INVESTIGATION OF MECHANICAL PROPERTIES OF YARNS AND FABRICS PRODUCED NATURALLY COLOURED COTTON FIBERS

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NAZAN AVCIOĞLU KALEBEK

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Approval of the Graduate School of Natural and Applied Sciences

Prof. Dr. Bülent GÖNÜL
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Asist. Prof. Dr. Mehmet TOPALBEKİROĞLU
Chairman of the Department

This is the certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Prof. Dr. Ali KİREÇCİ
Supervisor

Examining Committee Members

Prof. Dr. Ali KİREÇCİ

Assoc. Prof. Dr. Osman BABAARSLAN

Assist. Prof. Dr. Mehmet TOPALBEKİROĞLU

ABSTRACT

INVESTIGATION OF MECHANICAL PROPERTIES OF YARNS AND FABRICS PRODUCED NATURALLY COLOURED COTTON FIBERS

KALEBEK AVCIOĞLU Nazan

M.Sc.thesis, Textile Engineering Department

Supervisor: Prof. Dr. Ali KİREÇCİ

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The starting of the naturally coloured cotton (NCC) production for improving textile industry product range and for increasing the returning to nature also play a significant role on saving the ecology. NCC are produced by crossbreeding with different featured fiber seeds on nature such as fiber colour, length, micronaire and strength or by genes transfer.

In this study, the properties of naturally coloured and orijinal cotton's produced at Nazilli Cotton Research Institue (NCRI) and Kahramanmaraş Agricultural Research Institue (KARI) were investigated. These cotton samples were analysed by High Volume Instrument (HVI) and Advance Fiber Information System (AFIS). Examination results show that depending on progress seed technology, the quality of derived NCC approach to the quality of normal cotton fibers. Small quantities of cotton samples were converted to ring spinning yarn in a laboratory conditions. According to Uster Evenness and Tensorapid tester data, the parameters of the yarns which were produced by crossbred cottons were better than yarn parameter which were obtained from crossbred cottons. Colorfastness and pilling tests were performed on to the fabrics which were knitted from these yarns. It is observed that the fabrics of NCC were more resistance to fading of colour than dyed fabrics and their pilling properties were similar with white coloured knitted fabrics.

Key words: Cotton, naturally coloured cotton (NCC), HVI, AFIS, Uster Evenness Tester

ÖZ

DOĞAL OLARAK YETİŞTİRİLMİŞ RENKLİ PAMUKTAN ÜRETİLEN İPLİK VE KUMAŞLARIN FİZİKSEL ÖZELLİKLERİN İNCELENMESİ

KALEBEK AVCIOĞLU Nazan

Yüksek Lisans Tezi, Tekstil Mühendisliği Bölümü

Tez Yöneticisi: Prof. Dr. Ali KİREÇCİ

Ekim,2003

Tekstil Endüstrisinin ürün yelpazesini genişletmek ve doğaya dönüş çabalarını hızlandırmak amacıyla başlatılan doğal renkli pamuk üretimi, ekolojinin korunmasında da büyük rol üstlenmiştir. Türetilmiş renkli pamuklar doğada bulunan farklı özelliklerdeki (lif rengi, boyu inceliği ve mukavemeti gibi) tohumlarının çaprazlanması veya gen transferi yöntemiyle üretilmektedir.

Bu çalışmada Nazilli Pamuk Araştırma Enstitüsü'nde türetilmiş renkli pamukların ve çaprazlamada kullanılan orijinal pamukların, ayrıca Kahramanmaraş Tarımsal Araştırma Enstitüsü tarafından üretilen orijinal renkli ve beyaz pamukların lif özellikleri incelenmeye alınmıştır. Pamuk numuneleri HVI ve AFIS cihazlarıyla analiz edilmiştir. Araştırma sonuçları türetilmiş renkli pamuk lif kalitesinin, tohum teknolojisindeki ilerlemelere paralel olarak normal pamuk lifi kalitesine yaklaştığını göstermektedir. Küçük miktarlarda alınan pamuk numuneleri laboratuvar şartlarında ring ipliği haline getirilmiş ve bunlar Uster düzgünsüzlük ve mukavemet cihazlarıyla test edilmiştir. Veriler, çaprazlamadan elde edilen pamuklardan üretilen iplik parametrelerinin, çaprazlamada kullanılan pamuklardan elde edilen iplik parametrelerinden daha iyi olduğu göstermektedir. Bu ipliklerden üretilen örme kumaşların renk haslıkları ve boncuklanma deneyleri yapılmıştır. Boyalı kumaşlarda görülen renk atmasının aksine doğal renkli kumaşlarının renklerinin daha canlı oldukları ve boncuklanma özelliklerin beyaz kumaşlardaki gibi olduğu gözlenmiştir.

Anahtar kelimeler: Pamuk, doğal renkli pamuk, HVI, AFIS, Uster Düzgünsüzlük Cihazı

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CHAPTER 1
INTRODUCTION

1.1. Introduction

Word of textile is used for all process from fiber to products. However fiber is only used for raw material of textile industry. As can be described below fibers are the primary materials from which most textile products are made. The textile industry uses many different kinds of fibers as its raw materials. Some of these fibers were known and used in the earlier years of civilization, as well as in modern times. Other fibers have acquired varied degrees of importance in recent years. It is considered that the introduction of fundamentally new fibre types has become so expensive that new fibre can be introduced only if it has considerable advantages in performance or cost. However this does not exclude the possibility of important developments in the existing fibre. The factors influencing the development and utilization of all these fibers include their ability to be spun, their availability in sufficient quantity, the cost or economy of production, and the desirability of their properties to consumers [1,2].

As a result of the development of new fibers, difficulties arose in the textile industry in terms of nomenclature, classification, and identification. During the manufacture of fibres there is scope for the modification of the fibre by the introduction of additives to the structure [3].

For commercial reasons deviations from the 'regular' fibre can be indicated in the technical literature with the trade-name suffixed by a coded letter or number. Some modified fibres carry distinctive trade-names to highlight the fibre qualities. 'Tactei', for instance, is a very fine nylon fibre, and 'Mitrelle' a very fine polyester fibre. And also powerful promotional tools, especially when include or use a memorable logo or symbol. Logo of pure cotton is shown in Figure 1.1 [4,5].

Figure 1.1. Logo of pure cotton

1.2. Classification of Textile Fibers

Most basic of all in selecting fabrics is the behavior of the fibers, the smallest visible components of most fabrics.

This arrangement has brought about some standardization, clarification, and easier identification of fibers. The fibres used in modern textile manufacture can be classified into two main groups;

a) natural which is found in nature as fibers that can be used to make fabrics,

b) man-made that is a fiber-forming raw material in the form of a thick, sticky liquid is "spun" or extruded through spinneret holes, forming streams that are solidified into fibers depending on their orijin and chemical.

The natural fibres are those, such as cotton, wool, silk and flax, which are provided by nature in a ready-made fibrous form. The man-made fibres, on the other hand, are those in which man has generated a fibre for himself from something which was not previously in a suitable fibrous form. Only a limited number of these materials are useful in the production of yarn or fabrics. The natural and the manufactured, or manmade, fibers are identified in Table 1.1 by classifying them according to type and name [6,7].

Table 1.1. Classification of textile fibers

- **NATURAL FIBERS**
  - **CELLULOSE**
    - **Seed Hair**: cotton, kapok
    - **Bast**: linen, ramie, jute, hemp, kenaf
    - **Leaf and Other**: agave, coir, henequen, sisal, yucca, pina, sacaton
  - **RUBBER**
  - **MINERAL**
    - asbestos
  - PROTEIN
    - **Animal Hair**: wool, cashmere, camel, mohair, qiviut, alpaca, ilama, huarizo, misti, vicuna, guanaco, cashgora
    - **Extruded**: silk
- **MANUFACTURED FIBERS**
  - **REGENERATED**
    - **Cellulose**: viscose rayon, acetate, triacetate, high-wet-modulus-rayon, cuprammonium rayon, lyocell
    - **Protein**: azlon
  - **INORGANIC**
    - glass, ceramic, metallic
  - **SYNTHETIC**
    - nylon, vinyon, saran, olefin, modacrylic, acrylic, polyester, spandex, aramid, anidex, novoloid, sulfar, P.B.I., carbon, nytril, vinal, fluoropolymer

1.3. What is Cotton?

From prehistory to almost 1900 A.D. fabrics were made of natural fibers, the major ones being cotton, wool, flax, and silk. Vegetable fibers include the most important of all textile fibres are cotton [4].

Cotton is the backbone of the world's textile trade. Many of our everyday textile fabrics are made from cotton; fabrics that are hard-wearing and capable of infinite variety of weave and colouring.

The bast and leaf fibres are of very great value to the world, they cannot begin to compare in importance as textile fibres with the seed fibre, cotton. Like the other plant fibres, cotton is essentially cellulose. But it is not produced by the plant as part of its skeleton structure, as are the bast and leaf fibres. Cotton is attached to the seeds of plants of the mallow family; the fibre serves probably to accumulate moisture for germination of the seed [8]. Cellulose is a main building material of plants, likened to the (protein) flesh of animals. The woody plant material lignin, found in the stiffer plant parts, especially in trees, acts like bone, while binders such as plant pectins act like animal ligaments. Cellulose is a carbohydrate, composed of carbon (C), hydrogen (H), and oxygen (0), making simple sugar units. These polymerize; that is, they join together, with water (H_20) given off, to form very long molecular chains of 2,000 units or more; this makes cellulose a polysaccharide.

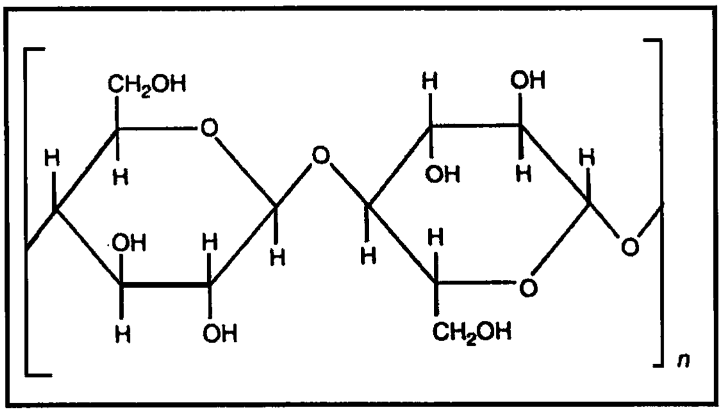


Figure 1.2. Chemical structure of a cellulose chain

A representation of chemical structure of a cellulose commonly used for many years is shown in Figure 1.2. It is interesting to note that the unit of starch, another very large carbohydrate molecule, is also a glucose but in a slightly different form; it produces long chains, but is less suitable for a textile fiber [9].

Cellulose is sensitive to mineral acids, but not to alkali or chlorine bleach; it can be attacked by mildew growth, rot, and silverfish. It has a cool hand and good heat resistance. Cellulose is fairly rigid or stiff. Cellulose fibers swell in water and, although they return to their original size when dry, fabrics made of them shrink when the fibers are wet and swollen. Cellulose is flammable, burning quickly with the familiar odor of burning plant material, such as wood or leaves, and glows for some time after a flame is extinguished [4].

Cotton as the most important textile fibre covering the seeds of the cotton plant, grows in any part of the world where the growing season is long and climate is temperate to hot with adequate rainfall or irrigation. Upon maturing, the fibres are picked together with the seeds and sent to ginneries for cotton primary processing, where the fibres are seperated from seeds. Cotton fiber presents many exceptional features i.e. great flexibility, cohesive properties, very small thickness, but high strength and wear resistance. Moreover, the fiber may be easily dyed.

Figure 1.3. Cotton seed boll

The cotton fiber grows in the seedpod, or boll, of the cotton plant (Figure 1.3.). The fibre length is sufficiently regular and reaches 25-40 mm. Each fiber is a single elongated cell that is flat, twisted, and ribbonlike with a wide inner hollow (lumen). It is composed of about 90 percent cellulose and about 6 percent moisture; the remainder consists of natural impurities. The outer surface of the fiber is covered with a protective waxlike coating, which gives the fiber a somewhat adhesive quality.

This characteristics combined with its natural twist contribute to making cotton an excellent fiber for spinning into yarn. Cotton yarn is used to make fabrics that are universally used for all types of apparel, home furnishing, and industrial application.

1.4. History of Cotton

Cotton has been cultivated for more than 5000 years. Archeological finds indicate cotton was grown and used for textile purposes in the Indus Valley well before 2100 B.C., in Mexico by 3500 B.C., in Peru by 2500 B.C., and in the southwestern United States by 500 B.C. Fragments of fiber and bolls dating from 5800 B.C. were found in Mexico, although there is a question as to whether cotton was used as a textile that early. Cotton was used extensively in the Medo-Persian Empire and may have been used in ancient Egypt as well. The idea of using these fine seed-hairs as textile fibres came at an early stage in textile manufacture. Cotton fabrics were made by the Ancient Egyptians and by the earliest of Chinese civilizations. It was introduced into the Mediterranean countries by the Arabs and into other parts of Europe by the Crusaders. The use of cotton in England is mentioned in writings of the thirteenth century, a though its use did not become genes until the first half of the sixteenth century. In the United States, cotton was cultivated by the colonists in the early seventeenth century. The impetus of the industrial revolution, represented in the cotton industry by the invention of the carding machine and the spinning mule England and by the invention of the cotton gin in the United States, resulted in vastly increased cotton production as manufacturing [5,6].

The eighteenth century saw textiles developing as a national industry in place of the local guilds that had served during mediaeval times. In 1736, the Manchester Act wiped out the law of 1700 which had been engineered by the wool merchants to prohibit the sale of cotton goods in England. Lancashire then set out to become the cotton centre of the world.

During the latter half of the eighteenth century, the Industrial Revolution in Britain transformed production methods in the textile industry. This was the age of invention that was to make Britain the workshop of the world.

At this time, most British cotton was being imported from the West India, with a certain amount from India and Brazil. Cotton has been planted and grown for commercial use in Virginia since 1607, but the production of American cotton was held up owing to difficulty in removing the cotton from the seeds to which the fibres clung tenaciously. In 1793, Eli Whitney invented the cotton gin, a machine for removing the fibres from cotton seeds, and America entered the world market as a cotton producer. From this time on, Lancashire was to reign unchallenged as the cotton manufacturing centre of the world - a position she held until the First World War [8].

Since then, the great consumer countries of the East have developed their own manufacturing industries, and Lancashire no longer holds her former position in the textile world. Many factors have combined to intensify the changing conditions in the cotton trade; better home heating and changing fashions have reduced the clothing worn by women to a quarter of the yardage carried by their Victorian grandparents. And man-made fibres like nylon and rayon are encroaching steadily in the fields where cotton was previously employed.

Cotton fabrics have been so well known and so extensively used through out the world for hundreds of years the spinning of the cotton fiber into yarn, the wearing of cotton fabric, and many of the finishing processes used for cotton goods come first to mind and naturally serve as foremost examples in a study of fiber and fabric. Cotton has been of service to mankind for so long that its versatility is almost unlimited and new uses are instantly being discovered. It can be depended on to serve many purposes. Not only is cotton a textile in its own right, but some of its by products form the base for some of the manmade textile fibers [2].

1.5. Naturally Coloured Cotton (NCC)

White is the most common color of fibre for normal standart cotton that is chemically dyed for apparel and consumer use. However some genes display color properties in a variety of earth tones, eliminating the need for dyes. NCC is a naturally pigmented fiber that grows in shades of green and brown. NCC has existed for thousands of years in many countries around the world. So it is not new for textile and agricultural industry. According to historical records lint colours generally ranges from shades of cream and tan, to tones of brown, red, and green, but pink, purple, mauve, gray, and black cottons have been reported.

The cultivars can be grown using organic or conventional farming methods, but both offer ecological advantages since chemical dyeing is necessary. NCC can offer unique attributes and selective advantages over common white varieties. Besides some advantages of NCC, it received little attention in the recent past because the fibres were not suitable for commercial processing. Some coloured fibres are shorter, weaker, and finer than white cotton. These characteristics contribute to their unique appearance, unusual softness, flexibility, and luster. Short comings of the fibres may include color variation, cost, and limitations associated with processing and performance. Therefore, genetic breeding has improved certain cultivars and made spinning possible on conventional machinery. The genus Gossypium contains many species of cotton that yield colored lint. Some pigmented fibers are extremely short and others are considerably longer, while some are very fine and others are very coarse. Genetic engineers have performed crossing with selected fiber characteristics to obtain desired properties of cotton. For example it is known that genetic mutant play an increasingly important role in cotton improvement as plant breeders work to design and develop cotton plants for newer production systems and increased efficiency. Mutant cotton and conventional standart white cotton is crossed in order to plant new colours. The colour of cotton is controlled by larger or dominant gene, the improvement of that characteristic is simple, but it cannot be accomplished without self-focundation controlled by the improves, to avoid segregation or undesirable contamination. On the other hand, some shades of colours are highly influenced by the environment (sunray, soil, type and year). Breeding studies takes years effort to introgress the desired gene into a genetic background that favors high quality fiber production. A successful outcome for colored cotton in genes on a combination of breeding for enhance strength and development of suitable manufacturing methods.

There is a growing public interest in healthy products and environmentally responsible practices in the market today. Despite some recent commercial and economical disappointment, the softness and beauty of NCC helps it keep a hold on niche markets. If the current limitations of naturally coloured cotton were overcome, many new production methods of cotton, yarn and fabrics could be developed. Scientist can only speculate about the possibility of development new colors eventually. In the meantime, breeders continue to improve existing colored cultivars, while researchers continue to develop and refine processing methods for these and other fibers.

1.6. Purpose of This Thesis

The aim of the study is to investigate the fiber, yarn and fabric parameter of NCC, and comparison of these parameters with the properties of fiber, yarn and fabric parameters of conventional white cotton.

