Chapter 28
Quality Aspects of Cotton Lint

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Abstract Cotton is the key natural fibre used in the textile industry, the quality of which is extremely critical for successful processing. Many factors influence its fibre quality. The fibre quality of the open boll is affected by pre-harvesting and post-harvesting practices. Mature seed cotton is harvested and transferred to the ginning industry. The separation of fibres from the seed is the main goal of ginning. Besides varietal and environmental factors, the pre- and post-ginning practices decide the quality. The quality of cotton is determined by multiple measurements like fibre length, strength, micronaire, colour, trash, etc. These parameters play a necessary role in marketing.

This chapter deliberates all post-harvesting factors that affect quality like handling, storage, cleaning, ginning, operational health and safety and classification of cotton.

Keywords Fibre quality · Seed cotton · Ginning

Abbreviations

AFIS	Advanced fibre information system
FEC	Feeder-extractor-cleaner
GI	Galvanized iron
GOT	Ginning out-turn
HVI	High-volume instrument
LVI	Low-volume instrument
PCSI	Pakistan Cotton Standard Institute
USDA	United States Department of Agriculture

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28.1 Concept of Cotton Fibre Quality

Cotton is the backbone of the world's textile trade. Most of our everyday fabrics are made from cotton. It is a natural fibre mainly composed of cellulose which is the most abundant natural material present in wood (Usman et al. 2009; Ahmad et al. 2014, 2017, 2018; Abbas and Ahmad 2018; Ahmad and Raza 2014; Ali et al. 2011, 2013a, b, 2014a, b). It is seed hair, a single hyper-extended cell rising from the protodermal cells of the external integument layer of the seed coat. Cotton fibre development responds independently to variations in the micro- and macro-environments likewise with all living plant cells (Amin et al. 2017, 2018; Khan et al. 2004; Rahman et al. 2018; Tariq et al. 2017, 2018). Consequently, the fibres on a sole seed constitute diversities of cell wall thickness, fibre length, shape and physical maturity. Environmental variations inside the canopy of the plant and amongst distinct plants and within and amongst fields confirm that the population of fibre in each boll, definitely on each seed, incorporates an extensive range of fibre traits and that every single bale of cotton holds a highly variable fibre population. The cellulose contents of raw cotton vary from 88% to 96% of the dry weight. Scoured, bleached or dry cotton fabric is approximately 99% cellulose. The original quality and traits of the fibre are dependent primarily on the variety, environmental conditions during development and agronomical practices. When there is no weathering effect, the highest-quality fibre is obtained from fully mature and newly opened cotton bolls. The successful processing of lint depends on the proper management of highly variable fibre properties that have been proven to affect the quality and productivity of the finished product during and after the harvest. If fibre blending strategies and subsequent spinning and dyeing processes are to be optimized for specific end uses and profitability, textile mill managers need accurate and effective methods for descriptive and predictive quantitative measurement of these highly variable fibre properties. Fibre quality means approximately entirely changed for cotton growers and cotton processors. Growers or processors do not have contact to post-harvest mechanisms that improve the intrinsic fibre quality. Cotton quality has historically employed both visual and mechanical methods (Anthony and Mayfield 1994). Cotton quality characteristics, e.g. fibre length, fineness, micronaire value, strength and colour, have ever been influential in defining the values of fibre as discussed below.

28.1.1 Fibre Length

It is "the mean length by number of the longer one-half of the fibres, by weight, in sample". It is typically the measurement of longer fibres or most frequently occurring fibres. Fibre length differs with variety. The fibre length and distribution of length on seed are also influenced by the stresses throughout development of fibre as well as the mechanical processes at harvest and post-harvest. The length of the fibre

