industries also consume raw wool.
* **Jammu and Kashmir, Jaipur-Agra-Gwalior, Bhadohi-Mirzapur, and Warangal-Eleru** are **major carpet production** regions in India.
* Apparel wool breeds include **Hissardale, Nilgiri, Kashmir Merino, and Bharat Merino**, which are crossbreeds of native and exotic fine wool/dual-purpose breeds.
* **Hissardale** breed originated from **Australian Merino rams crossed with Bikaneri (Magra) ewes**, with about 75% exotic inheritance.
* **Nilgiri breed**, from the 19th century, has crossbred origins and uncertain ancestry, medium-sized with convex face, and improvements were achieved through **Rambouillet and Russian merino crosses**.
* **Kashmir Merino** breed comes from crosses of **various Merino types with native breeds like Gaddi, Bhakarwal, and Poonchi**, with variable inheritance levels.
* **Bharat Merino** sheep developed from **Chokla and Nali sheep crossbred with Rambouillet and Merino rams**, stabilized at 75% exotic inheritance.
* **Bharat Merino's** annual greasy wool production is 2.5 kg, with a **fiber diameter of 19-20 microns**, and it's distributed to Kolar District, Karnataka, and Tamil Nadu areas.
* Superior carpet wool breeds include **Chokla, Nali, Marwari, Magra, Jaisalmeri, Pugal, Patanwadi, Tibetan, Bonpala, Gaddi, Rampur Bushair, Poonchi, Karnah, Gurez, and Changthangi**.
* **Chokla sheep**, mainly found in Rajasthan, have fine carpet wool quality with a **range of 54s to 60s count** and greasy fleece yields of 0.940 kg to 2.39 kg.
* **Magra sheep**, distributed in Rajasthan, have medium carpet quality wool, and greasy fleece yields of 0.912 kg to 2.071 kg, with a fiber diameter of 32.55μ and **staple length of 4.2 to 6.8cm**.
* **Marwari sheep**, found in Rajasthan and Gujarat, have white fleece of medium carpet quality, with greasy fleece yields of 607.16g to 631.25g, and **average fiber diameter of 31.9μ**.
* **Nali sheep**, present in Rajasthan and Haryana, yield coarse, dense, and long-stapled white fleece, with greasy fleece yields of 1.01 kg to 2.84 kg and a **fiber diameter of 29.89μ**.
* **Jaisalmeri sheep, located in Rajasthan**, have medium carpet quality fleece, with a white coat and characteristic Roman nose.
* **Pugal sheep in Rajasthan** have black faces with small light brown stripes, yielding a white fleece.
* **Patanwadi sheep in Gujarat** come in non-migratory, migratory, and meat strains, with distinct wool qualities and body characteristics.
* **Gaddi sheep are distributed across Jammu & Kashmir, Himachal Pradesh, and Uttarakhand**, with medium size and various coat colors.
* **Avikalin sheep, developed from Rambouillet x Malpura halfbred base**, produce 1.75 kg greasy wool with 27 microns diameter, 27% medullation, and 4.75 cm staple length, suitable for **carpet wool** and mutton production.
* Coarse carpet wool breeds **include Malpura, Sonadi, Kheri, Muzaffarnagri, Jalauni, Deccani, Bellary, Coimbatore, Chhotanagpuri, Balangiri, Ganjam, Bhakharwal, and Shahabadi.**
* **Malpura sheep, found in Rajasthan**, have coarse and hairy white fleece, with greasy fleece yields of 551g to 810g and an average fiber diameter of 41.67μ.
* **Sonadi sheep, located in Rajasthan and Gujarat**, have white fleece that is coarse and hairy, with greasy fleece yields of 528g to 417g.
* **Muzaffarnagri sheep, distributed in Uttar Pradesh**, have white and open coarse fleece, with greasy fleece yields and body weights varying under farm conditions.
* **Deccani sheep, present in central peninsular regions of India**, have predominantly black or black with white markings, coarse and open fleece, and varying color patterns.
* **Coimbatore sheep in Tamil Nadu** have white fleece with black or brown spots, coarse and hairy, open fleece, with average 6-monthly greasy fleece weight of 365g and fiber diameter of 41 microns.
* **Shearing** is the process of removing wool from sheep, done by hand or machine.
* Hand shearing is slower (15-20 fine wool or 30-40 coarse wool sheep/day) but gentler.
* Machine shearing is faster (70-80 sheep/day), but improper use can lead to injuries.
* In India, shearing is typically done twice a year: Feb/March and Sept/Oct.
* Three methods of shearing sheep: hand shearing, mechanical shearing using power-operated machines, and chemical shearing.
* Hand shearing variations: along the sheep (long furrow from jaw to crutch), around the sheep (circular strokes).
* Advantages of hand shearing: local availability of shearers, neat wool.
* Disadvantages of hand shearing: uneven shearing, double cuts, reduced staple length, labor-intensive, less efficient, uneven fleece.
* Mechanical shearing with machines: driven by electric motor, comb and cutters, good results with proper adjustments and lubrication.
* Advantages of machine shearing: faster, even cuts, smooth and economical, universally followed.
* Disadvantage of machine shearing: potential for major cuts or wounds.
* Chemical shearing process: using **Cyclophosphamide (CPA)**, wool removed after drug administration.
* Comparison of machine and hand shearing: machine costs, abrasion issues, fleece yield differences, machine ownership feasibility, electricity availability.
* **Wool types:** fine for apparel, medium and coarse for carpets.
* **Morphology:** cuticle layer with scales, cortex with three cell types (ortho, para, meso).
* Cortex's influence on wool characteristics: ortho cortex more reactive to dyes.
* Medulla present in some wools: air-filled cells or hollow tube.
* Different medulla types: absent, fragmented, unbroken, heavily medullated.
* Wool lipid content: 0.8-1.0%, mainly cholesterol sulphate.
* Two classes of polar lipids: insoluble non-swelling (free fatty acid, cholesterol), insoluble swelling (cerebroside).
* Wool's chemical structure: belongs to keratin family, high sulfur content, disulfide bonds due to cystine.
* Amino acid composition varies by breed, species, nutrition, weathering.
* Key amino acids: cystine, methionine, serene, tyrosine, tryptophan, aniline, phenylalanine, histidine, valine, leucine, isoleucine, proline.
* Reduction of keratin yields three SCMK (S-Carboxyl Methylene Keratin) fractions with varying sulfur content and molecular weights.
* Low sulfur fraction (SCMKA) contributes to helix formation, high sulfur fraction (SCMKB) rich in cystine, proline, serine, threonine.
* High-glycine tyrosine proteins (HGT) from non-helical parts, varying in different keratin types.