The physical properties of eight naturally coloured cotton with different hues ranging light brown to dark brown and green produced by Nazilli Cotton Research Institue (NCRI) and Kahramanmaraş Agricultural Research Institue (KARI) and also three white conventional cotton which were cultivated into same conditions are investigated by HVI (High Volume Instruments) ve AFIS (Advanced Fiber Information System). HVI and AFIS fiber testers determine many fiber parameters as shown in Table 4.10 and Table 4.11, however in this study only some important fiber parameters that directly effect the yarn and fabrics properties are analysed. These fiber parameters are;

a) fiber fineness (micronaire),
b) fiber length,
c) fiber strength and elongation,
d) maturity,
e) neps.

Table 1.2. List of fibers used in this study.

Type of cotton	Fiber Color	Origin
DTN-5	Light Brown	NCRI
NDT-10	Light Brown	NCRI
NDT-11	Light Brown	NCRI
NDT-13	Light Brown	NCRI
NDT-15	Light Brown	NCRI
CAMEL	Camel	NCRI
NAZİLLİ-84(S)	White	NCRI
K.MARAŞ-BROWN	Dark Brown	KARI

K.MARAŞ-GREEN	Green	KARI
SAYAR-314	White	KARI
ERŞAN-92	White	KARI

In order to produce yarn from each sample 25 sliver, which were produced by Zellweger Uster's Microdust and Trash Analyzer with Rotorring Machine 3rd generation (MDTA 3) and a 5 grams of weight, were combined and spun on to a bobbin by a roving machine at a desired thickness. These roving slivers were than spun into 20 Ne yarns by means of an industrial ring spinning machine. The evenness and strength of each yarn was tested by Uster Evenness Tester III and Uster Tensorapid Instrument. Like HVI and AFIS fiber tester, Uster Evenness Tester III and Uster Tensorapid Instrument give many test data related with yarn as seen in Table 5.10, but only these following parameteres are investigated;

a) strength and elongation,
b) hairness,
c) evenness (neps, thin places, thick places, coefficient of variation).

Lastly, all of these yarns are converted into to knitted samples and some tests were performed according to ISO standards which are;

a) washing fastness,
b) hypochlorite bleach fastness,
c) rubbing fastness,
   - dry rubbing fastness
   - wet rubbing fastness
d) perspiration fastness,
   - alkaline perspiration fastness
   - acid perpiration fastness
e) pilling resistance.

The sequence of process and tests are shown schematically in Figure 1.4.

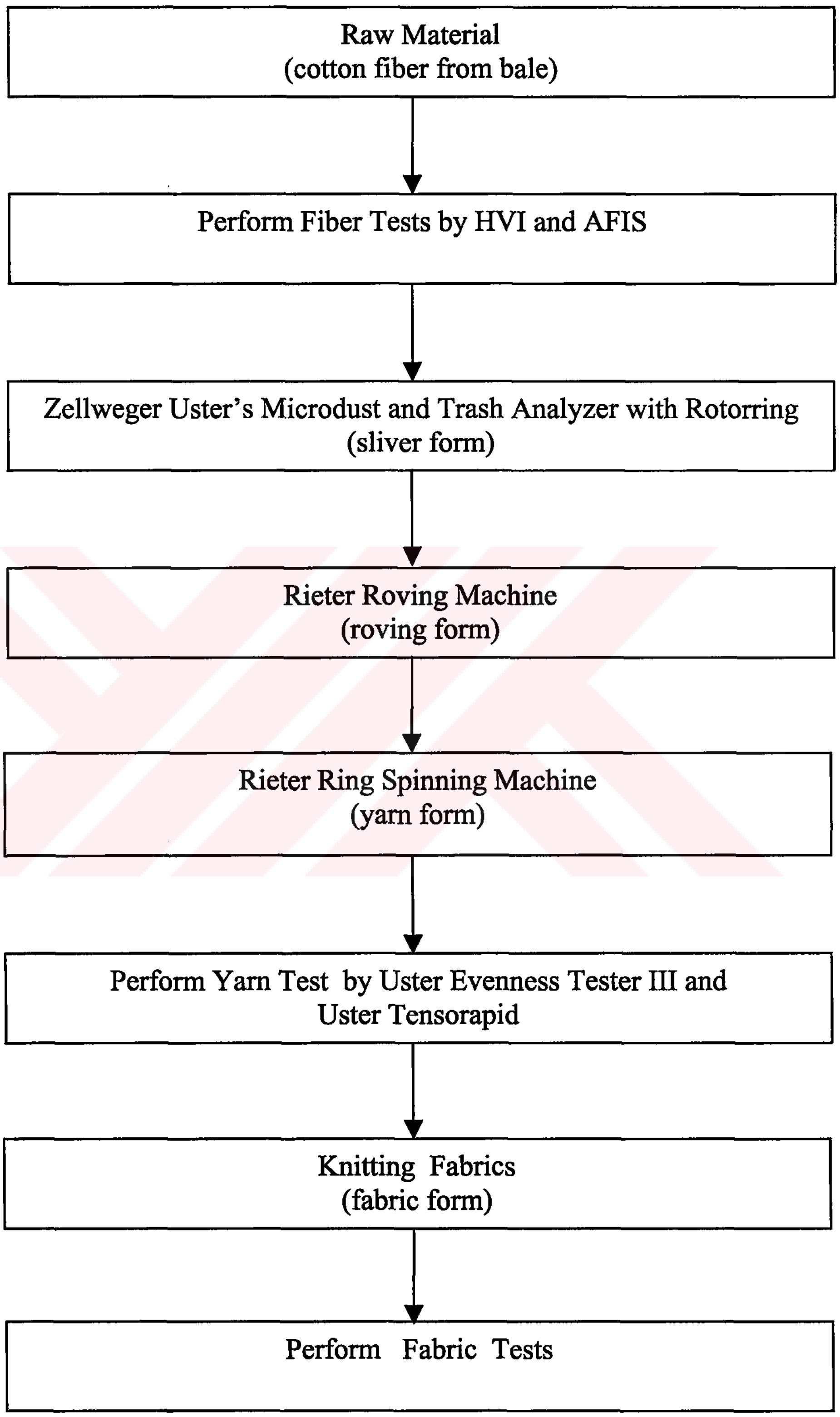


Figure 1.4. Sequence of processes

1.7. Structure of Thesis

Chapter 2 includes the detail information about production condition and areas, by giving growing areas of the world map, harvesting and planting period table. After giving brief explanation about major steps in cotton production such as land preparation, planting, cultivation and harvesting, ginning and spinning processes were described. All physical properties of cotton fibers such as shape, fiber fineness, fiber length, fiber strength, neps, elongation and elasticity, uniformity index, maturity, crimp, color, luster, linear density, elastiscity and resilince, absorbency and moisture regains, dimensional stability, heat and electrical conductivity, and also management to improve cotton fiber physical and mechanical characteristics were expalined in detail. And marketing, end uses, care procedures and futures exchanges of cotton were also explained in this chapter.

Chapter 3 includes certain types of cotton fiber outside the traditional production/ market/ utilization chain that satisfy the requirement for niche industries. NCC is a naturally pigmented fiber that grown in nature shades like brown and green. Fiber colour of cotton is determined by genetics. Therefore the detail informations about widely used methods for improving physical and mechanical properties of fibers such as, mutation, crossbreeding and gene transfer were explained. And also physical and chemical properties, review studies, benefits, market and demand and lastly future of NCC were expalined.

In chapter 4, concept of quality and quality control were described. Firstly what is quality, types of quality, variation due to testing, test criteria, international organization such as ISO and ASTM, conditions for textile testing were given. All tests and test methods which were performed on cotton fiber by HVI and AFIS including fibre fineness, length, strength, short fiber content, maturity, neps were explained in this chapter

Chapter 5 was given information about yarn analysis that contain yarn number, yarn twist, yarn strength and elongation, evenness and hairness. There are several yarn analysis methods and instruments with different principle in textile industry. The most commonly used method is Uster Tester which ensures higher accuracy, universally available than conventional testers all over the world. Therefore Uster tester was used for yarn analysis.

In addition to finer content and yarn structure, the several fabric physical properties affecting final performance of fabrics were explained in Chapter 6. The main physical properties of fabric are colour fastness (dry and wet crocking, laundering, hypocholorite, acid and alkaline perspriation) and pilling resistance. Importance of these tests, methods, instruments, test datas, evaluation of them according to standarts were clarified in detail with figures, graphics and tables.

The conclusion of this thesis and recommendation for further studies were included in chapter 7.

CHAPTER 2
COTTON

2.1. Introduction

Seed fibers are those from the seed pod of the plant and the most important seed fiber is cotton. Cotton still accounts for quarter of all fiber use. It certainly has desirable properties, but the success of " King Cotton" lies in production; the fiber is readily available from the plant.

2.2. Production and Processing

Cotton grows in any part of the world where the growing season is long and hot climate with adequate rainfall or irrigation. Cotton production requires a semitropical climate (nearly 200 days frostfree), with sun and water needed to produce the best fiber seen in Figure 2.1 and Table 2.1. Soil types, climate, moisture, growing conditions, and topography influence cultural practices and determine such factors as types of cotton planted, size of farms, crop income, and per-acre yields [4,6].

Land preparation, planting, cultivating, and harvesting are the major steps in cotton production. Irrigation is practiced in areas where moisture is insufficient. Supplementary practices which are often followed to increase production or guard against losses include: fertilizing, thinning the young plants, insect control, artificially defoliating the plant, destroying and turning under the stalks after harvesting, and planting winter cover crops [1,10].

The first step in the culture of cotton is disposal of residue from the previous crop. Where cotton follows corn or a previous crop of cotton, a stalk cutter or shredder is usually used to destroy the old plants. Machines called "disk harrows," or other suitable soil turning equipment, may be used further to break up and cover the stalks.

Before planting, the soil is tilled to a depth of several inches. After the land is properly prepared, a mechanical planter opens a small furrow, drops and covers the seed, and packs the earth on top. In some cases, fertilizer is applied at the same time the seed are planted.

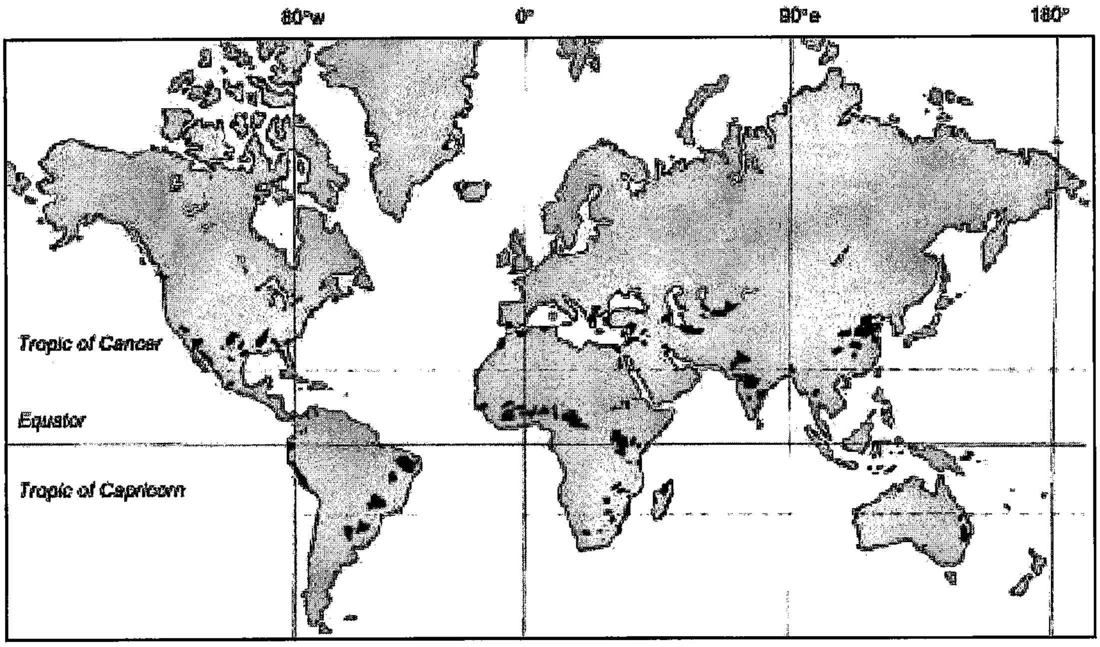


Figure 2.1. Cotton growing areas of the world

After the young plants begin to grow, they must be thinned so that there are two or three plants per hill every nine to fourteen inches. Thinning is usually done by workers with hand hoes, although mechanical chopping is increasing in importance every year. Whole families often work together at this first step in cultivation, chopping out surplus stalks, weeds, and grass with big, broad-bladed hoes.

Cotton grows inside the seed pods of a wide variety of plant species included in the Gossypium family. The early primitive cottons grew naturally as perennials, and for many years cultivated cotton was also grown as a perennial. In the tropics, perennial cotton plants may grow 6m high. Nowadays, with only one or two major exceptions, the world's cotton is grown by raising annual crops, the plants reaching a height of between 1.2 and 1.8 m.

A single boll will contain 150,000 fibres or more. The boll itself is a fruit which forms when the flowers drop from the cotton plant. The young fruit that remains increases in size for perhaps seven weeks, forming the ripe boll; this then opens to expose the mass of cotton fibres which expand and dry into a light fluffy mass [8].

Table 2.1. Properties of cotton produced in different countries [11]

No	Country	Planting Period	Harvesting	Staple-mm	Mic.	Variety
1	AFGHANISTAN	APRIL-MAY	OCT-DEC	26-28	4.0	ACALA
2	ARGENTINA	SEPT-OCT	FEB-JUNE	24-28	3.9-4.1	TOBA
3	AUSTRALIA	SEPT-NOV	MAR-JUNE	24-29	3.2-4.9	DPL
4	BRAZIL	OCT-NOV	MAR-JUNE	26-28	3.2-4.0	IAC
	BRAZIL	PERENNIAL	MAR-JUNE	32-35	3.2-4.8	MOCO
5	BURKIN	JUNE-JULY	NOV-DEC	25-28	3.6-4.8	ALLEN
6	CAMERRON	JUNE-JULY	NOV-DEC	25-28	3.8-4.3	ALLEN
7	CENTRAL AFRICA	JUN-JULY	NOV-DEC	25-28	3.8-4.2	ALLEN
8	CHAD	JUNE-JULY	NOV-DEC	25-28	3.8-4.4	ALLEN
9	CHINA	APRIL-JUNE	SEPT-OCT	22-28	3.5-4.7	SHANDONG
	CHINA	APRIL-JUNE	SEPT-OCT	22-28	3.5-4.7	XINJIANG
	CHINA	APRIL-JUNE	SEPT-OCT	22-28	3.5-4.7	MNH-93
10	COTED IVORIE	JUN-AUG	OCT-JAN	24-28	2.6-4.6	ALLEN
11	EGYPT	MARCH	SEPT-OCT	31-40	3.2-4.6	GIZA
12	GREECE	APRIL	SEPT-OCT	26-28	3.8-4.2	4S
13	INDIA	APRIL-NOV	SEPT-NOV	16-38	2.8-7.9	
	INDIA	SEPT-NOV	FEB-APR	16-38	2.8-7.9	
14	IRAN	MAR-APR	SEPT-NOV	26-28	3.9-4.5	COKER
15	ISRAEL	APRIL	SEPT-OCT	26-37	3.5-4.3	ACALA
	ISRAEL	APRIL	SEPT-OCT	26-37	3.5-4.3	PIMA
16	MALI	JUN-JULY	OCT-NOV	26-27	3.7-4.5	BJA
17	MEXICO	MAR-JUNE	AUG-DEC	26-29	3.5-4.5	DELTAPINE
18	MOZAMBIQUE	NOV-DEC	APR-MAY	25-29	3.6-4.2	A637
19	NIGARIA	JUL-AUG	DEC-FEB	24-26	2.5-4.0	SAMARU
20	PAKISTAN	APR-JUN	SEP-DEC	12-33	3.5-6.0	
21	PARAGUAY	OCT-DEC	MAR-APR	26-28	3.3-4.2	EMPIRE
22	SPAIN	APR-MAY	SEP-NOV	25-28	3.3-4.9	CAROLINA
23	SYRIA	APR-MAY	SEP-NOV	25-29	3.8-4.8	ALEPPO
24	TOGO	JUN-JULY	NOV-DEC	28-29	4.3-5.5	ALLEN
25	TURKMENISTAN	APR-MAY	SEP-NOV	24-29	3.5-5.5	DELTAPINE
	TURKMENISTAN	APR-MAY	SEP-NOV	24-29	3.5-5.5	COKER
26	**TURKEY**	**APR-MAY**	**SEP-NOV**	**24-28**	**3.5-5.5**	**DELTAPINE**
27	UGANDA	APR-JUN	NOV-FEB	26-28	3.3-4.8	BAP-SATU
28	UZBEKISTAN	APR-MAY	SEP-NOV	24-41	3.5-4.7	
29	USA	APR-MAY	SEP-DEC	26-40	3.8-4.5	VARIETIES
	USA	APR-MAY	SEP-DEC	28-30	3.0-4.0	ACALA 151T
	USA	APR-MAY	SEP-DEC	28-29	3.8-4.6	DELTAPINENC
	USA	APR-MAY	SEP-DEC	25-28	3.2-4.6	PAYMASTER 280
	USA	APR-MAY	SEP-DEC	27-28	3.7-4.7	STONOVILLE ST
	USA	APR-MAY	SEP-DEC	35-40	3.5-4.5	PIMA S7
30	YEMEN	AUG-SEP	JUN-APR	36-40	3.5-4.9	K4

Experiments have shown that cotton grown under constant artificial illumination and constant temperature has no growth-rings. On the other hand, cotton grown in artificial light switched off and on develops rings like the natural fibre. The cellulose is laid down in the form of spiral fibrils or tiny threads, some 1,000 or more to each ring. The deposition of cellulose continues for about twenty-four days, so that each mature cotton fibre can be regarded as being constructed from thousands of fibrils of cellulose arranged in spiral form.