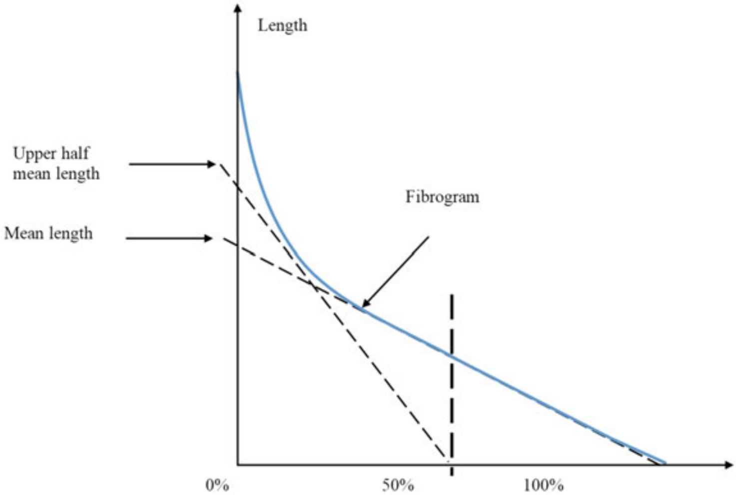

Fig. 28.1 Cotton fibre length measured by HVI

determines the spinning machine setting (Fig. 28.1). Longer fibres can take lower twist levels, have higher yarn strength and can be spun at higher processing speeds for more finer counts of yarn.

28.1.2 Fibre Strength

It is "the amount of force required to break a bundle of fibres, reported in grams force per tex". A tex is equivalent to mass in grams of one thousand metres of fibres. The capacity of cotton to survive tensile forces plays a vital role in spinning. Fabric and yarn strength are related to fibre strength.

28.1.3 Length Uniformity

It is "the ratio between the mean length and the upper half mean length of the fibres, expressed as a percentage". Variations in length result in increased processing waste and decline in process ability and quality of yarn.

28.1.4 Micronaire

"It is measurement of fibre fineness and maturity"; principle of air flow is used for the measurement. The linear density determines the amount of fibres required for the

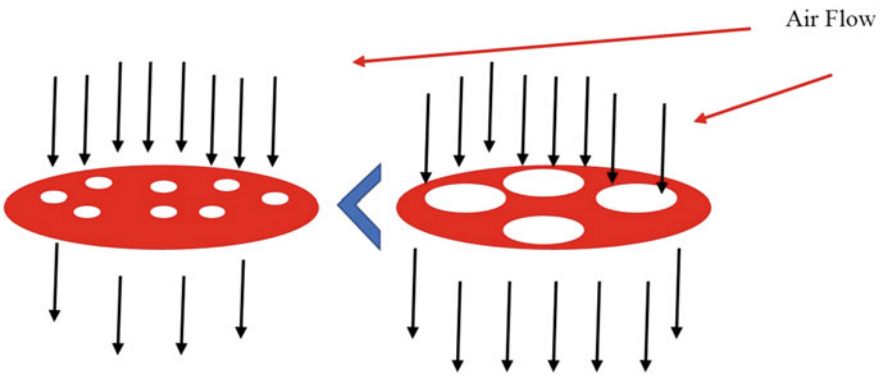

Fig. 28.2 Principle of micronaire measurement

cross section of the yarn to determine the spinnable count. Immature fibres are obtained in cotton with a low micronaire value. Cotton with a high micronaire value is taken as coarse (high linear density) which gives less fibres in yarn cross section (Fig. 28.2).

28.1.5 Colour Grade

The colour grade is ascertained by the degree of whiteness (Rd) and yellowness (+b). Reflectance specifies how dull or bright the cotton is and yellowness designates the degree of colour pigmentation. In addition to severe staining, cotton colour and "preparation" levels have no direct effect on processing capacity. Significant differences in colour can create problems in dyeing.

28.1.6 Trash %

It is the quantity of the non-lint constituents in cotton, such as bark and leaves from the cotton plant. Trash denotes to the portion of the plant that is added during the harvest and is then broken down into smaller portions during ginning process. Although it is easy to remove large particles, excessive trash leads to an increase in spinning waste. High dust levels can affect the rotor spinning efficiency and quality of the product. Grass and bark are tough to isolate from cotton fibres in mill.

28.2 Post-harvesting and Storage Management

Cotton is Pakistan's main cash income crop and its products are obtained in the shape of cottonseed and lint. The higher the market interest rate, the more the growers will be sought to maintain their quality and high standards. In fact, the grower has achieved the production target but forgot the quality steps. Pakistani cotton is genetically sustained and healthy. However, it belongs to the unclassified classification, including the use of incorrect methods for picking, processing and ginning, and there are always pricing issues depending on the quality of the seed cotton. This is why low-standard cotton enters the market.