**Physical and chemical properties of wool**

* Fiber Fineness:
* Influences 80% of product performance and quality.
* Affects spinnability, processing, and end-product attributes.
* Positive correlation between spinning quality and average fiber diameter.
* Varies across breeds and even within the same flock.
* Ranges from 16-17 mm in fine merino wool to over 40 mm in coarser types.
* Fiber Length:
* Important for wool quality and processing.
* Combined with diameter, determines spinning limit.
* Fine wool's length is 1.2-1.3 times staple length due to crimp.
* Indian wool has similar fiber and staple length due to low crimp.
* Fiber length varies from 55 mm to 200 mm.
* Fiber Crimp:
* Wavy form with twist adds bulkiness and warmth.
* Crimp results from ortho and para cortex arrangement.
* Fine merino wool has 21-30 crimps per inch.
* Coarse Indian wool has less than two crimps per cm.
* Influences yarn spinnability and product quality.
* Crimp wavelength decreases with increased fiber diameter.
* Typical wavelength: 2 μm for merino, 20 μm for Lincoln wool.
* Circularity Factor:
* Wool fiber cross section shape ranges from circular to oval.
* Contour ratio (major axis to minor axis) indicates shape.
* Higher ratio indicates deviation from circularity.
* Ellipticity factor around 1.22, slightly lower in finer wools.