During its period of growth, cotton is compressed tightly into the limited accommodation available inside the boll. As the cell walls thicken, the fibres are fixed in their distorted positions. Then when the boll bursts and the fibres dry out in the air, they twist lengthwise, forming convolutions which are characteristic of the fibre. These twists take place in both directions in the fibre; some are left-handed and others right-handed, with an almost equal number of each in any individual fibre.The number of convolutions varies greatly; on average, a fibre will have some 50 twists per cm [8].

Harvesting losses as high as 20 percent occur regularly, while some growers consistently keep their losses around 5 percent. Cotton is usually picked by hand or by machine in the autumn.

2.2.1. Ginning

After cotton has been picked from the plant is separated from the seed. Gins today also are equipped to remove excessive moisture, trash, and foreign matter from cotton, in order that a higher quality bale may be delivered to the spinning mill [12-13].

The gin "stand" consists of a series of circular saws mounted on a horizontal revolving shaft. These saws project through a set of steel ribs, and as the cotton is fed onto the ribs, the revolving saws engage the lint, pull it from the seed, and carry it through the ribs. It is then removed from the saws, either by brushes or by air suction, and conveyed to the baling press where it is compressed and packaged into bales. Each bale is wrapped in bagging material and tied with strong steel bands. From the gin, the fiber and the seed journey separate roads [14].

There are two forms of ginning in general use, The saw gin and roller gin.The saw gin is used mainly for short and medium length cotton, and the roller gin is often preferred for longer fibres. Roller ginning is a slower and more costly process.

2.2.1.1. The saw gin

This consists of a steel grating in which are narrow slits as shown in Figure 2.2. Through these come toothed saws that revolve, catching the fibres in their teeth and pulling them through the slits. The seeds are too big to go through, and remain behind. The ginned cotton is called 'lint'.

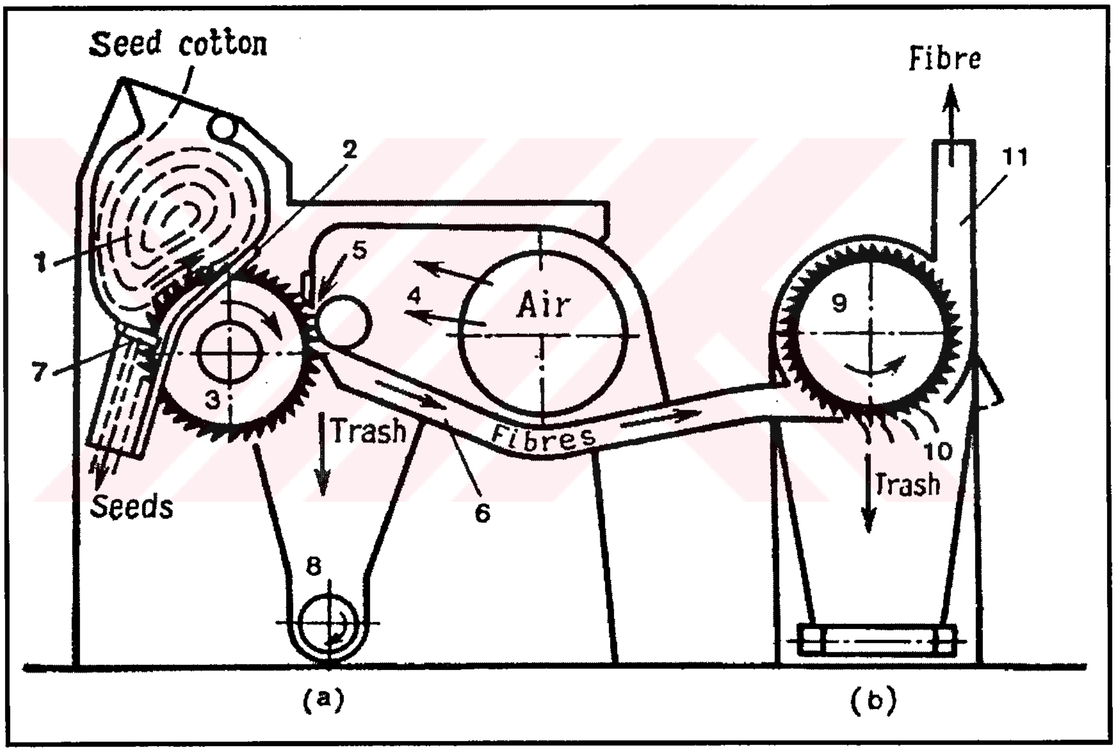


Figure 2.2. Saw-toothed fibre separator gin (a) with fibre cleaner (b) 1-Working chamber 2-Grid bar 3-Saw-toothed disk 4, 6-Pipe 5-Nozzle 7-Comb 8-Chamber 9-Disk 10-Grid

Ginning does not remove all the cotton; short fibres are left adhering to the seeds. These fibres are removed by passing the seed through another gin, and the mass of short fibre produced is used for stuffing upholstery and as a source of pure cellulose for industry [8,12].

2.2.1.2. The roller gin

The roller gin was the first mechanical device used for ginning cotton. The roller gin was invented in India centuries ago and this concept is still used in modern gins. It is a king of cotton gin which rolls are used for separating the seeds from the fiber. The main working organ of a roller gin is a roller with a pile surface by means of which the fibre is torn away from the seeds. Ginned cotton is pressed and packed into bales weighing 91 – 327 kg and sent off for spinning into yarns [12].

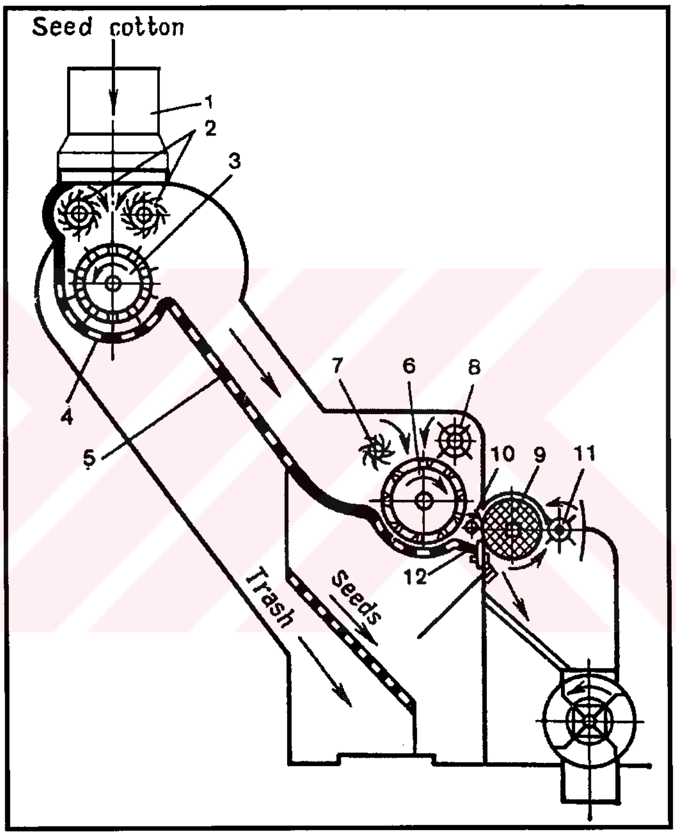


Figure 2.3. Roller gin 1-Hopper 2-Feeding roller 3-Opening drum 4-Net 5-Inclined trough 6-Needle drum 7-Ejecting drum 8-Accelerating drum 9-Working roller 10-Backing-off roller 11-Doffing roller

2.3. Spinning Processes

Cotton arriving at the mill is normally dirty and contaminated by bits of leaf, dust and twigs. Impurities will commonly amount to about 2- 3 % of the total weight. The cotton has also been compressed tightly in the bale in order to minimize transport costs.

Cotton fibers are subjected to several different processes prior to the actual formation into yarns. Before the actual spinning of the cotton can be carried out, the fibres are subjected to several preliminary processes which is including conditioning, opening and blending, cleaning, carding, drawing, combing, roving and lastly spinning. The purpose of these procedures is to open, or fluff, the fibers, clean them of any impurities, and mix and blend them into even strands in preperation for spinning process. The spinning process is a matter of reducing the prepared strands to the proper size and twisting them in such a way so that they will bind together and thus form yarns suitable for further processing into knitted or woven fabrics and other products [15].

2.3. Physical Properties of Cotton

It must be realised that there is no fibre type that possesses all the properties generally required for most end uses. The properties that are sometimes looked for in clothing are comfort, warmth, easy laundering, and the ability to withstand hard wear, hold pleats, and shed unwanted creases after use. Many finishing processes are available for modifying particular fibre properties for special purposes.

Another method of obtaining a better combination of desirable properties than is available in one type of fibre is by blending, that is mixing together fibres of different types.

Choice of fabric for particular purposes, such as beachwear, evening-wear, rainwear, cool or warm clothing, is consciously or subconsciously influenced by the properties of the fibre. The physical properties of most interest to us are listed and discussed below [16,17].

2.4.1. Shape

The cotton fiber is made up of a cuticle, primary wall, secondary wall, and lumen (Figure 2.4). The fiber grows to almost full length as a hollow tube before the secondary wall begins to form. The cuticle is a waxlike film covering the primary, or outer, wall. The lumen is the central canal, through which the nourishment travels during growth. When the fiber matures, the dried nutrients in the lumen may result in dark areas visible under the microscope. In cross section, the fiber has a U or kidney bean shape with a central canal known as the lumen. During growth this channel carries nutrients to the developing fiber. The secondary wall is made up of layers of cellulose (Figure 2.5).

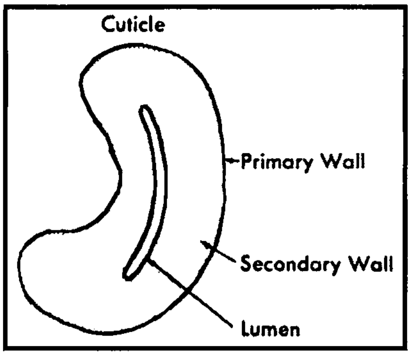


Figure 2.4. Cotton fiber

The cuticle: The cuticle of the cotton fibre is a very thin layer tightly moulded to the outside of the primary wall. It appears to consist essentially of a surface deposit of cotton wax, a complex mixture of fats, waxes and resins. During the first stage of growth, in which the fibre attains its full length, the cuticle appears as an oily film. During the second stage, in which the secondary wall is laid down, there is little or no further deposition of fats and waxes, and the cuticle becomes hard like a varnish.

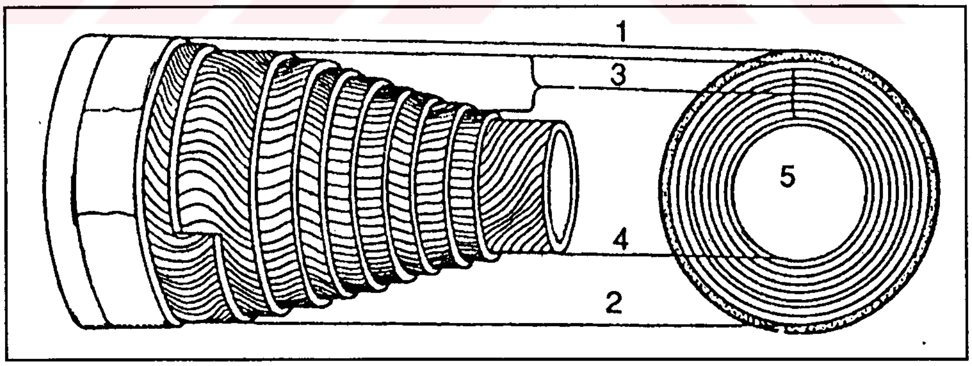


Figure 2.5. Fiber structure 1-Primary wall 2,3,4-Secondary wall 5-Lumen

The primary wall: The primary wall encloses the nucleus and protoplasm, which are the living contents of the growing plant cell. Unlike the cuticle, the primary wall is built up from cellulose, though it contains a high proportion of other substances, some of which are allied to pectin. The cellulose appears to be laid down from the initiation of growth, tending to increase as a proportion of the whole during the later stages of cell elongation.

At the base of the growing fibre, where it emerges from the epidermis of the seed, there is a constriction, but over most of its length the diameter is fairly constant. Only towards the growing tip does the fibre taper to a point. The diameter of the circular cell is of the order of 20µ (0.02 mm) but varies markedly from variety to variety and from fibre to fibre of the same variety. The primary wall is very thin, being about 0.2µ (0.0002 mm) in thickness.

With suitable swelling techniques, microscopical examination shows that the cellulose in the primary wall is in the form of fine threads, or fibrils. These fibrils do not run parallel to the length of the fibre but spiral at an angle of about 70° round the fibre axis. Both right-handed (Z) and left-handed (S) spirals are present, and a third set, almost at right-angles to the axis, has also been detected. The angle of the fibrils in the primary wall is not quite constant over the length of the fibre, being somewhat greater at the tip than at the base. Available information indicates that the S and Z spirals do not reverse direction, along the length of the fibres.

In the technical literature the term cuticle is often loosely applied to the complex consisting of the cuticle proper and the primary wall.

The secondary wall: The secondary wall, which contributes most of the weight of the cotton fibre, is composed mainly of cellulose. It is not laid down uniformly but consists of concentric layers of fibrils in spiral formation. The winding, or first layer of secondary thickening deposited on the inside of the primary wall, is largely built up of fibrils which spiral at an angle of about 20° to 30° about the fibre axis, compared with the angle of 70° noted for the most prominent fibrils in the primary wall. The fibrils in the subsequent layers of secondary thickening are finer than those in the winding, and spiral round the fibre at an angle of 20° to 45°. In these later layers all fibrils tend to follow a closely similar pattern. Fibrils are not structural features of definite length and thickness but represent portions of cellulose wall with better local crystallization.

Unlike the spirals in the primary wall, those in the secondary wall change their direction of rotation at frequent intervals along the fibre length. At the reversal points the fibrils may simply bend round in a curve; frequently, however, one set of fibrillar strands ends and a second set begins to spiral in the opposite direction. The pattern of the inclination of the spirals, and the occurrence of reversals, in the major portion of the secondary wall rarely coincide with those of the winding [18].

When transverse sections of cotton fibres are treated with a suitable swelling agent and examined under the microscope the layers in the secondary wall are seen as so called growth-rings or lamellae. Workers differ about the cause of these rings. It has been suggested that one ring is built up daily-not continuously, but with a compact zone formed during daylight and a more porous zone deposited at night. In some experiments with plants grown under continuous illumination no differentiation of the secondary wall into growth-rings could be detected [19].

The lumen: The area of the lumen of a typical fully developed fibre in the closed boll occupies about one-third to one-half of the total area of the cross-section, although there is a large variation in size of the lumen even from fibre to fibre on the same seed. After collapse of the fibre wall the area of the lumen of typical fibres is reduced to about 10 % of the whole. The contents of the lumen largely evaporate following boll-split, so that in the dried state of the fibre the lumen contains the desiccated remains of the protoplasm and nucleus.

The colour of raw cotton is chiefly determined by other contents of the lumen; this colouring matter is termed the endochrome. Most cultivated cottons range from near white in colour to a medium cream shade; there are, however, a few varieties that are khaki coloured, whilst mahogany and green strains are also known.

The layers deposited at night differ in density from those deposited during the day; this causes growth rings, which can be seen in the cross section. The cellulose layers are composed of fibrils-bundles of cellulose chains-arranged spirally. At some points the fibrils reverse direction. These reverse spirals (Figure 2.6) are important in the development of convolutions that contribute to elastic recovery and elongation of the fiber. They are also the weak spots, being 15-30 % weaker than the rest [13].

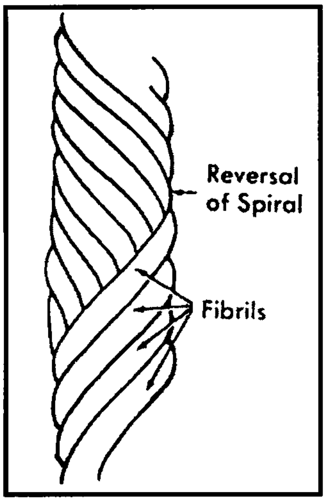


Figure 2.6. Spirality of cotton fiber

Each layer is made up of small fibrils, or minute fibrous segments. As these fibril layers are deposited, they form a complex series of spirals that reverse direction at some points. The spiraling of the cellulose fibrils causes the characteristic twists, or convolutions, in the lengthwise direction of the fiber. These twists give the magnified cotton fiber the appearance of a twisted ribbon, and they make cotton easier to spin. Long staple cotton has about 300 twists per inch; short cotton has less than 200. In spite of the twisted shape of the cotton fiber, it is relatively uniform in its size [4-20].

2.4.2. Fiber fineness

Fibre fineness is a fundamental property and governs the use to which the fibre can be put. The fineness determines how many fibres are present in the cross-section of a yarn of given thickness. Additional fibres in the cross-section provide not only additional strength but also a better distribution in the yarn. Fiber fineness influences primarily;

a) spinning limit,
b) yarn strength,
c) yarn evenness,
d) yarn fullness,
e) drape of the fabric product,
f) lustre,
g) handle,
h) productivity of the process.

Productivity is influenced via the end-breakage rate, the number of turns per inc required in the yarn (giving improvement of the handle), and generally better spinning conditions [21].

The term fiber fineness can be defined in various ways. For practical purposes it is necessary to consider only two definitions, gravimetric fineness and biological fineness.

Gravimetric fineness can be expressed as the mass per unit length of a fiber. The traditional units for linear density or mass per unit length of cotton fibers have been micrograms per inch in the USA and micrograms per centimeters in Europe. More recently the Tex system has been adopted for the linear density of fibers and yarn. Tex is grams per kilometer or milligrams per meter. The linear density of fibers is also frequently expressed as millitex, or micrograms per meter.