Pakistani cotton is hand-picked, which should be done after 60% bolls are fully opened. The picking of cotton should be done after 10:00 am in the presence of sunlight when crop is fully dry from humidity and dew. The picking should be done variety-wise and it is necessary that picked seed cotton be labelled and reserved variety-wise and/or be sent to the ginning factory to sustain cottonseed and lint variety-wise.

The work of cotton picking is assigned mostly to female sects in the population, and they can easily complete work in a shorter period of time than male counterparts. Women have better picking skills, which is the main reason for saving time. Female cotton-picking personnel for training purposes should be carried out under the supervision of an expert or trained grower whilst standing in the crop to obtain clean cotton and maintain its standards. Women must be using cotton cloth to collect seed cotton, and materials made of any synthetic fibres must be avoided. However, in order to avoid impurities such as dust in the seed cotton, it should be sorted from the lower side to the top. This step leads to clean cotton picking.

Cotton picking should be carried out after the crop has been dry from dew. It is reported that during the picking period, the cotton crop may show dew due to the persistence of climatic conditions. Therefore, picking in early time may increase the probabilities of seed cotton adding humidity and dew. Dew-mixed cotton or lint that remains wet or damp when stored in a place causes damage to nearby lint and cottonseeds; lint quality and seed germination may be getting deteriorated. The ginning factories do not have facilities for cottonseed drying.

In the case of precipitation, seed cotton would not be picked instantly, but crops and seed cotton should be kept dry. Cotton should be picked when the seed cotton or lint is dried after exposure to air and sunlight. There is a risk of shower during picking, and in the case of rain, the fibres turn black and will get a low price. In fact, spoilage and impurities in seed cotton may occur due to serious damage caused by pests and diseases. This damage is largely determined by the production of cotton plants, such as cotton bolls, squares and flowers, which may rot immediately. Dark and rotten seed cotton appears when the boll is open. Therefore, seed cotton should be picked at the time of picking. Otherwise it will open and the empty boll will be picked and mixed with the lint as it is picked quickly. On several occasions, due to unskilled picking of cotton crop leaves, empty cotton bolls, leaves and stems, flowers, immature bolls, branches and weeds were mute by lint. These materials must not be left behind and mixed with cotton, but care should be taken to remove these impurities. The picking, storage and sale of such cotton or lint is at risk.

Weeds can cause difficulties when picking cotton from cotton bolls, and easy mixing can damage the quality of the lint. Cotton must be harvested in a timely manner and a second pick will be maintained after the first picking interval of 15–20. If picked before time, raw materials or immature fibres can be picked, which will be sold at a low price on the market. Agricultural experts recommend first picking on each planting. This seed can be highly germinated and does not contain many pests (including insects and diseases). However, cotton should not be picked early or late. In the case of early picking, a small fibre length with shrinkage quality will be obtained which will result in immature fibres and substandard fabrics; also fibres obtained from early-picked cotton bolls will immediately darken. Seeds obtained from early picking did not have any good quality in terms of low seed germination and low edible oil content. Irrigation water should be limited during picking to properly use the cotton boll, which helps to easily pick cotton and increase the strength of the cotton fibre.

For delayed picking, the quality of lint may be lost. Seed cotton may be lost for a long time, and continuous dew and air blowing through the dust on the cotton will change the colour of the lint. Fast winds may shed seed cotton or lint from open cotton bolls and may be one of the sources of reduced yield per acre. The cotton fibres selected in the later stage made the appearance dirty, reducing the fineness and lustre of the clothes. Because of lack of fibre strength in late-picked cotton, low-quality fibres may often be produced in textile and garment factories.

There is a growing trend for impurities or contamination during cotton picking, storage and transportation to the factory. Rural female folks engaged in cotton picking began picking before dew and humidity were dry. The reason behind this is to increase the weight and volume of the picked cotton in the case of dew or humidity, in order to achieve higher wages. There is a risk of directly affecting the quality of lint. This effect of dew or humidity can be traced when filling bales and storing lint. The second increasing trend in impurities and pollution in cotton lint may be rural women who use plastic bags and silk scarves to pick seed cotton. This type of contaminating impurities can occur during spinning and dyeing of fibres, threads and clothing.