**Physical Properties of Indian Wool:**

* Mean ranges for Indian wool properties: fineness (30-45 micron), staple length (50-70 mm), medullation (30-80%), burr content (2-5%), clean wool yield (60-80%).
* Most Indian wools lack crimp (less than five crimps per inch).
* Vary in color from lustrous white to iron gray.
* A crossbred type named Bharat merino exhibits properties similar to fine merino wool.
* Colour and Lustre:
* Wool color is generally white to light creamy due to disulphide bonds.
* Lustre, or light reflection, varies with origin, breed, and climate.
* High lustrous wools are sought after for carpets.
* Coarse wool possesses higher lustre than fine merino wool.
* Hygroscopic Nature:
* Wool absorbs about 30% of its weight in moisture without feeling wet.
* Moisture absorption depends on humidity and temperature.
* Merino wool's moisture regain at 63.3% RH is 13.97%.
* Indian wool absorbs less moisture than merino wool.
* Heat of Wetting:
* Wool gives off heat while absorbing moisture (heat of wetting).
* Wool has the highest heat of wetting among textile fibers (113 Joules/g).
* Heat evolved is proportional to moisture absorption.
* Resilience:
* Resiliency is wool's ability to recover after folding or creasing.
* Natural crimp in wool provides elasticity and resilience.
* Coarser wool generally has higher resiliency.
* Indian wool fibers are particularly resilient.
* Compressibility:
* Compressibility indicates wool's touch and feel.
* Low compressibility leads to a softer handle.
* Fine short wool fibers with higher crimp have lower resistance to compression.
* Frictional Properties:
* Friction plays a crucial role in processing and felting.
* Friction holds fibers in spun yarn and interlacing threads in fabric.
* Wool's scales affect frictional properties.
* Fine wools have higher friction forces than coarse wools.
* Stress-Strain Behavior:
* Wool's stress-strain behavior depends on temperature and humidity.
* Coarse wool is stronger than fine wool.
* Medullation in coarse wool influences stress-strain characteristics.
* Elasticity:
* Wool has excellent elastic recovery due to crimp and keratin configuration.
* Fine fibers are more elastic; medullated fibers have better recovery.
* Wool can stretch 25-30% of its natural length before breaking.
* Stress Relaxation:
* Wool fibers experience stress relaxation after stretching.
* Relaxation results from breaking and reformation of crosslinks.
* Tenacity:
* Wool is the weakest natural fiber with tenacity of 1 to 1.8 gm/denier.
* Strength decreases by 25% in wet conditions.

**Chemical Properties of Indian Wool:**

* Chemical processing involves treatments with various chemicals at different temperatures.
* Acids have less impact on wool strength compared to alkalis.
* Wool dissolves easily in alkaline solutions, especially at higher temperatures.

**Indian Wool Chemical Properties:**

* Indian wools have lower reactivity due to more paracortex, lower urea-bisulfite solubility.
* Prone to damage from alkaline suint; higher alkaline pH (7.1-10.5) in Indian wool.
* Autumn-clipped wool has higher pH than spring-clipped wool.
* Grease Content:
* Indian wool has lower grease content (4%) due to low secondary to primary follicle ratio.
* Scouring yield is higher due to inherent alkalinity.
* Common vegetable contamination in Indian wool (5-11%).
* Sulphur and Cystine Content:
* Indian wools have higher alpha and gamma keratose due to crosslinking.
* Indian wools have lower sulphur (2.8-3.1%) and cystine content.
* High lanthionine content (2-3.5%) due to alkaline suint action.
* Scale Pattern of Indian Wool:
* Indian wool has more scales per inch and higher scale height, but lower scale index.
* Different scale structures in Indian wool (flattened and reticulate) compared to fine wool.
* Scale index in non-medullated Indian wool is 0.5, while it's 0.85 in fine wool.
* Canary Colouration:
* Canary colored wools occur during autumn clip due to suint pigments and alkali migration.
* Damaged epicuticle allows suint pigments and alkali to migrate inside the fiber, causing yellowish coloration.
* Canary colored wools have high alkaline pH, low UB solubility, low cystine and sulfur content, and high lanthionine content.
* These wools are difficult to set during finishing processes and easily absorb smoke and toxins.
* Weakness of Indian Wool:
* Indian wool often contains hairy and kemp fibers that reduce its value and appearance.
* These fibers give a chalky white appearance and cause skittery appearance after dyeing.
* Coarse fibers in Indian wool have multiple scale structures.
* Canary colored Indian wools quickly pick up dye due to lack of epicuticle, but this color is light fugitive.
* **Contaminant Removal:** Wool processing involves thorough removal of contaminants like grease, dirt, and vegetable matter, which can affect the quality of the final product.
* **Scouring Efficiency:** Proper scouring ensures removal of grease and dirt while minimizing damage to the wool fibers.
* **Carbonizing Purpose:** Carbonizing eliminates vegetable matter through chemical and mechanical processes, enhancing the quality of wool.
* **Acidizing Effect:** Sulfuric acid in the carbonizing process chemically breaks down vegetable matter, but careful control is needed to prevent fiber damage.
* **Drying and Baking:** Controlled drying and baking stages during carbonizing eliminate moisture and brittle vegetable matter without harming wool fibers.
* **Burr-Crushing and De-Dusting:** Mechanical processing removes charred vegetable matter, which can otherwise lead to yarn breakages and speckiness in fabrics.
* **Neutralization:** After carbonizing, neutralizing with alkali removes residual acid, enhancing the fiber's condition and preventing damage.