Biological fineness is defined either as the perimeter of the cross section of the fiber or the diameter of the cross-section of the fiber if that section was taken to be circular. Gravimetric fineness can be related to biological fineness if the wall thickness or maturity is known.

Before talking of fineness and maturity in detail, it is useful to review some facts about formation of the fiber, its growth, and the parameters to consider for a better understanding [22,23].

In a yarn of given tex the finer the fibres the greater the number in the yarn crosssection. It is found that a more regular yarn can be spun from a staple fibre if the average number of fibres in the cross-section is high. If the number is too low the yarn is irregular and liable to break at the weakest places. Thus fine staple fibres are needed for the production of fine yarns.

Table 2.2. Fiber fineness scale of cotton [21]

Micronaire value	Fineness
Up to 3.1	Very Fine
3.1 - 3.9	Fine
4.0 - 4.9	Medium
5.0 - 5.9	Slightly Coarse
Above 6.0	Coarse

Cloth made from fine fibres or filaments has a softer and smoother 'handle' than an identical cloth made from coarser fibres or filaments, because the finer fibres are much softer than coarser ones. Since the yarns are more regular the cloths are more regular in appearance and held up to the light are likely to appear better covered. The cloths form the finer fibres are also likely to have a softer and more lustre. Finer fibres are, of course, more easily damaged than coarser ones and for this reason they are associated with a lower resistance to abrasion in the fabric. Being also more flexible they are likewise more liable to become entangled in the little balls of fibre associated with the defect known as 'pilling' [1,20].

2.4.3. Fiber length

Fiber length is one of the more important characteristics of raw cotton and probably the most valuable to the spinner is the length. It influences;

a) spinning limit,
b) yarn strength,
c) yarn evenness,
d) handle of the product,
e) lustre of the product,
f) yam hairiness,
g) productivity.

Productivity is influenced via the end-breakage rate, the quantity of waste, the required turns of twist (which affects the handle), and general spinning conditions [21].

The term “staple length” refers to the length of the fiber. Cotton of a given variety will produce fibers classifiable within a more or less definite length range. Since the length of fibers in a single bale may vary, the designated staple length is that which the classer considers predominant [14].

Staple length is an assessment of a fibre with respect to its technically most important length. In the case of cotton, staple length corresponds very closely with the most frequent length of the fibres when measured in a straightened condition. Staple length is very important because it affects how the fiber is handled during spinning and relates to fiber fineness and fiber tensile strength. Longer cotton fibers are finer and make stronger yarns.

In spinning, one staple length cannot be substituted for another differing more than a small fraction of an inch without readjustment of the machinery. Difference in staple length also affects the strength of the yarn and the fineness to which it can be spun.

On the basis of staple length, cotton may be divided into four commonly used groupings. Fiber length classification is shown in Table 2.3.

Table 2.3. Fiber length scale of cotton

Length value in mm	Classification
Below 24.5	Short
25.5 – 29.0	Medium
29.0 – 32.8	Long
Upto 32.8	Extra Long

The longer the fibre, the more it contacts other fibres in the yarn and the more they are difficult to draw apart. Consequently, using longer fibres it is possible to obtain a stronger yarn of the same linear density, or also from longer fibres it is possible to produce finer yarn of normal strength. Long-staple fibers are considered to be of finer quality because they can made into softer, smoother, stronger, and more lustrous fabrics. They have a higher price and less is produced than the medium and short staple lengths [20,22].

2.4.3.1. Management to increase length

Fiber length is controlled to a large degree by variety, although weather and management can also influence the final fiber length. Since maximum fiber length is determined during the elongation phase of fiber development (the first 16 to 20 days), fiber length of young bolls will be most effected by weather and management. High temperatures during the elongation phase of fiber development results in shorter fiber. Fiber length is also decreased by severe water stress and potassium deficiency. Both of these decrease the internal water pressure or expansive force of the elongating fiber. To affect lint length, moisture stress must reach such a severe level, in excess of 24 bars, that yields would be cut by 25 to 50%. On the other hand, potassium deficiency can reduce fiber length even at moderate levels of yield loss due to the very sensitive nature of fiber quality to potassium levels in the boll [22].

Moderate temperatures during the first 3 weeks of a boll's development increase fiber length in that boll. The same cotton variety grown in mild or wet climates usually has longer fiber and lower micronaire than from hotter or dryer regions.

2.4.3.2. Ginning influence on length

Fiber length also can be influenced by ginning and lint cleaning, especially when the moisture is below recommended levels. Gin cleaners will remove more trash at low moisture, but more fiber damage will result. The ideal ginning moisture range is 6-8 %. For each 1 % reduction in fiber moisture below 5 %, the staple length would be reduced approximately 1 hundredth of an inch, and the uniformity reduced approximately 1 uniformity index percent.

2.4.3.3. Importance to spinning

One of the major differences between man-made fibers and cotton is the presence of short fibers in ginned cotton. Not only does fiber length on one seed vary widely, but also ginning and cleaning breaks fibers into shorter segments.

Length uniformity index, referred to as "Uniformity", is an indication of short fiber content and thus is important to the textile industry. Current technology does not allow us to measure short fiber content with HVI. But the combination of staple length and uniformity does allow the estimation of short fiber content (percentage by weight of fibers shorter than 1/2 inch). Excessive short fiber content is important because it increases textile manufacturing waste, lowers yarn strength, increases the difficulty of spinning fine count yarns, and causes fuzzy yarn and other imperfections. Higher short fiber content not only increases losses as these fibers are cleaned out in textile mills carding and combing but also contribute to spinning difficulties if not removed.

2.4.4. Strength

Fiber strength is its ability to withstand strecthing efforts. The strength is evaluated by the load at rupture, i.e. the highest effort which the fibre withstand before breakage. Cotton is a moderately strong fibre. The strength is affected greatly by moisture and by the test conditions such as rate of loading, and length of fibre section tested [8].

Table 2.4. HVI strength classification [8]

Degree of Strength	HVI Strength (g/tex)
Very strong	30 and above
Strong	26 – 29
Average	22 - 25
Intermadiate	18 - 21
Weak	17 and below

As can be understand the table above strength of cotton on a scale of high, medium, and low would rank as medium. It has a fairly high degree of crystallinity but somewhat lower orientation. The strength is increased by the lentgth of the polymer chains. In comparison with other cellulosic fibers, cotton is weaker than flax and stronger than rayon.

A single cotton fiber will sustain a dead weight of two to eight grams. Such a fiber is not very strong, but the finished cotton cloth can be made very strong if tightly twisted, mercerized yarns are used in it. Mercerization adds both strength and luster. Through scientific breeding, cotton farmers are growing a better product-longer, finer, more lustrous, and stronger. With further developments in scientific breeding there are even greater possibilities of improving the value of cotton for the end uses the consumer wants [13].

Cotton is 10 to 20 percent stronger when wet than when dry. Its strength can be increased by a process called mercerization in which yarns or fabrics held under tensions are treated with controlled solutions of sodium hydroxide. The alkali causes the fiber to sweel and straighten out and to become stronger and more lustrous [4,24].

2.4.4.1. Management to increase strength by variety

We have known for many years that fiber strength is highly controlled by variety, but only recently has this relationship been understood. Recent biochemical research into fiber strength has shown that varieties with strong fiber tend to produce longer cellulose molecules.

Longer cellulose molecules provide fewer break points in the lint and greater cross linkages between fibers. This relationship is perfectly analogous to the benefit of longer fibers in yarn strength. Long fibers can extend through more twists in the yarn with fewer breaks between fibers. Since short fibers are loosely inserted into the yarn, the load or strain is carried primarily by the long fibers. Other characteristics of cellulose deposition may also be important in fiber strength.

2.4.4.2. Management to increase strength by growing environment

Environment does have a small effect on strength, although the environmental factors that influence strength are unknown.

2.4.4.3. Management to increase strength by cultural practices

Potassium deficiency can decrease strength by up to 2 grams force per tex. Any factor that causes either physical or microbial damage to the fiber will reduce its strength, such as extreme weathering or over ginning. In the section on length, the relationship between high yield and high quality was discussed. Within a variety's potential, production practices that promote maximum yield also increase strength.

Selecting a high quality variety and growing it for maximum yield are two of the three most important steps to high quality cotton. The third step, is clean defoliation and timely harvest.

2.4.4.4. Management to increase strength by ginning effects on fiber strength

The effects of ginning on fiber strength are minimal except in the case of excessive heating, which decreases strength.

2.4.5. Neps

Neps are small tangled knots of lint hair that show up in ginned lint and manufactured cotton products. Nep in cotton have been a major problem in processing for many years. Neps appearing in all stages of textile processing up to dyed fabrics were extracted from cotton samples. We know that neps are formed during harvesting, ginning, and processing operations, but as yet no precise cause has been determined. Finer fibers tend to nep more frequently and easier than coarse fibers, but the significant of this sort of nepping is not high enough to create a major problem in textile processing, assuming that the maturity of the fine fibers is in a reasonable range [21,25]. In cloth neps appear as specks. Specks on a fine undyed fabric such as muslin or white poplin are objectionable because they spoil the translucent or level appearance. The trouble is frequently more pronounced in dyed fabrics, in which surface specks often differ in shade from the bulk of the material. Specks may be classified into various types according to their composition [18].

Specks in the form of balls of entangled fibres are termed neps. Sometimes they are fairly large, as much as 2-3 mm across; at the other extreme they consist of only a knotted single fibre. The number of neps often increases with staple length and fineness of the cotton used. It has been found useful to group neps into the following five main classes.

a) A process nep consists of a tangle of normal fibres or of fibres having about the same average maturity as the bulk. These neps are caused mainly by faulty processing (frequently bad carding) of a cotton that, if properly processed, would not give rise to trouble. Some may be formed by bad ginning.

b) A mixed nep is one which consists of a tangle of typical lint fibres gathered round a nucleus such as a fuzz fibre, a minute piece of foreign fibre accidentally present, or even an abnormally coarse, short lint fibre.

c) Immature neps are caused by the tangling of the weaker, poorly developed, and less rigid immature fibres, either with each other or with a few normal fibres. This type is often found in yarns spun from cottons containing a high proportion of dead and thin-walled fibres.

d) A homogeneous dead nep consists of a small close tangle of dead fibres, all with little or no secondary wall thickening. Like the previous class, it frequently occurs when a cotton is immature, because of either poor conditions of growth or severe attack of the plants by pest or disease.

e) A fuzz nep consists of a tuft of short fuzz fibres. In finished fabrics many of these neps originate from fuzzy motes from which the seed-coat has been removed in the finishing processes. Some, however, are caused by the wrenching of tufts of fuzz fibres from the seed during ginning. The short length of these fibres prevents satisfactory drafting and fibre-to-fibre separation in spinning. This fault is not peculiar to cottons with fuzz-coated seeds; it is sometimes noted in closely woven cloths spun from Egyptian-type cotton in which the small fuzzy tips of the seeds have disintegrated to cause the trouble.

2.4.6. Elongation and elasticity

Elongation and elasticity are also important fibre properties. When stretching efforts are applied to the fibres they are subjected to elongation, i.e. to deformation. We distinguish between two kinds of deformation: the reversible one comprising resilient and elastic deformations, and the irreversible or plastic deformation. The resilient elongation (resiliency) is connected with inconsiderable changes in the distances between particles of polymers composing the fibres, which disappears immediately as soon as the load is removed.

The elastic elongation (deformation) is that which does not disappear immediately upon removal of the load, but in the course of time.

The plastic (residual) elongation does not disappear, even after load removal. The elastic elongation is connected with a change in the configuration and array of fibre polymer macromolecules. Plastic elongation occurs as a result of irreversible shifts over comparatively great distances between the links of macromolecules.

Fibre elongation and particularly resilient elongation is a very precious property. The greater is the fibre elongation at the given load, the better it withstands spontaneous impacts. The greater is the fibre-resilient elongation, the better is the capacity of the fibre to withstand reiterated loads and the longer the goods produced from these fibres retain their shape and properties.

Cotton does not stretch easily. The total elongation of cotton fibres at rupture (depending on the quality) amounts to 5-10 % , half of which is due to flexible and elastic elongation. The resilient breaking elongation of the cotton is higher than that of bast fibres, yet inferior to that of wool and silk.

Such mechanical fibre properties as the resistance to wear, compression, bending, and slippage of one fibre over another are also of great importance. The resistance of fibres to rubbing is essential because yarn made of fibres with high wear resistance may be easier processed in the loom, where it is subjected to reiterated rubbing actions. Secondly, the goods or fabrics made of such fibres wear longer [5,21].

2.4.7. Uniformity index

Uniformity of fiber lengths within a bale or sample is measured using information about the fiber length distribution. Statistically, it is measured by the range, standart deviation or coefficient of variation.

HVI systems determine length uniformity by dividing the mean fiber length by the upper half mean length. Said another way, uniformity is the ratio of the average length of all the fibers to the average length of the longer half of the fibers. If fibers were all the same length they would have a theoretical uniformity of 100. A high uniformity (above 82) indicates that the mean length is close to the upper half mean length. Under these conditions, few short fibers (less than 1/2 inch) are present, thereby reducing waste in the textile mill. A uniformity of 85% is considered very high [22,26].

Table 2.5. Uster tester HVI uniformity index

Descriptive designation	HVI Uniformity Index
Very High	Above 86
High	83-85
Average	80-82
Low	77-79
Very Low	Below 76

2.4.7.1. Management to increase uniformity index

Unlike length and strength, uniformity index and short fiber content are affected little by variety. Fiber strength has a slight effect on uniformity. Stronger fibers are less vulnerable to breakage in the gin. Field weathering and ginning have a more dramatic effect on uniformity and short fiber content.

Cotton which has weathered due to excessive rain (greater than 2 inches) on the open bolls deteriorates and is more susceptible to fiber breakage during processing. Weathered cotton suffers increased short fiber content and reduced uniformity in the gin and textile mill. Boils set late in the season and boils on vegetative branches also suffer increased short fiber content. Preliminary information indicates that cotton produced in 30 inch rows may have higher uniformities and lower short fiber contents. High length uniformities (greater than 82) can be obtained by careful ginning and producing strong cotton for early harvest that avoids weathering, with a high percentage of the crop set early at the 1 st and 2 nd position on the fruiting branches.

2.4.7.2. Ginning effects on length uniformity

Ginning machinery can have a major influence on length uniformity, especially lint cleaning at low fiber moisture. Ginners should keep fiber moisture in the 6-8 % range and use only enough lint cleaning to deliver satisfactory trash levels. With good production and harvesting management, this should be accomplished with 2 stages of lint cleaning on trashy seed cotton and 1 stage on clean seed cotton.

2.4.8. Maturity

Maturity can be determined by viewing microscopic cross sections of cotton fibers that have been treated with a caustic solution. The ratio of cell wall thickness to fiber diameter reflects the degree of maturity [23].

Fibre maturity is not an estimate of the age of the cotton fibre, the period of growth between flowering and picking. It is simply a measure of thickening of the secondary fibre wall which established between the cessation of increase in fibre length and the bursting open of the fully-developed boll (Figure 2.7).

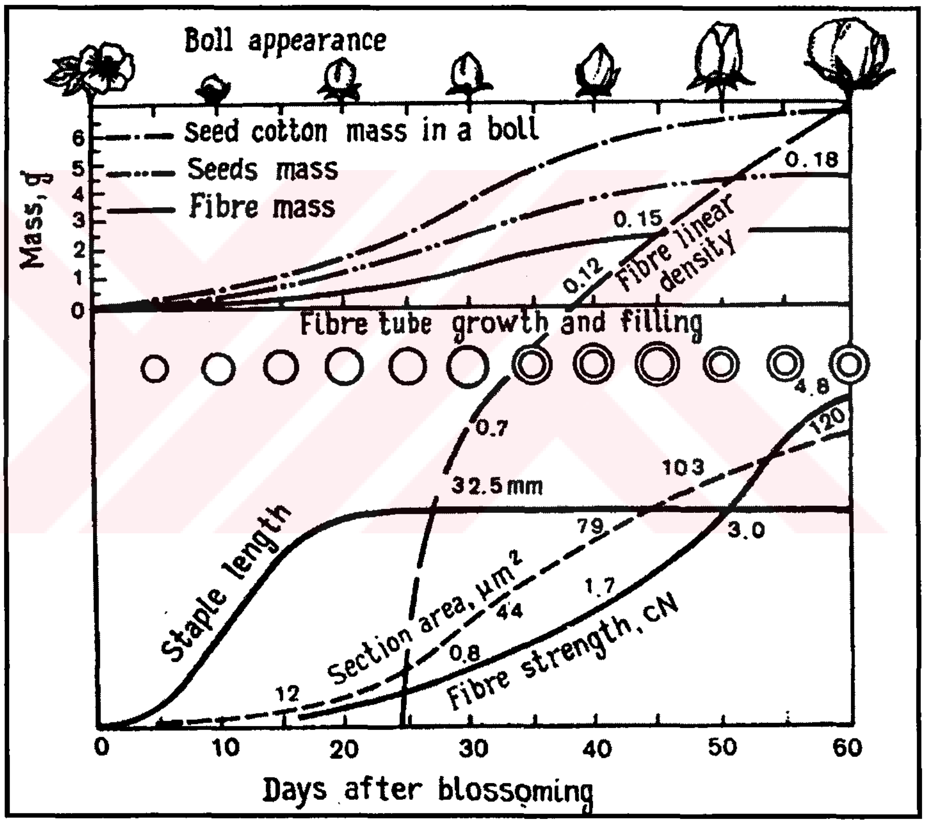
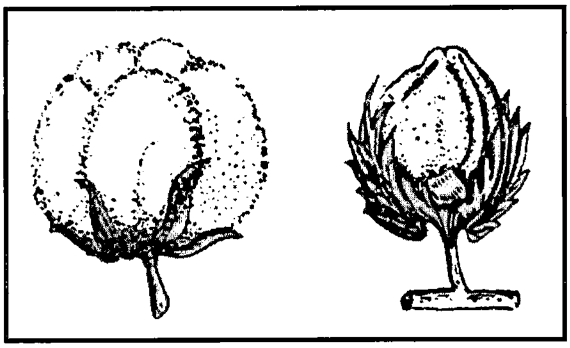


Figure 2.7. Fibre growing periods

Cotton grown under favourable conditions largely consists of mature fibres with fairly thick walls, but always contains some poorly-developed fibres. If growth conditions are not favourable, possibly as a result of attack by disease or pests, of plant senility, or occasionally because of the genetical nature of the variety, the onset of secondary wall thickening may first be delayed and then proceed at a reduced rate, and the ripened boll will contain a high proportion of poorly-developed immature fibres. Nevertheless, except under extreme conditions, even an immature sample generally contains a small amount of mature cotton (Figure 2.8. and Figure 2.9.).