The mixing of human hair during picking cotton creates problems in the ginning, spinning and weaving processes, which can cause losses to the textile industry. It is a drawback that the women put water into the harvested cotton at different time intervals to gain weight to get higher wages. This practice may undermine cotton and its quality, leading to low market prices.

Therefore, cotton must be saved from impurities and pollution when picking cotton after dew drying. This harvested cotton should not be stored on damp soil, but placed in a cloth bag and dry floor before being sent to the market or factory. If cotton is not treated immediately to the factory, then it is lying in an exposed place; in this case the cotton must be covered with cloth at night to avoid deterioration due to open air and moisture, but during the day the large cloth must be removed for proper sun exposure.

Many attributes affect the quality of seed cotton during storage. The most significant is the moisture content. Further these include time of storage, green matter, initial temperature of seed cotton, temperature of seed cotton, weather parameters (relative humidity, rainfall temperature) and protection from wet floor and rain. The findings provide useful guidance on how storage variables affect quality. These results clearly show that whilst it is not possible to accurately predict how stored variables affect quality, guidelines for safe, efficient storage are useful.

28.3 Handling and Heap Formation at Gin Yard

The collection of seed cotton from diverse regions is channeled by a cotton dealer to the ginning unit through different means of transportation, e.g. trolleys, trucks and animal carts. Cotton transport should be carried out in open trolleys covered with protective cotton, avoiding the use of polyproline, polyethylene and jute bags for cotton transport. The weighing of seed cotton is done initially on a factory-based weighing scale, and it is then passed through the factory gate and stored in the seed cotton storage yard. Some progressive units maintain internal laboratories to measure changes in the amount of lint (ginning out-turn, GOT), moisture percentage and impurities. Mostly the seed cotton quality is based on the experience of cotton selectors that do on-site qualitative valuation.

Batches of seed cotton from different places/sources are mixed/blend with one another for making cotton heap in the cotton storage yard. The heap is usually made to maintain the daily ginning capacity of the unit. The practice of manual labor is often used to make and mix cotton heaps. Due to unavailability of labors and also for time saving, some ginning units use mobile conveyors and/or tractors for making heaps. The main quality parameters considered for heap making are trash, moisture content percentage and colour.

28.4 Transportation of Seed Cotton Towards Gin Machine

There are actually two common alternative systems used for the feeding of seed cotton from the heap of cotton to the separator. First one is a pneumatic transmission system from cotton heap to the separator, in which a suction fan draws seed cotton and carries it over a pipe to bring it to the separator. A stone catcher in the suction line is also installed to isolate heavy elements such as brick pieces, heavy iron pieces, stones and particles.

A substitute system uses a conveyor belt for the feeding of cotton to the separator. Normally, two-stage conveyors are mounted in series with a fan between them for the extraction of heavy particles. The air flow produced by the fan is to throw the cotton bolls onto the second-stage conveyor belt, although the heavy particles fall into the trash container, placed directly below.

28.5 Cotton Contamination

The cotton lint quality is ascertained by the characteristics of the fibre. The most important thing is the degree of pollution, which greatly affects its price. Even a single foreign fibre can cause yarn or fabric degradation and is responsible for an estimated yearly loss in export earnings of US$1.4 billion to US$3 billion. Pakistani cotton is contaminated between 18 and 19 g/bale, whilst international standards necessitate up to 2.5 g/bale of cotton.

Most of the contamination comes from impurities that are incorporated into the bales during harvesting, ginning and baling and packaging due to human contact. The contamination of the seed cotton can be carried out at each step, from picking to ginning. Since cotton is picked by hand-picked methods by Pakistan's rural women, the main cause of contamination is human hair and any excess fabric. In addition, jute bags of pickers, sticks and weeds, leaves, immature bolls, dust, toffee lids and plastic bags are another key source. Furthermore, by adding water by the picker, picking the cotton early in the morning before the dew is dried and storing the cotton on moist soil to increase its weight, its quality is destroyed.

Measures to reduce contamination:

- Pickers should use cotton cloth bags instead of jute or polypropylene bags.
- The head of the picker should be covered by cotton fabric as hair or any other fabric fibre should not be mixed with seed cotton.
- Picking must be done at the appropriate period when air and sunshine have dried out the dew and moisture completely.
- Cotton must be stored on brick floors and covered with cotton sheets.
- Metallic body open trolleys would be for rapid conveyance of seed cotton from cotton field to factory or market.
- Eight percent moisture has to be sustained during pressing.