**Wool Processing Overview:**

* Shorn wool is called fleece, containing oil and lanolin.
* Cleaning is necessary to remove vegetable matter, manure, and oil.
* Up to 50% of fleece weight may not be wool.

1. SKIRTING A FLEECE

* "Tags" or manure-filled wool from back, legs, belly are removed.
* Skirting removes edges, sorts fleece into fine, coarse, short, long types.
* Washing the wool
* Grease removal is crucial.
* Removal methods: soap/detergent with water or acid bath (scouring).
* Key issues: effective contaminant removal, insecticide residues, fiber suitability, entanglement reduction.
* Scouring Treatment:
* Aqueous process in bowls (4-6 stages).
* Water, soda, and surfactant used at pH 10-11 and moderate temps.
* Organic solvent options: per-chloroethane, dichloroethane.
* Combining water/iso-propanol/hexane for grease removal.
* Contaminant removal stages: penetration, swelling, dissolution, removal.
* Factors Affecting Scouring Performance:
* Open wool before scouring.
* Bowl design, number, detergent type, water quality.
* Immersion time, temperature, mechanical action, drying.
* Control mechanisms, squeeze presses, production rate.
* Recent Developments:
* Siroscour technology: optimized contaminant removal.
* Consideration of "Working Points" to minimize entanglement.
* Hybrid Scours combining suction-drums and rakes for superfine wool.
* Computer control for monitoring and adjusting operations.
* Scouring of Indian Coarse Wools:
* Indian wools (36S + 4) are open, less greasy.
* Immersion in lukewarm water, addition of detergent and soda, rinsing, and drying.

2. CARBONIZATION

* Removal of acquired vegetable matter.
* Pre-processing removes some, but mechanical processing is crucial.
* Carbonizing process involves scouring, acidizing, drying and baking, burr crushing, neutralizing.
* Acidizing:
* Sulphuric acid treatment to remove burrs.
* Cold/warm acid solution, protection with wetting agents.
* Drying and Baking:
* Moisture evaporation at 70°C.
* Concentrated sulphuric acid attacks burrs, care needed to prevent fiber damage.
* Second "Baker" dryer at 105°-110°C to char burrs.
* Burr-crushing and De-dusting:
* Crushing charred burrs using heavy rollers.
* Dedusting machine removes resulting dust.
* Neutralizing:
* Removal of residual acid content.
* Treatment with soda ash, mild scour, rinse, final drying.
* Recent Developments:
* Suction-drum technology in carbonizing process.
* Rapid-carbonizing process with shorter immersion times.

3. PICKING

* Teasing or picking opens wool locks, creating an even web.
* Wool is blown into a room while adding spinning oil to aid fibers' sliding and bonding.

4. CARDING

* Carding separates and straightens wool fibers for spinning.
* Metal teeth comb fibers into slivers, removing dirt and matter.
* Woollen cards produce random alignment, worsted aligns fibers.
* Carded wool for woollen yarn is directly spun, worsted wool is combed.

5. ROVING

* Carded web becomes pencil rovings, collected on spools for spinning.

6. SPINNING

* Roving without twist is held by oil and hooks on fibers' surface.
* Spinning frame adds twist, turning roving into yarn, collected on bobbins.

7. WIND and/or SKEINING

* Yarn-filled bobbins transferred to paper cones for weaving/knitting.
* Plain weave for woollen yarns, twill weave for worsted yarns, creating distinct fabrics.

8. FINISHING

* Yarn finishing varies, sometimes needing lubricant removal by washing.
* Washing sets twist, allowing fibers to open up, creating loftier yarn.
* Final products like cloth, socks, sweaters can be woven/knitted, then washed and blocked.