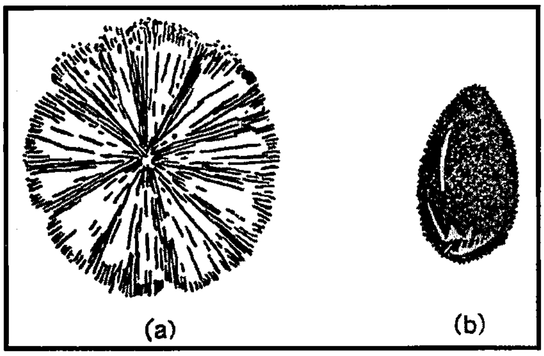


Figure 2.8. Maturing of cotton boll

Figure 2.9. Mature cotton
a) pappus b) seed

Degree of maturity

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0

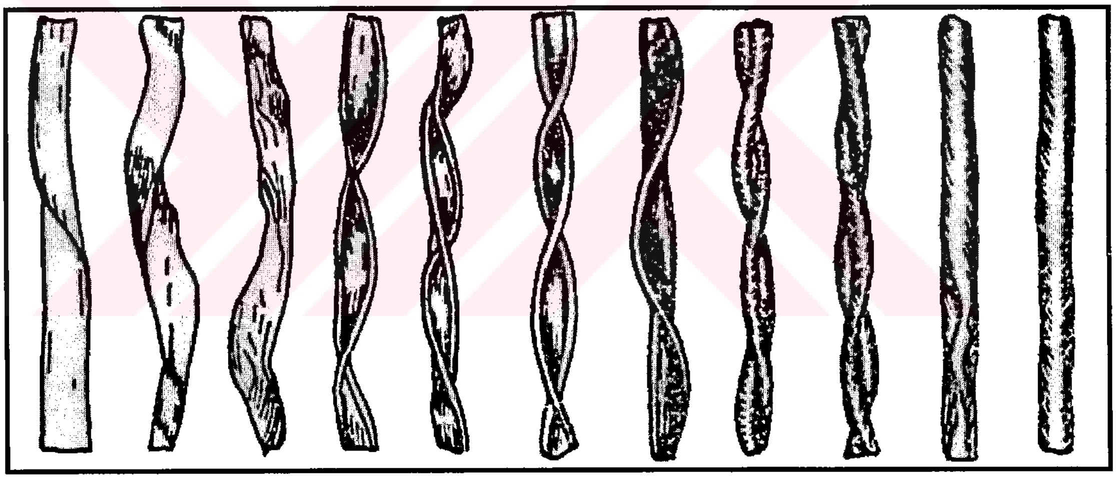


Figure 2.10. Fiber apperance as viewed through microscope

0.0 Absolutely immature – Dead fibre, 1.0 Immature, 2.0 Not quite mature, 3.0 Mature, 4.0 Completely mature, 5.0 Overmature [7]

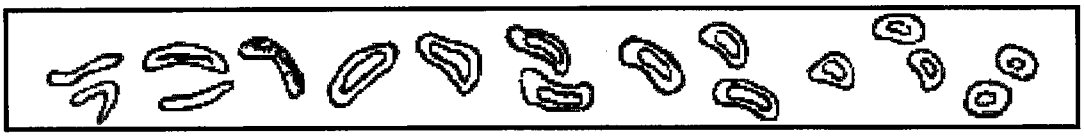


Figure 2.11. Fiber cross sections

Fibres from different fields, different plants, different bolls, or even from the same seed differ markedly in the pattern of growth of their wall thickening. Hence, in any handful of raw cotton there are large variations in the maturity of individual fibres (Figure 2.10. and Figure 2.11.) [19].

2.4.9. Crimp

A characteristic feature of practically all staple fibres, which cannot be neglected in any discussion of fibre length, is crimp. Crimp, which in general terms may be defined as the waviness of a fibre, is of technological importance in several contexts. In brief, it determines the capacity of the fibres to cohere under light pressure and so in turn determines the cohesiveness of card webs, the amount of fly liberated during processing, and the hairiness of the resultant yarn. It is also the principal feature governing the bulking power of a textile material and, generally, the specific volume of yarns and fabrics.

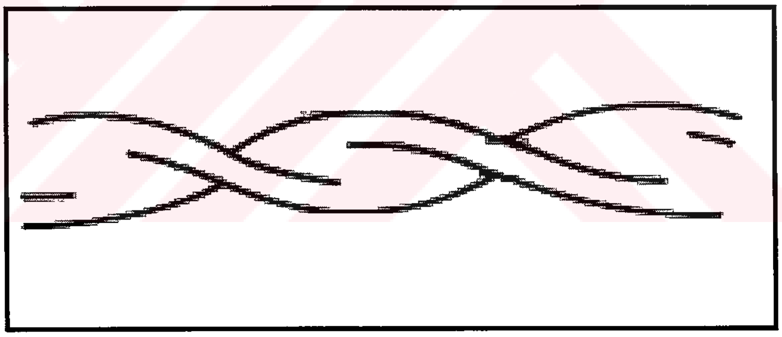


Figure 2.12. Natural crimp of cotton fiber

It may be measured in terms of either the number of crimps or waves per unit length or the percentage increase in extent of the fibre on removal of the crimp. With strongly crimped fibres, the force necessary to straighten a fibre may be enough to cause some actual elongation of its axial length, but this is not likely to be of any moment unless the fibre is exceptionally extensible (Figure 2.12.).

2.4.10. Color

Cotton fiber is generally white to tan or creamy white in colour. As it ages, it becomes more beige. If it rained on just before harvest, the fiber is grayer. White fiber is preferred [24].

Picking and ginning affect the appearance of cotton fibers. Carefully picked cotton is cleaner. Well-ginned cotton tends to be more uniform in appearance and whiter in color. Poorly ginned cotton has brown flecks in it called trash, such as bits of leaf, stem, or dirt. These brown flecks decrease the quality of the fiber, fabrics made from such fibers include utility cloth and occasionally are fashionable when a "natural" look is popular [23].

NCC is also available. Small quantities of cotton in shades of brown, rust, and green are produced in California, Arizona, Texas, and also in Turkey. The developer is working on growing naturally colored blue, yellow, and lavender cotton, and also marketing.

There are also six distinct color groupings indicating the degree of whiteness, these being;

a) extra white,
b) white,
c) spotted,
d) tinged,
e) yellow stained,
f) grey.

2.4.11. Luster

The characteristic of cotton known as lustre is difficult to define. It is a subjective visual attribute and so may be appreciated differently by different people. For example, when an observer examines a piece of fabric for lustre commonly rotates it about in order to note the light reflected from it at different angles. In some positions the surface appears bright and in others dull; if the effect is both pronounced and pleasing the observer considers that there is a desirable lustre. Lustre is thus a complicated aspect of light reflection from a surface.

When light falls on a surface, part is reflected, part passes through the medium, and the remainder is absorbed and converted into heat energy. The first component, the directly reflected light, is frequently the most important factor determining lustre.

Because lustrous effects depend on regular reflection along the length of the fibres it will be appreciated that there will be a more pronounced mirror effect if the fibres are in the form of round cylinders rather than if they are irregular in shape. By measuring the intensity of reflected light at the angle of specular reflection, various workers have found that lustre increases as the fibres tend to become more circular in crosssection. Thus mature cottons are generally more lustrous than immature cottons. Untreated cotton has no pronounced luster. Therefore cotton fabrics that need to be lustrous to imitate silk must be mercerized to produce the desired results. Mercerization of cotton produces fibres with a more circular cross-section, and is a process carried out commercially on yarns and fabrics primarily to give a more pleasing lustrous appearance [13,24].

Nevertheless, the shape of cotton fibres is not the sole factor responsible for lustre. Cotton mercerized without tension has a much rounder shape of section than untreated cotton, but there is no corresponding pronounced increase in lustre. Again, fine long cottons usually appear more lustrous than coarse short cottons of the same maturity. Attention must also be given to other light-scattering effects, particularly to those within the fibre. A fibre is relatively transparent, and much more light passes through it than is reflected at its outer surface.

Intrinsic fineness may be an important factor in itself, quite apart from the relation it normally has with orientation, because intrinsically fine varieties have a smaller wall thickness than intrinsically coarse types for a given fibre maturity. Light that has penetrated the top fibres in a layer, and subsequently emerges after undergoing possibly several stages of reflection and refraction, makes a bigger contribution to the specular effect if at each stage it passes through the small thicknesses of fine fibres [19].

2.4.12. Linear density

The fibre linear density is of a very great importance of textile fibres. The strength of the yarn manufactured of fibres depends on their strength and on the friction forces between them. The greater is the number of contacts between the fibres in the cross section (which in its turn depends on the number of fibres), the higher are the friction forces. In consequence, the finer the fibres, i.e. the lower the linear density, the greater is their number in the cross section of the given yarn and the stronger is the yarn. Otherwise said, the finer the fibres, the finer is the yarn with normal strength which may be obtained at their processing. Therefore, medium staple cotton is used for manufacturing yarn of medium linear density and long staple cotton-yarn of low linear density used to manufacture thin or high-strength fabrics, knitted goods and threads. The greater is the fibre cross-sectional area, the higher its linear density. Cotton has a specific gravity of 1.54. (Compare with that of polyester at 1.38 or nylon at 1.14.) This means that cotton fabrics will feel heavier in weight than will comparable fabrics made from polyester or nylon [5,24].

2.4.13. Elasticity and resilience

Like most other cellulosic fibers, cotton has low elasticity and elastic recovery. Cotton fabrics also wrinkle easily and do not recover well from wrinkling. In stretching or wrinkling, hyrogen bonds between chains are broken and then reformed in the new position, holding in the wrinkle or other deformation. Through the application of durable press resin finishes, however, resilience can be improved. Unfinished cotton fabrics generally must be ironed after laundering.

2.4.14. Absorbency and moisture regains

Because of its many hydroxyl groups, which attract water, cotton is an absorbent fiber. Its good absorbency makes cotton comfortable in hot weather and suitable for materials where absorbency is important (such as diapers and towels). It is relatively slow to dry because the absorbed moisture must be evaporated from the fiber. For the same reason, cotton fibers take waterborne dyes readily. The percentage moisture regain of cotton is 7 to 8 percent at standard temperature and humidity [27].

2.4.15. Dimensional stability

Cotton fibers swell considerably in the transverse direction when wet. Unfinished woven or knitted cotton fabrics will shrink in the first few launderings because the laundering releases tensions created during weaving or finishing. The relaxation of these tensions may cause changes in the fabric dimensions. Cotton fabrics can be given special finishes to prevent this relaxation shrinkage.

2.4.16. Heat and electrical conductivity

Cotton conducts electricity and thus does not build up static electrical charges. It has moderately high heat conductivity; which makes the fabric comfortable in hot weather. Cotton is not thermoplastic and will not melt. Exposure to dry heat at temperatures about 148°C, however, does cause gradual decomposition and deterioration of the fiber. Excessively high ironing temperatures cause cotton to scorch or turn yellow.

Cotton is compustible. It burns upon exposure to a flame and will continue to burn when the flame has been removed. Burning cotton fabric smells like burning paper, and a fluffy, gray ash residue remains. It is not possible to distinquish cotton from other cellulosic fibers by burning.

2.5. End Uses

The range of items for which cotton fabrics are used is enormous. In wearing apparel, the qualities of comfort, dyeability, and launderability have led to its wide use in articles ranging from underwear to evening gowns. In the home, bed linens, table linens, draperies, upholsery and slipcover fabrics, and towels are frequently made from cotton.

CHAPTER 3
NATURALLY COLOURED COTTON (NCC)

3.1. Introduction

Cotton is a cheap textile and the plant is easily cultivated and handled in primitive home industry, it spread far into temperate climates, and races of annual habit were formed in each species.

There are certain kinds of cotton fiber outside the traditional production/ market/ utilization chain that satisfy the requirement for "niche" industries. These fibers address specialty markets, environmental agendas or new research technology for improved quality. Three major niche fibers and their classifications are:

a) Organically produced cotton
b) Cage - ginned cotton
c) Naturally coloured cotton (NCC)

Other possibilities for niche markets include high micronaire cotton for tube socks or very coarse fiber for shoulder pads, genetically engineered cotton with high absorbency for medical and industrial uses, markets for reclaimed gin motes, and fiber contracted with special processing requests in harvesting or ginning.

Whether the special value of a niche cotton comes from production method, fiber characteristic, or technology, they all require some kind of special care or handling and a departure from the traditional classification and/or marketing of fiber [22].

3.1.1. Organically-grown cotton

Organically-grown cotton has appeared as a small, new niche in the international cotton market. Market research indicates that consumer interest in organic cotton products is increasing, not due to concern about detrimental residues on conventional cotton products but because of consumers' concern about the environment in general. Organically grown cotton is an environmental agenda market brought about by major shifts in values.

The market for organically produced food has increased dramatically in the last decade because of consumer concern about food safety. Those consumers who have expressed a preference for organic clothing and bedding are not worried about the effects of traditionally produced textiles on their health; rather, they would like to use their buying power to encourage producers and processors to use environmentally benign methods.

The fiber properties available in organic cotton are similar to the fiber properties available in conventional cotton in each region. Organic producers traditionally choose varieties with high-quality potential because it is a valuable crop. In regard to quality other than the genetic potential of physical fiber properties, organic production can affect.

3.1.2. Cage-ginned cotton

This is an example of a niche market created by technology. In saw ginning, cotton fiber is pulled by rotating saws through slots too small for the seed to pass between. The initial fibers grasped by the saws are normally the longest fibers. As the seed cotton continues to rotate in relation to the saws, all the fibers are ultimately removed to create the Poisson distribution of fiber lengths naturally present on the cotton seed. In cage ginning, the first fibers removed are separated, creating a lint sample that is more skewed to the long end of the fiber spectrum.

Benefits:

a) more uniform length distribution,
b) longer fiber,
c) less waste,
d) ability to produce more expensive end-products less expensively.

Limitations:

a) limited to the long-fibered upland cottons,
b) pima cottons are roller-ginned and the procedure is not cost-effective for short or medium staple cottons,
c) expensive procedure.

For a technological niche to succeed, the benefits must outweigh the costs. In this case, it is not the expense of growing the cotton, but the added expense in ginning that demands the premium. This technology is so new that there is not enough data to definitively state a cost/ benefit relationship [22].

3.1.3. Naturally coloured cotton (NCC)

NCC is a naturally pigmented fiber that grows in shades of green and brown. Historical records report the existence of browns with pink and lavender lints. The natural color is due to the plant's inherent genetic properties. Shades of coloured cotton can vary over seasons and geographic location due to climate and soil variations. It is a specialty market fiber for people allergic to synthetic dyes or upscale environmentally-conscious consumers. NCC is also used as a supplement fiber in organically manufactured cotton.

Kerr is investigated growing ring structure of secondary wall in cotton, he found that green lint colour is located in secondary wall [28]. It is reported that for the first time seed capsule of cotton is opened, very bright green colour is faded to tan when exposed to light.

Ware and Benedict are investigated economical importance of NCC [29]. They are clarified that NCC is used in two ways with different aims. One of them is pointing out of gene and other is directly used in textile industry with no dyestuff need. The majority of NCC varieties are of lesser quality (strength, length, micronaire etc.) than most conventional standart white cotton fibre and also directly influenced the yarn properties. Therefore it is not suitable for conventional manufacturing methods.

Infusıno and Brookhart are informed that Sally Fox is started to breeding programs in California in 1982, she managed to produce machine spinnable naturally coloured cotton in 1988 [30]. In measurement of color change after laundering with detergent alone, the NCC fabrics tended to become more colour intense. There has been growing interests in the use of NCC in niche market where chemically dyed textiles have traditionally been used. It grows worldwide in a variety of earth tones, eliminating the need for dyes. It also eliminates not only wastefull expenditure of dyestuff but also labour cost, time and money if we consider the yarn and fabrics dyeing and printing expanture. Therefore it is more economical than conventional standart white cottons. And also they introduced that Sally Fox is working on improving fibre quality in a range of others colour; greys, oranges, yellows even a mauve. She plan to insert into cotton plants the genes that are responsible for production of the blue and black colour.

Apodaca is researched to NCC and organic cotton's cultivation, marketing, processing. Low input cost, decrease agricultural chemist or eliminates pesticide, herbicide are another advantages of cultivation NCC and organic cotton. Not only farmers, but also textile industry attract attention of using them for low cost and environmentally friendly products. In order to marketing of these products, there must be some advantages besides white cotton for example economical, demands from customer, supporting by goverment and etc.