The lack of awareness is the main cause of this contamination. Achieving the zero contamination target is not possible, but dropping it to a lower level is considerably feasible. In order to improve the quality of cotton, the government has introduced a gradual scale of premium.

28.6 Pre-cleaning System

The pre-cleaning phase during the ginning process is very important. The effectiveness and success rate of this stage can be attained by effectively using the available contact area. A feed bucket is fitted out with a feed roller mounted in front of the beater and cleaner. This will adjust the feeding of seed cotton to these machines.

The productivity of cleaning of seed cotton is dependent on numerous factors, including cotton moisture content, machine design, degree of treatment, adjustment of speed and machine condition, quantity and nature of waste, cotton distribution throughout the machine and the varieties of cotton. One recommendation is to use a SMEDA-approved standard instrument to adjust the cleaning machine and optimize the speed of the roller based on the machine's physical conditions, the machine manufacturer's recommendations and the seed cotton quality. Four hundred to 600 rpm is the standard speed of the cleaner rolls.

In order to sustain the productivity and efficiency of the machines, preventive maintenance is also necessary. As this process does not contain material other than cotton, so it is very efficient at this stage. This is attained by the effective action of the stone catcher in the pneumatic transportation system and/or an effective air-flow supply in the two phases of conveyor system.

The spikes length must be from 1.50 to 2.00 in., and the spacing of 6.34 mm should be between the spikes pair. The 6–8 mm holes should have mesh/screen. Replace the broken and bent spikes with new even spikes during maintenance. The grid should be monitored and replaced by the new grid immediately after wearing. Also, keep in mind, when choosing a new or modifying a present beater, that an inclined beater along with grid bar/rod has a prominent efficiency of cleaning than a horizontal beater because of gravitational force.

28.7 Mechanized Cleaning

This step involves the cleaning of pre-cleaned seed cotton which is then beaten by the beater. The beater contains rollers about four to six with spikes on the external surface of the roller. The fibres are opened up and further trash is removed as the seed cotton passes through the rollers. These impurities are passed to the dust chamber by a suction blower (commonly referred to as a selection fan). The cotton is conveyed by a belt conveyor or pneumatically to the beater and then to the gin machine.

28.8 Parts of Gin Stand and Their Impact on Production and Quality

Ginning is the main process to execute on the gin stand. A saw-type gin stand is generally installed in Pakistan, usually mentioned as a saw gin. The unit for ginning consists of five to six serrated gin stands that are fitted side-by-side.

After mechanized cleaning, a feeding worm is installed above from the gin stand to carry the seed cotton to the feed bucket of the ginning machine. Saw gins generally consist of a pair of feed rolls, a set of beater rolls, a saw roll and a hull roll. The main part of saw ginning machine is the saw roll. It has a precise length, and its circular saws are of exact diameter with a number of circumferential teeth. The saw rolls are mounted on the iron shaft that is driven by an electrical motor. Also, some ginning units are installed with feeder-extractor-cleaner (FEC) before the beater of the gin machine for advanced cleaning.

The saw ginning machine separates the lint from the seed and other undesirable matters such as neps and motes. One or two transportation fans are installed accompanied by a network of ducts to carry the lint cotton from the ginning machine to the condenser's top. The delivery air is inserted into the saw roller edges through the nozzle and carries the lint along with it. The seed detached from lint is accumulated for further processing.

The ginning has a high impact on the cotton quality, the regulation of cotton moisture throughout ginning and cleaning and the degree of cleanliness. It has large influence on some quality traits but very little impact on others. Fibre length and the relevant parameters and quality traits like short fibre index and length uniformity are mostly affected by the ginning process. Fibre damage is higher when damp or dry cotton is processed. Ginning affects grade in regard to preparation and foreign matter but has little effect on fibre colour except in extreme cases (Abdullah et al. 2014).