**Impurity of wool**

* 60% of raw wool consists of impurities; only 40% is usable wool.
* Impurities categorized into natural (suint, wool grease), acquired (soil, dust, burr), and applied (treatments, markings).
* Suint is water-soluble dried sheep perspiration; wool grease (lanolin) is water-insoluble.
* Acquired impurities from grazing include plant parts, burrs (hooked seeds), and galvanized burrs in drought.
* Applied impurities from treatments and markings on sheep.
* Greasy wool after shearing; scoured wool after impurity removal.
* Recovery of wool grease involves centrifugation; used in fuel, greases, leather softeners.
* Lanolin (refined wool grease) used in cosmetics, pharmaceuticals, industrial applications.
* Skirting: separating valuable wool from inferior, dirty, seedy, or hairy parts.
* Defects include hairiness, breaks due to factors like nutrition or disease, cotts (coarse fibers felting), lack of uniformity, impurities (vegetable, mineral, brands), degradation from parasitic diseases.

**Factors influencing quality of wool**

* Genetic and environmental factors influence wool quality and quantity.
* Bacterial, viral, fungal, and parasitic diseases affect wool.
* Wool traits like weight, follicle count, diameter, length, and crimp are heritable.
* Genotype sets wool production rate and quality variation.
* Different sheep breeds have distinct wool-growing capacities.
* Nutrition during fetal and early postnatal stages affects follicle development.
* Poor pregnancy nutrition reduces secondary follicle initiation.
* Adult nutrition (amino acids, sulfur, zinc, copper) influences wool growth.
* Hormones (growth hormone, pituitary, ACTH) impact wool quality.
* Age, sex, and reproduction affect wool production and quality.
* Exogenous chemicals (thallium, cortisol analogues) influence fiber growth.
* Parasites and diseases (internal, external) can reduce wool growth.
* Infections lead to damaged fibres, fleece rot, and mycotic dermatitis.

**English/British system has 12 different grades of wool.**

|  |  |  |
| --- | --- | --- |
| **Sl. No.** | **Grades** | **Characteristics** |
| 1 | Diamond wool | Finest white British wool, 1”-1.5” long |
| 2 | Pick | Less fine than diamond wool, about 1” long. |
| 3 | Extra-pick | Less fine than pick grade of wool, < 1” long. |
| 4 | Shafty | Pick teg wool with extra length |
| 5 | Super | Less fine wool of 4”-5” length |
| 6 | Half-bred | Wool coarser than super but 6”-7” long |
| 7 | Deep half-bred | Wool longer and coarser than half-bred |
| 8 | Lusture | Long curly wool with natural sheen |
| 9 | Roller | Lusture hogg wool, 12”-15” long. It is considered as a speciality grade |
| 10 | Cotts | Matted wool |
| 11 | Arable | Wool containing dusty soil |
| 12 | Cash | Fleece with bad faults |

**Table 12.1: American Blood System grades of wool**

|  |  |
| --- | --- |
| **Blood** | **Spinning Count** |
| Fine (Pure Merino). | 64’s and above. |
| 1/2 blood | 58-60’s |
| 3/8 blood | 56’s |
| 1/4 blood | 48-56’s |
| Low 1/4 blood | 44-46’s |
| Common | 40’s |
| Braid | 36’s |

**Table 12.2: The Indian Grading System**

|  |  |  |
| --- | --- | --- |
| **Grade** | **Spinning Count** | **Diameter (μm)** |
| Super A- Super-Fine Quality | > 58’s | < 25 microns |
| A - Fine wool Quality | 54-56’s | < 34.4 microns |
| B - Medium Wool Quality | 46-50’s | 34.4-37.4 microns |
| C - Strong Wool Quality | 40-44’s | 37.4-40.4 microns |
| D - Coarse Wool Quality | < 40’s | > 40.1 microns |

**Table 12.3: Wool Grading System of Indian Standard Institute (B.I.S.)**

|  |  |  |  |
| --- | --- | --- | --- |
| Category A | Fineness < 34.4 Microns | Length Above 75 mm, LB < 3.0%, | Colour White |
| Category B | Fineness 34.4-37.0 Microns | Length Below 75 mm, MB 3.0-5.0 %, | Colour Tinged White (TW) |
| Category C | Fineness 37.1-40 Microns | HB >5.0%, | Colour Light Yellow (LY) |
| Category D | Fineness > 40.1 Microns | HB >5.0%, | Colour Heavy Yellow (HY) |