The aim of Vreeland's work is about historical perspective and cotton's anthropology [31]. James M.Vreeland, who has been researching on coloured cotton, reports in an article in Scientific American (April 1999) that has a history of more than 5000 years. Several lint colours brown, black, mahogany red, red, khaki, pink, blue, green, dirty white and, of course, white are found in the four species of the genus Gossypium. The species Gossypium barbadense and Gossypium hirsutum were being cultivated in South and Central America as early as 2300 B.C. Fibre from these was mainly used for weaving fishing nets. The idea was that colour nets might not be readily seen by the fish. In the sixteenth century, it was a tradition to present clothes made of coloured cotton as gifts. The other two species-Gossypium arboreum and Gossypium herbaceum were cultivated mainly in Asia and Africa, about 4200 years ago. And also Egyptian were used to wrap mummies. Coloured cotton was probably brought to the United States from Mexico, where it was routinely hand spun and woven by slaves on plantations. NCC has been used by hand spinners and weavers of Acadian communities in Louisiana since the 1700s, and by others in Mississippi. It is reported that in the Second World War, because of the shortage of synthetic dyes, the earstwhile Soviet Union cultivated coloured cotton in large quantities to produce soldiers uniforms. Textile companies wanted to market NCC products internationally. We, now produce colourful cotton products in a large product range from socks to sheet. Indeed, the future of coloured cotton looks brigth in many places.

It is reported officially in 1994 that brown cottons and high fiber quality white upland cotton is crossbreed as generating of new types of coloured cottons [32]. The results shown that new crossed brown lint cotton fibers have better physical and mechanical properties than orijinal brown cottons. Therefore, genetics tried to improve characteristics of NCC for commercial production by using crossbreed methods.

In Kimmel study, as we know that earthy tones colourful cottons fibers tend to be shorter and weaker than white varieties, which limits their commercial prospects [33]. As a results, spinning coloured cotton yarn is difficult unless the coloured fibers are mixed with white cotton. This king of blending helps textile makers to process the fiber and strength the yarns, but it is also reduces colour intensity. Kimmel used two patented methods ARS, staple-core and filament-core spinning, to produce composite yarns. Yarns made this methods contain an outer layer of NCC fiber and inner core of stronger white cotton or synthetic fibers. The results, a bicomponent yarn contain two types of fibers that are securely sandwiched together. Consequently, the fabrics look and feel like solid coloured cotton but are stronger than those made from the same fibers on typical machine. The goal of this technology is to maintain desirable attributes of cotton, such as comfort and style while deriving benefits from the fibers hidden in the center of the yarn. According to experimental results, synthetic corefibers achieve improved fabric appearance and durability for cottons in general. When heat-set, these fabrics would allow clothing to hold its shape better after laundering with fewer chemicals. One advantages of these techniques is that they are easily adapted to conventional spinning frames. Both staple-core and filament-core spinning methods use special devices to control the fibers and direct them to their proper position in the yarn. The core fibers, which give the yarn strength, are hold in the center by a carefully engineered groove, while the coloured fibers converge from both sides, intelocking around them. Experimental yarns containing pure coloured cotton surfaces are up to 50 % stronger than pure coloured yarns spun by traditional methods.

Abdalah and William examine the color effects of known (quantified) contamination of naturally white cotton with existing varieties of NCC, using bleaching procedures that are considered to be moderate in the U.S. textile industry [34]. Results provide

(1) perspective about risk inherent in allowing NCC varieties to be grown along with the naturally white cotton varieties, and (2) quidance to the textile industry in processing naturally white cotton that is contaminated with NCC. The coexistence of NCC with the naturally white varieties brings, even with effective regulatory controls, a possibility of minor contamination that worries the textile manufacturing sector and the cotton production sector that serves it.

McDaniel shown that there has been growing interests in the use of NCC in niche markets where chemically dyed textiles have traditionally been used [35]. Although the color range of NCC is limited and these fibers appear to be weaker than their conventinal white counterparts, the need for a naturally colored textile which does not require man-made dyes, appears to be growing among certain user groups. In this study small quantities of four cottons with distinctive hues ranging from light tan to cinnamon and green, grown by the University of Arizona, are converted into sliver and spun into both ring and rotor yarns using industrial-scale equipment. Fiber and yarn test are performed in order to compare the cottons, and the yarns are inserted into a woven fabrics as a filling yarns. There is evidence that shades varies with micronaire value. The weakest, shortest cotton is the dark cinnamon type, which provides the weakest, least regular yarns. The strongest cotton is the champagne variety, which is also the longest and coarsest of four types evaluated. The strongest, most regular yarns are provided by the green cotton. Light cinnamon and champagne cottons produce yarns of similar tensile and regularity properties.

Dickerson is evaluated the effects of various laundry aids- detergents with optical brightness, phosphades, and chlorine and non-chlorine bleaches- on color retention, durability, abrasion, bursting strength of fabrics constructed of naturally coloured cotton and white pima cotton fabrics [36]. Test fabrics were 100 percent naturally coloured cotton with green, brown and red cotton fibres provided by BC Cotton Inc. Fibers in this study came from the same season, and were grown in approximately the same geopraphical area. Yarns and fabrics were constructed from the same spinning and knitting machines. Conventional dyed fabrics typically fade or change in some way during the laundering process. Consumer laundary products contain a variety of ingredients designed to lift and remove soil, bleach stain, brighten colours and soften hand. These products can change the aesthetic apperance of the fabric by altering the colour and/or texture. NCC knit and white pima cotton fabrics, had relatively good abrasion resistance, dimensional stability and pilling resistance. NCC fabrics had less bursting strength than the white pima cotton fabrics. All fabrics were laundered by each of the five laundering methods 5, 10, 15, 20 laundery periods and evaluate at designated laundary periods for selected performance characteristics. Colour of fabrics may not change significantly close to the orijinal hue, however colour is more sensitive, 5 as “negligible” or “no change”.

Parmar is studied is to determine how coloured cottons behave during burning and what are the main factors and their effects on burning characteristics [37]. The flammable components in gaseous products burn to produce additional heat to convert the liquid and tarry products to flammable vapors that further propagate flamming combustion. This process continous till only a carbonized residue is left. Because this residue does not support flaming, the fist phase of combustion-flaming combustion–comes to an end. Although naturally coloured cotton has a similar composition of different components like cellulose, etc. the presence of the natural colour makes it different from white cotton. The limited oxygen index value of it is also higher than for white cotton, which makes its flammability poor.

3.2. Genetics of Cotton

The textile industry is a dynamic one. Constant pressure from synthetic fibers and blended fibers has prompted cotton textile manufacturers to look ahead for better and more efficient ways to manufacture products containing cotton fiber. Improved gin technology, high-speed spinning technology, and new and creative ways of blending and finishing fiber have all placed increased demands on not only conventional white cotton but also NCC lint. The message to the grower, the genetic engineers, the agriculturist and the breeder is that new niche market NCC will be needed to meet the needs of twenty-first-century textile manufacture [38].

Most of the commercially useful characters in cotton, whether partly qualitative or altogether quantitative, are gradually built up to higher expression levels by addition of more supporting modifiers or genes. Most characteristics for improving cotton are inherited as quantitative traits. Factors such as yield, earliness, fiber properties, resistance to pests, stress resistance, and ease of management are conditioned by quantitative genes. Many researchers have been frustrated in attempting to solve their genetic problems by using simple genetic models, however few genetic parameters are used to describe complex situations. Quantitative traits are difficult to study because,

a) their expression is modified by environmental and management fluctuations,
b) a trait, such as yield, is a composite of many other traits, each influenced by many genes, each of which has variable effects,
c) the expression of an individual gene is often modified by the expression of other genes,
d) linkage blocks are difficult to breakup,
e) the optimum genotype for a given environment-management system may require gene contributions from many diverse sources.

The gene action and reproductive system of a genetic population provide the information necessary to choose the best selection strategy for that population. The most widely used method in cotton has been the mutation, crossbreeding, as a traditional improvement and gene transfer [39,40].

3.2.1. Mutation

Genetic mutant play an increasingly important role in cotton improvement as plant breeders work to design and develop cotton plants for newer production systems and increased efficiency. Although white is the most common color of fiber in normal standart cotton, some lines display brown lint fibers, and others have green lint [23,41].

Lint color in cotton is determined by qualitative genetics. The color heritage of fibers is usually controlled by dominant gene. Colour of cotton is controlled by larger genes, the improvement of that characteristic is simple, but it cannot be accomplished without self-focundation controlled by the improves, to avoid segregation or undesirable contamination. On the other hand, some shades of colours are highly influenced by the environment (sunray, soil type and year). Among the color shades, green is the most influenced by the environment, while cream and brown are the most stable ones. In the cultivated allotetraploids, separate loci determine brown lint in Gossypium hirsutum and Gossypium barbadense:

Gossypium hirsutum: Lc_1 — incomplete dominant

Gossypium barbadense: Lc_2 — dominant

Geneticists have been studying the complex inheritance pattern of colour in cotton. The lint colour is determined by a group of genes situated at two loci, Lc_1 and Lc_2. Gossypium barbadense cultivars have extra-long, strong, and fine fibers. These cultivars include Sea Island, Egyptian, and Pima cottons as well as extra-long staple cultivars grown in USSR, Sudan, Peru, India, and other countries. Cultivars of Gossypium hirsutum, Upland cotton, have shorter and weaker fibers, but are usually higher yielding than those of Gossypium barbadense. They are dominant over the white colour and operate in association with modifier genes that are either suppressors or intensifiers. In the presence of strong suppressors, white lint is produced. Often, the genes for lint colour are controlled more than one trait. This has been the most important problem in the development of economically and technically superior coloured cotton. For example, the gene for brown colour in Gossypium arboreum and Gossypium barbadense suppresses lint length and its fineness. Similarly, green and brown lints in Gossypium hirsutum inhibit fibre development. Generally, all colour genotypes have fibre qualities far below the white variety. Some fibre properties of Gossypium hirsutum with brown and green color is given below.

For Gossypium hirsutum:

Typical Fiber Property Range — Brown	
Length, inches	0.95 - 1.02
Length Uniformity ,	76 - 79
Strength, g/tex	18 - 23
Elongation, %	8.0 -11.0
Micronaire, units	2.7 -3.4

Typical Fiber Property Range — Green	
Length, inches	0.79 - 0.98
Length Uniformity, %	76 -79
Strength, g/tex	14 -19
Elongation, %	8.5 - 12.0
Micronaire, units	2.2 - 3.0

Colour development in the fibre occurs between 30 and 40 days after boll formation. The first 30 days of boll formation, the fibre is white. The 40 days old bolls shows colour fibre [42].

The lint of cotton occur in colors ranging from white to various shades of green and brown (Table 3.1.). Cultivated Gossypium hirsutum typically has a white lint, whereas cultivated Gossypium barbadense often has a creamy colored lint. Early investigations of the brown lint color determined that it was conditioned by separate loci, Lc_1 and Lc_2, in Gossypium hirsutum and Gossypium barbadense, respectively. A third brown lint variant, dirty white (Dw), was transferred from Gossypium raimondii to Gossypium hirsutum where its expression was equivalent to Lc_1. It was determined that Dw is the D subgenome homeolog of Lc_1. Subsequent investigation of brown lint variants has revealed the involvement of additional loci determining lint color. Kohel has reported four additional loci possessing dominant brown lint alleles and has assigned the symbols Lc_3, Lc_4, Lc_5, and Lc_6 to these alleles [23]. None of the four loci reported by Kohel are known to be multiallelic. Green lint and fuzz color conditioned by a dominant mutant, Lg, has been reported in Gossypium hirsutum. The lint and fuzz color of Lg are prominent at boll opening but soon fade to a khaki color. An allelic variant of Lg has been found in which the green color is confined to the seed fuzz while the lint remains white. The green-fuzz - white-lint allele has been assigned the symbol Lgf. [15,18].

Table 3.1. Gene symbol,name and origin of cotton [23]

Gene symbol	Name	Gossypium species origin
B_4	Blackarm resistance	arboreum
B_{6m}	Blackarm resistance intensifier	arboreum
B_8	Blackarm resistance	arboreum
B_9	Blackarm resistance	herbaceum
Chl_1	chlorophyll deficient	herbaceum
Chl_2	chlorophyll deficient	arboreum
Cl	short branch	herbaceum
Cp_a,Cp_b	Crumpled(complementary)	arboreum and herbaceum
Cr	crinkled	arboreum
Cu	curly	arboreum and herbaceum
D	female-sterile dwarf	arboreum
D_1	Anakapalle dwarf	arboreum
D_2	Cocanada dwarf	arboreum
D_3	dwarf bushy	herbaceum
De_1,De_2	incomplete boll dehiscence	herbaceum and arboreum
* Dw	Dirty white lint	hirsutum
Fz/fz	Tufted seed/fuzzy	arboreum
G	no ovary	arboreum and herbaceum
H_1	Hairy leaves	herbaceum
H^{vl}	Super stellate hairs	herbaceum
h_a	glabrous-lintless	arboreum
h_b	glabrous-lintless	arboreum and herbaceum
L	Narrow-leaves	arboreum
L^b	Mutant broad leaves	arboreum
L^j	Mutant intermediate leaves	arboreum
L^L	Laciniate leaves	arboreum
L^N	Narrow leaves	arboreum
* Ld_1^K	Khaki lint	arboreum and herbaceum
Lc_2	white lint	arboreum and herbaceum
* Lc_2^B	Light brown lint	arboreum and herbaceum
* Lc_2^K	Khaki lint	arboreum and herbaceum
* Lc_2^M	Medium brown lint	arboreum and herbaceum
* Lc_2^V	Very light brown lint	arboreum and herbaceum
* Lc_3^B	Light brown lint	arboreum and herbaceum
* Lc_4^K	Khaki lint	arboreum
* Lg	Green lint	hirsutum
li_b	hairy-lintless	herbaceum
li_c	hairy-lintless(lethal)	arboreum
li_d	hairy-lintless(lethal)	herbaceum
li_e	hairy-lintless(lethal)	arboreum
$li_{(sh)}$	short lint	arboreum
li_{sp}	sparse lint	arboreum
Lm	immature lint	arboreum
Ls	single lobed leaf	arboreum

M_1	increased no. of floral parts	arboreum
M_2	multibracteolate	herbaceum
Ne	nectaries absent	arboreum and herbaceum
P_a,P_b	Pollen color;P_aP_b yellow, p_aP_b cream,	
	P_ap_b pale, p_ap_b cream	herbaceum
Ppf	Petalody	arboreum
Pte	pistillate	arboreum and herbaceum
* R_2^{ASA}	Sun-red spotted	arboreum
* R_2^{BO}	Sun-red, spotless	arboreum
* R_2^{CS}	Red calyx, spotted	herbaceum
* R_2^{DS}	Thumb-nail red, spotted	arboreum
* R_2^{DO}	Thumb-nail red, spotless	herbaceum
R_2^{FO}	Greenstem spotless	arboreum
* R_2^{GS}	Tinged petal weak thumbnail red,	
	spotted	arboreum
R_2^{HO}	Greenstem spotless, untinged petal	arboreum
* R_2^{LO}	Red leaf, spotless	arboreum and herbaceum
* R^{LS}	Red leaf, spotted	herbaceum
* R_2^{MS}	Red margin, spotted	arboreum
* R_2^{MM}	Red margin, spotless	arboreum
R_2^{OS}	Greenstem, ghost spot	arboreum and herbaceum
* R_2^{RS}	Full red, spotted	arboreum
R_2^{TS}	Greenstem, tinged, ghost spot	arboreum
* R_2^{VS}	Red vein, spotted	arboreum
* R_2^{VO}	Red vein, spotless	arboreum
R_3^{oo}	Green, spotless	arboreum
* Rl_a	Red lethal, complementary with	
	Factor from G. hirsutum	arboreum
Sr	spot reducer	arboreum
stg	female sterile	herbaceum
stp	male-sterile	arboreum and herbaceum
* v_1	virescent yellow	hirsutum
* v_2	virescent yellow	hirsutum
* v_3	virescent yellow	hirsutum
* v_4	virescent yellow	hirsutum
Vc	few loculed bolls	arboreum
W_1	Fusarium resistance	arboreum and herbaceum
W_2	Fusarium resistance	arboreum and herbaceum
W_3	Fusarium resistance	arboreum and herbaceum
X	Lint color modifier	arboreum and herbaceum
Y_a	Yellow petal	arboreum and herbaceum
Y_a^p	Pale petal	arboreum and herbaceum
y_a	white petal	arboreum and herbaceum
Y_b	Chinese yellow petal	arboreum and herbaceum
Y_b^p	Chinese pale petal	arboreum and herbaceum

* Genes that are effective on the colour of cotton

A series of pigment developmental chloroplast mutants have been found in both Gossypium barbadense and Gossypium hirsutum that include virescent loci v_1 through v_{11} yellow green, yg_1yg_2, and albivirescents, av_1 and av_2, identified in Gossypium barbadense. These mutants are expressed predominantly in the seedling stage; however, they vary widely in the intensity and duration of expression during growth of the plant, each influenced by the environment.

Other simply inherited plant variants which have received investigative attention include red, blue and especially black fiber color. Red plant color is defined by these symbols R_1 and R_2. Fiber color variants have been the focus of attempts to commercialize NCC. These commercialization efforts have been supported primarily by fashion and by the perceived environmental advantages of naturally coloured fabrics.

The mutants pale green, Pg, found in Gossypium hirsutum, and light green, ltg, found in Gossypium barbadense are not virescents and retain their expression.

3.2.2. Crossbreeding

The most used method which is applied to cotton is classical breeding. Classical breeding of cotton emphasizes inbreeding methods such as pedigree-based selection. Today, hybridization in other words crossbreeding within and among types, followed by selection, is the predominant method utilized for improvement of cotton. The appeal of this breeding approach stems from the fact that intercrossing, generally, expands the range of genetic variability within which a breeder can practice selection. In most instances, a pedigree system of selection is used, beginning with the primary selections in the F_2 generation. Under certain circumstances, a breeder will use a bulk breeding method in which plant selection is delayed for a few generations, allowing for natural selection to act on successive populations. Selected cotton seed as female and male is crossbreed and F_1 hybrid seed is obtained. However, F_1 hybrid seed production is limited by the requirement of bees or humans for pollen transfer, and it is therefore largely confined to developing countries where labor costs are low [38].