28.9 Lint Cleaning, Conditioning and Bale Pressing

The lint that is obtained from saw gin is transmitted into the condenser. The condenser is basically a roller filter that rotates at a controlled speed having a galvanized iron (GI) screen on its edges. The lint is converted into a thick plate, called a bat, as it passes through the condenser. Any dust remaining in the cotton lint will also be discharged to the chamber of dust chamber during this process. The bat is made at the channel of the condenser and is moved by gravity to the bale press. Generally, the slide is equipped with a sprinkler that enhances moisture to the lint. There is not any standard system to adjust the sprayer and install it before packing on the slide, except for the blow and test methods to maintain the lowest level of moisture in the cotton bale at 9%. The moisture metre is used to measure moisture.

There are two machines that are used for lint bat conversion into a lint bale, placed in order, called press and tramper. Trampers are mainly composed of a container and a power-driven plunger. The lint is filled up and compacted by repetitive stroking by the plunger. The belt pressure is driven by a hydraulic machine to a preset pressure and then by an oil-based hydraulic pump after passing through tramper. The wire is wrapped up around the bale after pressing. Ultimately, the bales are sent to the bale yard after being weighed on a scale.

28.10 Estimation of Cotton Fibre Quality

The cotton fibre quality can be estimated through different techniques and instruments. The main equipment are high-volume instrument (HVI), advanced fibre information system (AFIS), fibrograph, etc., which are available in the market.

Fig. 28.3 High-volume instrument (HVI)

28.10.1 High-Volume Instrument (HVI)

High-volume instrument is the major cotton testing instrument that is used throughout the globe for main cotton research operations with maximum accuracy and precision (Fig. 28.3). Fibre strength, length, micronaire value, uniformity, colour, impurities, fibre elongation, cotton maturity, short fibre index and moisture content are the standard measurements for assessing a particular cotton type. All of these characteristics are important for cotton research and new strains development. Approximately, a complete test on the HVI requires 30 g of lint sample.

28.10.1.1 Length/Strength Module (910)

The length/strength module evaluates two samples at the same time; placing around 8–10 g of cotton lint sample in each bucket, it automatically makes the combs from the bucket material. The comb slides along the comb track until the first comb is positioned in front of the brusher. The function of brusher is to automatically clean and align fibres in the beards and remove the loose fibres. After that both combs with fibre beard are moved along the comb track to the module scanner, where the fibre beards are scanned by lens and jaw system from the tip to base for measuring length, short fibre index and length uniformity. The ratio between the average length of the fibres and the average length of the upper half expressed as a percentage is the length uniformity. Fibre strength and elongation are determined by settling the clamps on the 3.2 mm (1/8 in.) spacing to break the tapered beard.

28.10.1.2 Micronaire Module (920)

Micronaire value is a measurement of fibre fineness and maturity. The air-flow equipment is used to quantify the air permeability of the lint weighing 8.5–11.5 g compacted into a fixed chamber.

28.10.2 Low-Volume Instrument (LVI)

Low-volume instrument measures uniformity, length and short fibre index. The working principle of LVI is photoelectric. The test sample is scanned by an optical system that is highly stable and sensitive. The light beam is convergent on single side of the beard, over the lens placement. The specialized light beam from the source passes by the beard and into the photocell. The passing of light beam by the beard measures the amount of fibres contained in the sample.

28.10.3 Advanced Fibre Information System (AFIS)

Fibre length, neps, fibre diameter and trash of individual fibre are measured by AFIS which delivers data on distribution of assessed properties. The method of splitting up a sample into individual fibres by the instrument is similar to the processing conditions in up-to-date textile technology.

28.11 The Cotton Classification

Cotton marketing is incomparable in all field and fruit crops. Cotton quality can be represented by numerous measurements made by the cotton classers and described in various grades. The term "cotton classification" brings up the covering of standardized measures to quantify the physical properties of raw cotton that affect the quality of finished products or process efficiency. Classification is developed by the United States Department of Agriculture (USDA) on international level based on HVI classification, and the Pakistan Cotton Standard Institute (PCSI) classifies Pakistani cotton for local market based on the classer's grade composed of three components: trash, preparation and colour.

Cotton fibre quality is primarily classified by its length, micronaire value, strength, maturity, uniformity index, colour grade and short fibre index. After the lint bale is prepared after the ginning process, samples taken from each bale are classified accordingly using a high-volume instrument (HVI) and with the assistance of a professional called a classer. A scientific quality control verification (calibration) is established periodically to settle if the instrument accuracy is maintained. To maintain the instrument accuracy, calibration (scientific quality control check) is done periodically as recommended by the manufacturer.