**Table 12.4: Wool grading system (F.A.O.)**

|  |  |  |
| --- | --- | --- |
| **Code No** | **Style** | **Description** |
| 1 | Good | Wool with good colour, washed, skirted, light burr (0-3%) with reasonable quality and strength |
| 2 | Good Average | Wool having yellow colour, well skirted, light burr (0-3%) with reasonable quality and strength |
| 3 | Average | Wool of average washing, well skirted, Medium burr (3-6%) |
| 4 | Inferior | Wool of poor washed category, Heavy Burr content >6.0% |

*Followed in states like Punjab, Haryana, Jammu and Kashmir, Gujrat and Karnataka.*

**Table 12.5: Breeds of sheep developed in India.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Genotype with utility /location** | **Parent breeds** | | **Level of exotic inheritance (%)** |
| **Indigenous** | **Exotic** |
| Avikalin, for carpet wool CSWRI, Avikanagar | Malpura | Rambouillet | 50 |
| Avivastra, for fine wool CSWRI, Avikanagar | Chokla, Nali | Rambouillet, Russian Merino | 50 |
| Bharat Marinho for fine wool CSWRI Avikanagar | Chokla, Nali,  Malpura,  Jaiselmeri | Rambouillet,  Russian Merino | 75 |
| Hisardale, for apparel wool Haryana State | Bikaneri | Australian Merino | 75 |
| Kashmir Merino, for fine wool J & K State | Gaddi, Bhakarwal,  Poonchi | Delaine Merino  Rambouillet, Soviet Merino | 50-75 |
| Nilgiri Synthetic, for apparel wool TNVASU Sandynallah | Nilgiri | Rambouillet,  Soviet Merino | 62.5/75 |
| Patanwadi Synthetic, for carpet wool GAU, Dantiwada | Patanwadi | Rambouillet,  Soviet Merino | 50 |

**Table 12.6: Varieties of sheep across diverse agro-ecological zones in India and their primary yields.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Southern Peninsular** | **North-Western Arid and Semi Arid** | **North Temperate** | **Eastern** |
| Bellary (MCW) | Chokla (CW) | Bhakarwal (CW) | Balangir (MCW) |
| Coimbatore (MCW) | Hissardale (AW) | Bushair(CW) | Bonpala (MCW) |
| Daccani (M) | Jaisalmeri (MCW) | Changthangi (CW) | Chottanagpuri (MCW) |
| Hassan (M) | Jalauni (MCW) | Gaddi (CW) | Ganjam (MCW) |
| Kenguri (M) | Kheri (MCW) | Gurez (CW) | Garole (M) |
| Kilakarsal (M) | Magra (CW) | Karnah (AW) | Tibetan (CW) |
| Madras Red (M) | Malpura (MCW) | Kashmir |  |
| Mandya (M) | Marwari (MCW) | Merino(AW) |  |
| Mecheri (M) | Munjal(M) | Poonchi (CW) |  |
| Nellore (M) | Muzaffarnagari(MCW) | Rampur |  |
| Nilgiri (AW) | Nali (CW) |  |  |
| Rammand White (M) | Patanwadi (CW) |  |  |
| Tiruchy Black (M) | Pugal (MCW) |  |  |
| Vembur (M) | Sonadi (MCW) |  |  |

*Reference: Arora et al. 2007; (AW): Apparel wool; (CW): Carpet wool; (MCW): Mutton and Carpet wool; (M): Mutton*

**Table 12.7: Grading of wool (BIS)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Fineness Range (Diameter-μm)** | **Length** | **Burr** | **Colour** |
| Below 34.4 - A | Above 75 mm | LB-Below 3% (Light burr) | White |
| 34.4 to 37.0 - B | Below 75 rnm | MB-3 to 5 % (Medium burr) | Tinged White(TW) |
| 37.1 to 40 - C |  | HB-Above 5% (High burr) | Light Yellow(LY) |
| 40.1& above - D |  |  | Heavy Yellow(HY) |

**References:**  
1. Economic survey of the Government of India (2007)

2. CSWRI (Central Sheep and Wool Research Institute). 2023. Accessed on 15-08-2023 available at http://cswri.res.in/breed\_profiles.asp#:~:text=The%20average%20body%20weight%20of,25%20and%2030%20kg%2C%20respectively.

3. India Budget, 2023. Wool production statistics available at https://www.indiabudget.gov.in/economicsurvey/doc/Statistical-Appendix-in-English.pdf