The fact that cotton is an industrial crop places unusual constraints on quality parameters that may have contributed to its narrow genetic base. Uniformity among the cultivars approved for production in some areas has been a long-standing policy, and it has helped to delineate products in the marketplace. However, the gene pools in such cotton production regions are dangerously narrow and are therefore vulnerable to both biotic and abiotic hazards.

Although two different sexually compatible cotton species are cultivated, there is relatively little active gene exchange between them. Historically, cultivated forms of Gossypium barbadense are, in fact, complex interspecific hybrids deriving some attributes from Gossypium hirsutum. Hybridization among types of Gossypium barbadense and with Gossypium hirsutum broadened the germplasm base sufficiently for significant improvement in plant type, production and maturity, while maintaining fiber quality.

For example, scientist The Central Institue for Cotton Research (CICR) laboratory at Coimbature, Tamilnadu, have crossed the colour strain Gossypium hirsutum L. With white linted strain to produce colour hybrids with qualities such as fibre length, strength, and colour fastness better than the colour parent [42].

By such means more resistance to disease organisms and insects, more strength and improvements in other properties of lint, more yield, higher lint percentage, more earliness, and further modifications in other plant-habit expressions are attained.

The backcross method is well known to plant breeders and has been used for decades in many crops to transfer simply inherited traits into existing cultivators. The greatest merits of the backcross method are that;

a) the outcome is relatively predictable compared with other methods and
b) a backcross program can be accomplished rather quickly. Smaller population sizes are required and, because selection is not necessary (except for the trait being transferred), several generations per year can be grown in a greenhouse. The principal disadvantage of the backcross method is that the resulting new cultivar is little more than a new version of an older cultivar with no improvement in quantitatively inherited traits such as yield.

If it is accepted that the addition of one or two genes justifies the effort required, the primary questions remaining are;

a) the number of backcrosses needed to sufficently reconstitute the recurrent parent and
b) when and how to screen progeny for presence of the trait being transferred.

The backcross method has been used to transfer morphological traits into desirable genetic backgrounds for genetic studies and to supply breeding lines [15].

3.2.3. Gene transfer

New characters often arise simultaneously in different areas. They are not always conditioned by the same gene or set of genes. Whenever the gene support varies, the character is intensified, usually by bringing the separate stocks together. This can be done by the cotton breeder and genetic engineers. Also, natural recombinations of isolated characters often occur under conditions of natural crossing.

The past decade has been a revolution in our ability to manipulate the genomes of plants. Before the early 1980s there had been no well-substantiated report of expression of a foreign gene in a genetically engineered plant. The situation has changed dramatically since then. Now it is possible to transfer any gene into plant as a routine procedure. Every cotton fiber have different genetic chain that designate physical and mechanical properties. Genetic engineers can change these properties by using gene transfer with selection on desired gene [39,40].

3.3. Benefits of NCC

Because the color is already present in the fiber, NCC does not have to be dyed in fabric manufacturing. Dyeing can be one of the most costly steps in fabric finishing. It is estimated that the elimination of dyeing can save up to one half the manufacturing costs and disposal of toxic dye waste. It is generally known that naturally "white" cottons vary in hues of "yellowness" depending on the growing region and variety. For dyeing purposes, a consistent white is necessary. Most fabrics require a bleaching step during the finishing process to ensure a uniform white prior to dyeing [43].

NCC does not fade in laundering as is typical of most conventionally dyed cottons. After laundering, the color becomes stronger and more intense. The length of time required to "bring out" the color varies with color and variety. Eventually the colors may start to return to their original hue. Some NCC darkens with exposure to light. However, green is the least stable and fades to tan when exposed to light. In the presence of light and wear, the molecules in the green cotton orient to reflect less light and produce a lighter-whiter appearance. During laundering the molecules will reorient to become smoother, causing the color to appear brighter and more intense [36].

NCC yields less per acre, but growers are paid higher prices for their harvest. In 1996, world market prices for NCC ranged from $1.80 to $5.00 per pound compared to $.75 to $1.15 per pound for conventional white cottons. Growers of NCC should experience a greater profit margin with very few production variations over conventional white cotton [36] .

Growers of NCC may find less need for pesticides. Colored cottons have many insect and disease-resistant qualities and are drought and salt tolerant. Colored cottons have been grown successfully with organic farming methods.

The majority of NCC varieties are of lesser quality (strength, length, micronaire, etc.) than most conventional cottons and are presently only available in a limited range of colors.

Even though breeders have improved the properties of NCC, in comparison to conventional white cotton, NCC fibers are still shorter and weaker. These factors make commercial spinning difficult. To develop improved colored cotton yarns and fabric two methods are applied to NCC. Staple-core and filament-core spinning are two methods being used to produce composite yarns that blend colored cotton fiber with stronger white cotton or synthetic fibers. These composite yarns are stronger while still retaining the softness and appearance of colored cotton yarns.

In some areas, restrictions on delinting and ginning of colored cotton have been imposed as a result of some contamination. Colored cotton fields need to be located some distance away from the white cotton to avoid cross-pollination. Ginning can take place at gins where seeds are crushed and not saved for planting. Certain distances must be maintained between colored and white cotton fields. The coexistence of NCC with the naturally white varieties brings, even with effective regulatory controls, a possibility of minor contamination that worries the textile manufacturing sector and the cotton production sector that serves it.

3.4. Market and Demand of NCC

The "natural" trend among consumers and the environmentally conscious social climate of the early 1990s helped to create an initial demand and niche market for NCC, organic fibers and other environmentally friendly textile products. In 1992, an estimated 4,000 acres of NCC was grown in the United States. This has declined due to limited market demand. The eco-fashion market peaked in 1993-94, and by 1995 many retailers had withdrawn from the market.

Sally Fox of Natural Cotton Colours, Inc. has attributed the decline to the bottleneck created by sporadic yarn production. According to Fox, NCC products sell out in record fashion, but reorders have not been possible because of the unavailability of yarn.

NCC has an extremely soft hand or "feel". This, combined with their unique non-fading and environmentally friendly properties, has helped to assure their niche market. Colored cotton's future depends on continued improvement of fiber quality and development of appropriate manufacturing procedures [4,22].

Early uses of coloured lint-worldwide;

a) artistic weaving,
b) subsistence farmers and slaves on plantation estates,
c) english manufacturers — blend with wool,
d) less visible fishing nets (Peru).

Modern uses of coloured cotton-worldwide;

a) Haiti,
   - industrially ginned and milled into khaki fabric in 1936
b) Soviet Union,
   - cloth producting due to petroleum-based dye shortages during World War II

c) Peru Project,
   - revive cultivation and artistic tradition for rural development.

Successful end-uses:

a) brown denim with natural white filling,
b) Levi Naturals,
c) mattress ticking stripe for futons,
d) knits,
e) color addition in flannel sheets,
f) towels (extra absorbency leads to other uses),
g) environmentally slanted mail order promotions,
h) children's clothing.

3.5. Future of NCC

Simply inherited plant variants which have received investigative attention include red, blue and especially black fiber color. Red plant color (R_1 and R_2) has been investigated primarily as a source of insect resistance. Fiber color variants have been the focus of attempts to commercialize NCC. These commercialization efforts have been supported primarily by fashion and by the perceived environmental advantages of naturally colored fabrics.

Large amounts of additive genetic and general combining ability variances indicate continued progress in breeding for yield and fiber properties is likely to continue in cotton. Genetic variability of most characteristics is correlated with changes in other characteristics. The fiber quality parameters of primary interest in evaluating genotypes are those that affect the market price of cotton; length, strength, micronaire, and market grade. Market grade (color and trash content), is determined primarily by environment and management (especially proper defoliation). Numerous properties of cotton fiber, in addition to those reflected in the current market structure, can affect spinning, weaving, and dyeing and thus the true value of the product to the industry. A long-term breeding strategy should also address these properties that may at some point in the future be addressed in the market by price or by the textile industry's choice of raw materials. Most of these characteristics have a significant genetic component and are thus amenable to manipulation through breeding.

Indeed, the future of coloured cotton looks bright in many places. Nowadays genetic engineers are most concerned with blue and especially black colour for industry. They plan to insert into cotton plants the genes that are responsible for the production of the blue and black colour. The source of blue and black dye until a cheaper synthetic method of making it was discovered. The genes would be engineered in such a way that they would be active only in the cotton fibres, so only the cotton boll would turn blue. Companies and customers are almost certain that blue and especially black cotton will be not only feasible but marketable, given the perennial popularity of jeans and the ever stricter environmental regulation for getting rid of toxic dye waste scientist only wants enough time and money and can do anything about not only producing blue and black NCC but also stronger, longer, finer, warmer and wrinkle free fibres.

CHAPTER 4
EXPERIMENTAL STUDY-FIBER

4.1. Introduction

Textile fabrics are manufactured for many different end uses, each of which has different performance requirements. The chemical and physical structures of textile material determine how it will perform, and ultimately whether it is acceptable for a particular use [44]. Textile testing, as a whole, has only in recent years begun to come into its own. Quality is built into the product at every stage of processing, has extended the testing program from the raw stock to the finished product. Textile testing is the natural result of the buyer's desire to receive the quality that he requires and the manufacturer's concern to deliver a satisfactory product. In order to satisfy these demands, new test instruments have been designed and techniques developed. Many of these tests were the direct result of the buyer's desire to make better purchases or to determine whether or not the goods met specifications. The manufacturer has accepted these instruments and techniques to better comply with customer demands. Both customer and manufacturer have benefited greatly by this exchange of ideas [45]. Quality products can be defined as products that meet or exceed the high performance expectations of consumers. As textile products perform acceptably, quality is maintained and consumer satisfaction increases.

Textile tests provide information about the physical or structural properties and the performance properties of the textile. Physical properties include those that characterize the physical structure of the textile, and tests that measure these properties are sometimes called characterization tests. Physical properties include factors, such as the length, fineness, and linear density of fibers and yarns, yarn twist, and fabric thickness, width, weight, and the number of yarns per unit fabric area (i.e. fabric count). Performance properties are those properties that typically represent the textile's response to some type of force, exposure, or treatment. These include properties such as strength, abrasion resistance, pilling, and colorfastness. Performance properties are almost always influenced by physical properties.

Although performance properties are often the primary factor in product development, aesthetic properties, such as the way a fabric feels or drapes, also enter into design and development decisions. In some cases, tradeoffs occur between performance characteristics and aesthetics, while in others, decisions based on aesthetic factors can also enhance product performance [44].

In this part of the study the fiber properties of some different cotton samples are examined. These samples are not ordinary cottons, they are NCC obtained by crossbreeding of white and orijinal NCC. The samples which used for crossbreeding are also tested.

4.2. Types of Quality

The actual manufacture of a product is not the only area where quality has to be considered. The parts of the process include the following [46].

Quality of design: This can be considered as the value inherent in the design. It is a measure of the excellence of the design in relation to the customer's requirements. The production of a quality product starts with its design. The initial meeting of the customer's requirements and the continued functioning of the product throughout its lifetime depend on choice of materials, construction and processes.

Quality of conformance: This is a measure of the fidelity with which the product taken at the point of acceptance conforms to the above design. This is the area that is usually thought of as the province of quality assurance. However, the overall quality depends also on the design as performance cannot be introduced at this stage if it is not present in the original design.

Quality of use: This is a measure of the extent to which the user is able to secure continuity of use from the product. Provided material is being produced which conforms to specification, the length of time the product lasts in use depends on the original design.

Quality of customer service: This is a measure of factors such as the speed of response to orders, the response to customer returns and complaints, the speed and quality of installation and servicing and the initial availability of the product.

4.3. Variation due to Testing

In interpreting test results, the above sampling variance is added to several sources of test variation [47];

a) variation due to calibration,
b) inter-laboratory variation,
c) variation between single instruments in a laboratory,
d) variation between observers,
e) variation between test specimens taken from the same sample,
f) variation between repeat readings on the same specimen.

4.4. Test Criteria

Textile test methods should meet three criteria, which can also be used when selecting among several standard methods. These criteria are simplicity, reproducibility and validity [44].

Enough samples must be taken so that any change or trend in the process will be revealed. This requires time, study and expense, but the results more than justify the efforts. Of course, if the sampling is not random and representative, the tests have no meaning or value. All laboratory equipment must be maintained in good operating condition and periodically inspected and calibrated to insure accurate measurements. The testing machine must be calibrated periodically, and actual testing techniques must be examined and improved, with human error eliminated. Tests should be made under standard conditions when circumstances permit. When this is not feasible, test results should be corrected to standard conditions. Many factors affect the tests and test results. Standard test procedures are strictly followed in order that extraneous factors may be reduced to a minimum. Additional precautions must be exercised to control causes of testing error. One of the most important factors is the attitude of the laboratory technician. An attitude of honesty, accuracy, and alertness is encouraged, not only by the selection of personnel and their direct supervision, but also indirectly by management of the laboratory [45]. Unless otherwise specified, all tests are made after the sample has been conditioned for a minimum of 4 hours at 70°F, 65% Relative Humidity.

Simplicity: The criterion of simplicity means that a textile test method should be easy to read and understand. It should provide enough information so as to leave no doubt as to how to perform the test; the procedure should be easily mastered with a minimum of practice, and the results should be easily obtained and interpreted.

Reproducibility: The results of a textile test should be reproducible with respect to user, time, and location. Two individuals who perform the same test on the same specimen should obtain the same results. Using the same test specimen, you should be able to obtain similar results from one day to the next. It should be noted that a lack of reproducibility with respect to user or time may be associated with a lack of simplicity. When a test is difficult to understand or perform or when it involves several steps or extensive handling of specimens, the results may also be difficult to reproduce.

Textile tests should also be reproducible with respect to location. Using identical specimens, a student working in a laboratory one place should obtain the same results as a student performing the same test in other places. The ideal textile test method specifies how to control factors that could influence reproducibility. In addition to these factors environmental factors (e.g., humidity and temperature) directly influence certain textile properties. When not carefully controlled, these environmental factors can reduce the reproducibility of textile tests.

Validity: The procedure followed in a textile test method should duplicate or closely simulate the actual end-use situation. In other words, the test method should be applicable to the end use.

In selecting an appropriate test method, the criteria of simplicity, reproducibility, and validity should be considered in conjunction with the goal of a particular test. All three test criteria are rarely met simultaneously in one textile test. Sometimes validity is partly compromised in order to achieve reproducibility, as in the case of weathering tests. Instrumental weathering tests cannot actually duplicate exposure to sun and changeable weather conditions, but they do offer reproducibility by allowing the user to control light exposure, temperature, and moisture, factors which would be impossible to control in actual outdoor exposure. Most instrumental tests also enhance simplicity by providing accelerated conditions, and shorter test cycles than would be possible under real-life conditions.

4.5. Conditions for Textile Testing

To avoid the problems resulting from differential moisture absorption of different fabrics, and to assure valid test results, textiles should be tested under standard conditions of temperature and relative humidity. Conditioning and testing must be carried out under constant standard atmospheric conditions. The standard temperate atmosphere for textile testing involves a temperature of 20±2 °C (68±4 °F) and 65±2% relative humidity. In tropical regions, maintaining a temperature of 27±2 °C (81±4 °F) at 65±2% relative humidity is legitimate, but then the absolute moisture content of the conditioned air is different.

Textiles are usually placed in these conditions for a sufficient amount of time to reach equilibrium moisture conditions. This process is called conditioning. Prior the testing, the samples must be conditioned under constant standard atmospheric conditions until in moisture equilibrium with the surrounding air. To attain the moisture equilibrium, a conditioning time of at least 24 hours is required, 48 hours is preferred. For samples with a high moisture content (thermally conditioned yarns), conditioning time should be at least 48 hours. The best practice is to precondition such samples in a dry atmosphere, so that the moisture equilibrium is later approached from the dry side. During conditioning, the samples must be removed from any boxes or containers used for transportation, cleared from all packing materials, placed in an upright position to expose the entire bobbin or package surface to the conditioned air, and arranged in such a fashion that ample space is left between the samples to allow conditioned air to circulate freely. Laboratory conditions should be monitored by appropriate devices that record both short-term fluctuation and long-term rift. References to standards defining the standard atmosphere for conditioning and testing: ISO 139, EN 20 139, DIN 53 802 [48].

4.6. Fiber Analysis

Fibers are the basic units in textile materials and their properties contribute significantly to the performance of yarns and fabric. Both the chemical make-up and the arrangement of molecules in the fibers, as well as the physical features, determine a fiber's properties. Fiber properties are considered carefully in developing textile products for specified end uses. Cotton has high moisture regains moderate strength, and is stronger when wet. It is, however, not abrasion or wrinkle resistant thus, other fabric structural features could be selected to provide more durability and easy care.

In the experiments, fiber properties of three different groups of cottons were examined. Table 4.1 shows the names, origins and futured of these samples.

Table 4.1. Names, origins and futured of the cotton samples.

		Fiber names	Origins	Futured
Group 1	1	DTN-5	NCRI	Obtained by crossbreeding
	2	NDT-10	NCRI	Obtained by crossbreeding
	3	NDT-11	NCRI	Obtained by crossbreeding
	4	NDT-13	NCRI	Obtained by crossbreeding
	5	NDT-15	NCRI	Obtained by crossbreeding
Group 2	1	Camel	NCRI	Original naturally coloured cotton
	2	Nazilli 84 (S)	NCRI	White cotton
Group 3	1	K.Maraş-Brown	KARI	Original naturally coloured cotton
	2	K.Maraş-Green	KARI	Original naturally coloured cotton
	3	Sayar-314	KARI	White cotton
	4	Erşan-92	KARI	White cotton

The following tests were applied to these fibers;

a) fiber fineness,
b) fiber length,
c) fiber strength and elongation,
d) fiber maturity.

All fiber test results taken from HVI and AFIS are given at the end of this section (Table 4.10 and Table 4.11).