28.11.1 USDA Cotton Classifications

Cotton as a natural product usually contains non-lint contents, such as leaves and bark from cotton plants, called trash. Bark and grass may be more difficult to move out because they align with the fibres and cause major problems during the spinning action. The trash amount also affects the value of cotton because of the spinning mill requirement to remove the trash before processing. The naturally varied differences in the quality of fibre, in combination with differences in end-use requirements, result in substantial inconsistency in the cost of the cotton lint to the processor. Hence, a classification of discounts and premiums has been well-known to denote a stated base quality. Generally, cotton fibre value increases as the bulk-averaged fibres increase in length, whiteness (+Rd), micronaire and strength, and discounts are made for equally low MIC (less than 3.5) and high MIC (more than 4.9). The USDA has established grading standards in collaboration with the whole cotton industry.

28.11.1.1 Fibre Length

Fibre length is associated with variety, but water stress, nutrient deficiency or cotton plant exposure to heat stress may shorten it. Cotton of a particular variety grows fibres of nearly identical length. Over-cleaning or low moisture content of seed cotton ginned at the plant also damages the length. Length influences yarn strength, evenness, yarn count and the efficiency of spinning. Other quality factors are also important. Fibre length rating is shown in Table 28.1.

28.11.1.2 Length Uniformity

It is the proportion of the average length to the average length of the upper half, stated as percentage. However, there is a variability in the fibre length naturally, so the length uniformity is lesser than 100. The fibres possibly will vary inside the bale,

Table 28.1 Rating of fibre length

Description	Rating (mm)
Short staple	20.64–23.81
Medium staple	24.61–27.78
Medium to long staple	28.58–30.96
Long staple	31.75–35.72
Extra-long staple	Above 36.51

Table 28.2 Rating of length uniformity

Description	Rating (%)
Very high	Above 85
High	83–85
Intermediate	80–82
Low	77–79
Very low	Below 77

Table 28.3 Rating of micronaire value

Description	Rating
Very fine	Below 3.0
Fine	3.0–3.9
Average	4.0–4.9
Coarse	5.0–5.9
Very coarse	6.0 and above

and length uniformity permits for determination of inconsistency within the bale. It affects yarn strength and evenness; also cotton with a low uniformity has high percentage of short fibres. The rating of length uniformity is shown in Table 28.2 (USDA 2001).

28.11.1.3 Fibre Micronaire

The fineness is important to determine the type of yarn that can be made from the fibres. The finer the fibres, the finer the yarn. During growth, the micronaire is affected by environmental conditions such as humidity, temperature, plant nutrition, and sunlight extremes in cotton bolls or plant populations. Fibre fineness influences the final product in a number of ways. To prevent fibre damage during opening, cleaning and discarding of low-micronaire-value cotton, processing speeds must be slow. Finer fibres have high yarn strength. Dye absorbency and retention are dependent on fineness and maturity; the greater the maturity, the greater will be the absorbency and retention as described in Table 28.3 (USDA 2001).

28.11.1.4 Fibre Strength

Fibre strength depends mainly on the variety. It can be influenced by deficiency of plant nutrient and climatic conditions. Yarn strength and fibre strength are highly correlated. Cotton with higher fibre strength can hold up breakage during processing. The strength of the fibres ultimately affects the fabric made from these fibres.

Fibre strength rating is given in Table 28.4.

Table 28.4 Rating of fibre strength

Description	Rating (g/tex)
Very strong	31 and above
Strong	29–30
Average	26–28
Intermediate	24–25
Weak	23 and below

Table 28.5 Colour grades of cotton

Description	White	Light spotted	Spotted	Tinged	Yellow stained
Good middling	11[a]	12	13	–	–
Strict middling	21[a]	22	23[a]	24	25
Middling	31[a]	32	33[a]	34[a]	35
Strict low middling	41[a]	42	43[a]	44[a]	–
Low middling	51[a]	52	53[a]	54[a]	–
Strict good ordinary	61[a]	62	63[a]	–	–
Good ordinary	71[a]	–	–	–	–
Below grade	81	82	83	84	85

Note: The sources for rating tables of fibre properties are from ICA Bremen and USDA cotton classification

[a]Physical standards: All others are descriptive

28.11.1.5 Colour Grade

The colour of fibres is also important. The colour grade is quantified by reflectance (Rd) and yellowness (+b). Very white cotton is usually more valuable, and the colour of the cotton may turn yellow when exposed to elements before harvest. When the boll is opened, the mature cotton is white and clean. Yellowing may be an important factor in frost, drought or early harvesting to aid in the early termination of growth. Grey is mainly the result of contact with moisture and weathering on site. Weathering can be controlled, but the risk of weathering damage can be reduced by minimizing the time between the first and last opening. Honeydew from mites, fungal growth or sugar on the lint can also produce grey cotton, but this can be managed by controlling the mites before they produce significant amounts of honeydew. Under certain conditions, such as drought stress, rain-grown cotton produces more spots than irrigated cotton. Otherwise the colours tend to be similar. Colour deterioration affects the capability of cotton fibres to retain and absorb dyes and finishes.

There are 25 official colour grades of cotton, plus five grades below the grade, as shown in the table below. The USDA maintains physical standards for 15 colour grades. Others are descriptive standards (Table 28.5).

Table 28.6 PCSI grading

Grade	Seed cotton	Lint
Super	• Open and healthy seed cotton • Colour white • Leaf particles in a little bit amount	• Colour white (Rd = 77.58%) • Trash % is less than 3% • A-index pricing value in international market
Grade-1	• Open and healthy seed cotton • Colour white • Leaf particles in a little amount	• Colour white (Rd = 75.40%) • Trash %age is 3–4% • A-index pricing value in International Market
Grade-2	• Open seed cotton with some un-opened bolls • Colour white • Leaf particles in a little amount	• Colour white (Rd = 73.16%) • Trash %age is 4–5% • B-index pricing value in international market
Grade-3	• Open seed cotton with some un-opened and yellow bolls • Colour average white • Leaf particles with little bit of stems of the plant	• Colour white (Rd = 70.22%) • Trash %age is 5–6% • Base grade with no deduction
Grade-4	• Immature seed cotton in great quantity • Colour yellowish white • Leaf particles with little bit of stems of the plant in great extent	• Used for coarser counts • Colour white (Rd = 67.00%) • Trash %age is 7–8%
Grade-5	• Immature seed cotton in great quantity • Colour yellowish grey • Leaf particles with stems of the plant in great extent and diseased bolls	• Used for coarser counts • Colour white (Rd = 63.89%) • Trash %age is 8–9%

28.11.2 PCSI Cotton Classification

Cotton trade around the world is based on grade, length of fibre and other fibre properties. PCSI recommends proper picking and better ginning practices, grading of seed cotton and lint classification as well as marketing system based on quality. PCSI classifies the cotton in the form of seed cotton and lint. There are six official grades based on classer's classification as illustrated in Table 28.6.

28.12 Occupational Safety and Health

The science of providing, implementing, assessing, and controlling hazards in the workplace that may endanger workers' health considers possible impacts on nearby communities and the overall environment.

The standards of occupational safety and health are significantly diverse amongst countries, economic sectors and firm sizes. The rate of workplace incidence of death differs in some countries, and there seems to be an important difference between developing and developed nations; for example, Pakistani factory workers are eight times more likely to die at work than French factory workers. Occupational safety and health performance rates vary widely amongst economic sectors in various countries. Statistics show that the world's highest occupational mortality rates are in construction, forestry, agriculture and mining. In general, large industries have good safety record than small enterprises. It seems that the death and severe injury rate in a small workplace (up to 50 workers) is two times that of a large workplace (more than 200 workers).

Like other processing industries, Pakistan's cotton ginning industry has many hazards. The gin causes the highest damage on the hands, followed by injuries to the spine, eyes, feet, arms, shoulders, legs, head and chest. The overall financial costs of injury and illness consist of direct costs (medicinal and other recompense) and indirect costs (loss of worktime, downtime, loss in revenue, costs of insurance, loss in productivity and numerous other loss aspects). It is easy to determine direct costs as they are lower than indirect costs.

The health syndromes in ginning enterprises are listed below:

1. Air quality
2. Noise exposure
3. Illumination
4. Physical safety
5. Firefighting system
6. Medical emergency procedure

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