4.6.1. Fiber fineness

Fineness is one of the most important properties of the fibres that affects several mechanical properties and therefore influences the behaviour of the fibre during processing and the properties of the resultant yarns and fabrics [49]. The finer the fibre, the finer is the yarn that can be spun from it. As the yarn becomes thinner, the number of fibres in its cross-section decreases and the yarn becomes increasingly uneven because the presence or absence of a single fibre has a greater effect on the yarn diameter.

Fineness of fibres is a highly prized commodity which enables garments to be made with a soft and luxurious handle. With natural materials such as cotton, silk, wool and other animal fibres the finer varieties are reserved for the more expensive apparel and hence command higher prices. It is therefore important commercially to be able to determine the fineness of natural fibres as this is an important factor in their quality and hence price [46]. There are a number of different method ways of measuring fibre fineness which are;

Direct measurement of gravimetric fineness: The measurement of mass per unit length is simple and straightforward. A small sample of fibers can be weighed individually and the length of each determined. Gravimetric fineness is then calculated as;

$$\mathrm{GF} = \sum W / \sum L \qquad (4.1)$$

where

W = the weight of an individual fiber

L = the corresponding length

Because the mass of each fiber is small, the error associated with weighing each fiber individually is great relative to its mass and hence this procedure is of doubtful accuracy. This method is useful for research purposes but it is too slow for use as practical measures for monitoring cotton quality [22]

Direct measurement of biological fineness: Measurement of the width of a cotton fiber can be used to provide an estimate of the diameter. A tuft of fibers is placed on a microscope slide and the dimensions at the widest and narrowest points of a convolution near the center of each fibers are measured by means of a micrometer. The two measurements are averaged to obtain an estimate of the diameter. In most cases this method of measurement underestimates the biological fineness.

Indirect measurements (Micronaire test): The micronaire test is the most widespread instrumental cotton fiber test in use. Details differ somewhat according to the particular type of instrument used, but essentially the quantity determined is an indirect measure of the air permeability of a test specimen of fixed mass contained in a holder of fixed dimensions as shown in Figure 4.1. Originally it was thought that the air permeability of a specimen was determined by its fiber linear density.

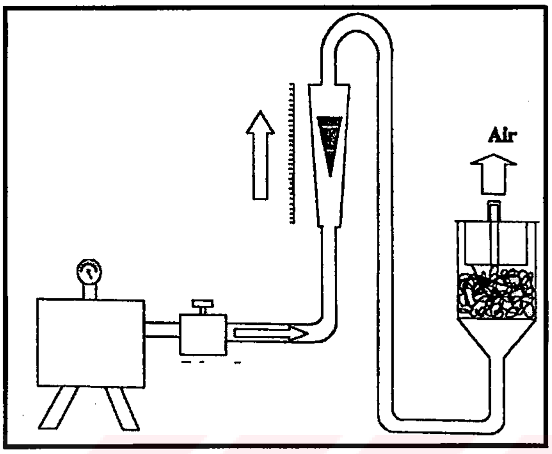


Figure 4.1. Fibronaire

In actual fact, micronaire is a function of both fiber maturity and fiber linear density with the result that the fiber linear density for a particular micronaire will depend upon the fiber maturity. This approach enables a more critical interpretation to be made of micronaire values. It implies that the effect of micronaire depends upon variations in both the intrinsic fineness of the cotton and the fiber maturity. Therefore, if a fiber's linear density remains constant, then micronaire reading will increase with increasing fiber maturity.

Measurements of fibre micronaire by HVI and AFIS: The modern tendency of some companies specialised in the construction of instruments for measurements on fibres is that of presenting a more or less complete range of instruments linked by a central computer capable of supplying an overall report on quality.

In the cotton sector, the integration of the various measurements has taken on a particular character with the development of the so-called HVI systems (High Volume Instruments) planned to make possible the effectuation of a large number of determinations in a short time, the objective being that of analysing every single bale of cotton in a lot.

The AFIS system, used in the cotton industry, includes a module for the optical measurement of the diameter and the length of the single fibres, previously straightened in a flow of air which feeds them into a field of parallel light rays see in Figure 4.2.

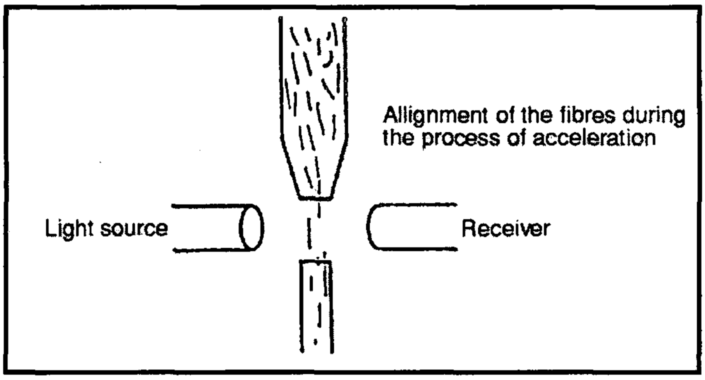


Figure 4.2. Measurement zone of AFIS

AFIS method begins with aeromechanical processing, similar to opening and carding. This means that the fibers are measured under conditions which are dynamically similar to real processing. The aeromechanical separator uses novel cleaning and fiber individualizing techniques to separate and present the various components - microdust, fiber, and trash - to the electro-optical sensors [50,51].

The fineness values of sample cottons obtained from HVI and classification of the cottons according to Table 2.2. are given in Table 4.2.

Table 4.2. Fiber fineness values and classification of the cotton samples

	Name	Fiber fineness (micronaire)	Classification
1	DTN-5	4.3	Medium
2	NDT-10	4.4	Medium
3	NDT-11	4.1	Medium
4	NDT-13	4.4	Medium
5	NDT-15	4.2	Medium
6	Camel	4.6	Medium
7	Nazilli 84 (S)	4.4	Medium
8	K.Maraş-Brown	5.0	Slightly Coarse
9	K.Maraş-Green	2.8	Very Fine
10	Erşan-92	3.2	Fine
11	Sayar-314	3.8	Fine

According to standart classification of Uster Statistics 2001, the samples: DTN-5, NDT-10, NDT-11, NDT-13 and NDT-15 belong to "Medium" class. Nazilli 84 (S) and Camel which are used as crossbreeding fibers are "Medium" class like other cottons. In other words, naturally coloured cottons obtained by crossbreeding (DTN-5, NDT-10, NDT-11, NDT-13 and NDT-15) and conventional standart white cottons are "Medium" class, however, the numerical values of fiber fineness of crossbred NCC are generally better than Camel and Nazilli 84 (S). Besides these results the cottons which are obtained from KARI, exhibit a large variation. For example, K.Maraş-Green is very thin (2.8 micronaire) but K.Maraş-Brown is slightly coarse (5.0 micronaire).

4.6.2. Fibre length

The length is another important property of a fibre. In general a longer average fibre length is to be preferred because it confers a number of advantages. Firstly, longer fibres are easier to process. Secondly, more even yarns can be produced from them because there are less fibre ends in a given length of yarn. Thirdly, a higher strength yarn can be produced from them for the same level of twist. Alternatively a yarn of the same strength can be produced but with a lower level of twist, thus giving a softer yarn.

The length of natural fibres, like their fineness, is not constant but it has a range of values even in samples taken from the same breed of animal or plant. Cotton is a comparatively short fibre with the finest variety of common textile fibres [46]. The longer the fiber, the finer and the more uniform is the yarn that can be spun, other things again being equal. Hence, for most purposes, longer fibres are preferable. From the point of view of cloth characteristics, however, short fibres have the advantage where it is desirable to produce a soft, hairy, and warm-handling surface. Here a large number of projecting fibre ends are desired, and, although the number of ends can be strongly influenced by the method of spinning employed, under any given set of conditions it must obviously vary inversely as the mean fibre length [16].

Staple length is claimed to be the best indicator of cotton fibre quality. One of the attributes of cotton which requires measurement is the 'staple length'. A definition of staple length could be as follows: 'A quantity estimated by personal judgement by which a sample of fibrous raw material is characterised as regards its technically most important fibre length' (Figure 4.3).

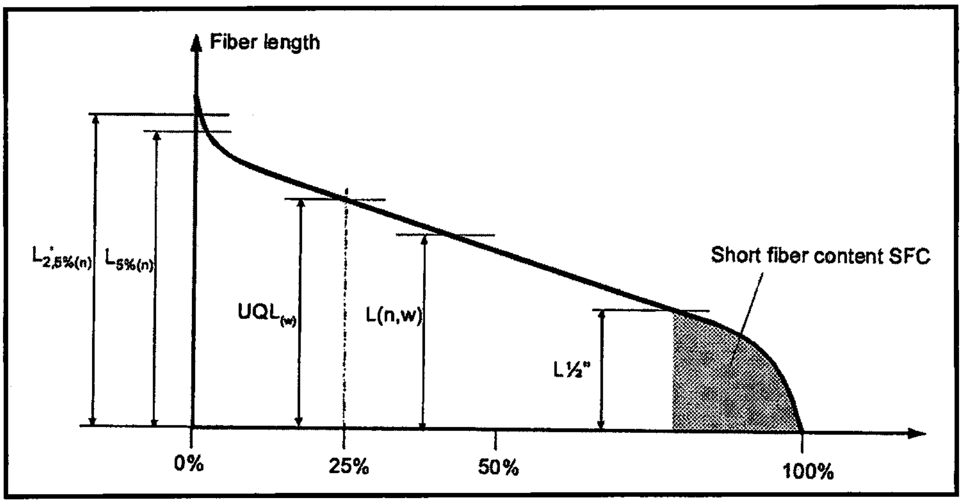


Figure 4.3. Staple Diagram

Length is the most obvious feature of a cotton fibre and has always attracted considerable attention; for this reason there is a wide range of length testing methods, apparatus and instruments [45,47]. We shall divide the methods and instruments of fiber measurement into the following sections:

1) Methods on individual fibres.
2) Methods on groups of fibres:
   a) comb sorter method,
   b) fibrograph method.

It is important to note the methods on groups of fibres, much more rapid than those on individual fibres. So generally methods on groups of fibres length measurement is used instead of individual fibres methods.

Comb-sorter methods: The comb sorter, different versions of which are used for both cotton and wool, uses a set of fine combs arranged at fixed intervals to hold the fibres and keep them straight. Determination of fibre length by use of comb sorter-diagrams is long established. The commonest type of sorter in use is the comb sorter, which, in a variety of forms, can be used for measurements of most kinds of fibres. The method is simple in principle and provides a full description of frequency distribution of fibre lengths in the material subjected to test [45,50]. In all cases, the operation involves two steps:

a) The preparation of a fringe or tuft of fibres, all of which are aligned at one end.
b) The withdrawal of the fibres from the fringe in the order of either their increasing or their decreasing length.

The fibrograph method: One of the most extensively used instruments in which photo-electric scanning is employed is the fibrograph. The fibrograph is an automated method of measuring the fibre length of a cotton sample. It uses an optical method of measuring the density along the length of a tuft of parallel fibres.

The first part of the measuring process is the preparation of a suitable sample. This can be done either by hand or with a fibrosampler. The fibrosampler has a rotating brush which withdraws cotton fibres from a perforated drum and deposits them on a comb. The outcome is that the fibres are placed on the comb in such a way that they are caught at random points along their length to form a beard. The beard is scanned photoelectrically by the fibrograph from the base to the tip. The intensity of light that passes through the beard at a given position is used as a measure of the number of fibres that extend to that distance from the comb. The sample density is then plotted against distance from the comb [49].

AFIS and HVI systems are also used to measure the length of fibres. Fibre length values and classification according to Table 2.3 which are obtained from HVI tester are given in Table 4.3.

Table 4.3. Fiber length values and classification of the cotton samples

	Name	Fiber length (mm)	Classification
1	DTN-5	26.55	Medium
2	NDT-10	28.80	Medium
3	NDT-11	29.20	Long
4	NDT-13	29.90	Long
5	NDT-15	29.85	Long
6	Camel	25.75	Medium
7	Nazilli 84 (S)	31.60	Long
8	K.Maraş-Brown	23.65	Medium
9	K.Maraş-Green	22.25	Short
10	Erşan-92	32.55	Long
11	Sayar-314	30.60	Long

According to the test results taken from HVI and AFIS Uster Instrument, fiber lengths of DTN-5, NDT-10, NDT-11, NDT-13 and NDT-15 obtained from NCRI are higher than Camel and lower than Nazilli 84 (S). However, as seen from the above table, the fiber lengths of K.Maraş-Brown and K.Maraş-Green are shorter than conventional standart white cottons (Sayar-314 and Erşan-92).

4.6.3. Length uniformity

With their bias towards the longer fibres in a sample, most measures of staple length are usually interpreted in the light of uniformity, to take account of the medium and short parts of the fibre length distribution. Three measures are:

a) Coefficient of variation (CV), the standard deviation (SD) as a fraction or percentage of the mean; as well as numerical calculation, the SD, or square root of the variance, can be obtained in principle from the fibrogram. If the peak is set equal to the maximum length, the area A between the mean-length tangent and the fibrogram curve is doubled to give the variance.

b) Uniformity index (UI), the ratio of the mean to the upper-half mean. It is typically just above 0.80 in HV instruments, 0.70 in comb sorters.

c) Uniformity ratio (UR), the ratio of the 50% span length to the 2.5% span length. It is lower than the UI by a factor close to 1.8.

Uniformity index values and classifications of the samples according to Table 2.5. are given in Table 4.4.

Table 4.4. Uniformity index values and classification of the cotton samples

	Name	Uniformity index	Classification
1	DTN-5	82.4	Average
2	NDT-10	83.4	High
3	NDT-11	82.5	Average
4	NDT-13	83.1	High
5	NDT-15	81.6	Average
6	Camel	77.3	Low
7	Nazilli 84 (S)	85.6	High
8	K.Maraş-Brown	79.8	Low
9	K.Maraş-Green	72.5	Very Low
10	Erşan-92	84.6	High
11	Sayar-314	83.7	High

When we examine the fiber uniformity index distribution of the samples it will be seen that, DTN-5, NDT-11 and NDT- 15 have "Average" , NDT-10 and NDT-13 have "High" class. However, Camel and Nazilli 84 (S) are situated "lower" and "very high" classes, respectively. While K.Maraş-Green has "Very Low", K.Maraş-Brown has "Low" value, but Erşan-92 and Sayar-314 have "High" classes.

4.6.4. Fiber strength and elongation

The strength of fibres and fibre structures is commonly regarded as the criterion of quality. That strength is of great importance for properties such as flexibility, resilience, moisture absorption, dye affinity, etc., should be included in the assessment of the 'goodness' or quality of a textile material [49].

Carrying out strength tests on fibres is difficult and time consuming. This is because, particularly with natural fibres, the individual strengths of the fibres vary a great deal and therefore a large number have to be measured to give statistical reliability to the result. Furthermore individual fibres are difficult to handle and grip in the clamps of a strength testing machine, a problem that increases as the fibres become finer. For these reasons single fibre strength tests are more often carried out for research purposes and not as routine industrial quality control tasks. Tests on fibre bundles, which overcome the problems of fibre handling and number of tests needed for accuracy, are carried out as part of the normal range of tests on cotton fibres [22].

Method of single fiber strength test

Tests on single fibers can be performed. However, most of them are very slow methods, requiring hours of labour per sample to obtain accurate average values. Different instruments have been designed to perform single fiber strength tests:

a) The Instron machine. An excellent determination of the strength and elongation of individual fibers (or ribbons) can be made with this machine. It is an expensive and complicated machine which works on the principle of strain gauge and provides load-elongation curves by means of a recorder after electronic amplification.
b) The Uster MANTIS (prototype only).

Method of bundle fiber strength test

The bundle methods are often used for shorter fibers that may be difficult to mount singly in a tensile tester.

The Pressley Tester: For this test, the cotton is hand-combed and the fibers are paralleled in the form of a flat ribbon and then placed in a set of breaking clamps. The protruding fibers are cut off, so that the clamp contains a bundle of fibers all of the same length. The Pressley Instrument (Figure 4.4.) consists essentially of a pivoted balance beam. The beam is slightly inclined. A free-rolling heavy weight is released to run down the inclined balance beam far enough to break the fibers held in clamps at the other end of the beam. When the bundle of fibers breaks, the force required to break the fibers is read off the beam to the nearest tenth of a pound. The two broken halves of the bundle are weighed (in milligrams) together on a very sensitive balance.

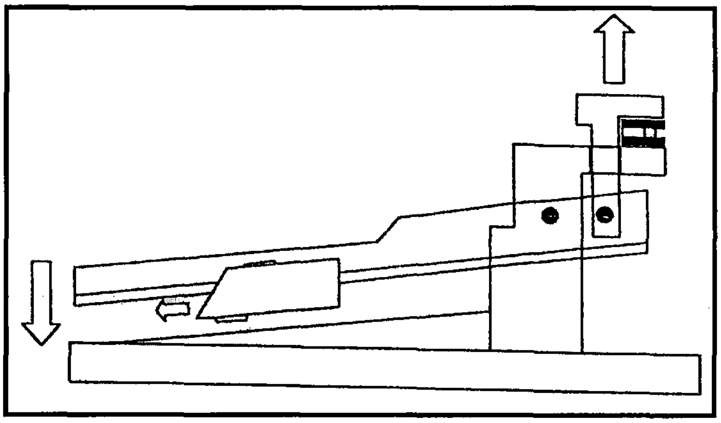


Figure 4.4. Pressley principle

Methods of expressing the results

- The Pressley Index (Sometimes called the strength index)

$$P.I = \frac{\text{Breaking load in pounds}}{\text{Bundle weight in mg}} \qquad (4.2)$$

- Tensile Strength (in thousands of pounds/inch^2). The following formula is used in converting the Pressley Index into tensile strength:

$$\text{Tensile Strength} = 10.8116 \times P.I - 0.12 \qquad (4.3)$$

- The Tensile Strength in gram per Tex. With the introduction of the Tex system it is more convenient for the purpose of standardization of textile testing to use gram/tex for the unit of strength per unit linear density. The tensile strength in g/tex can be expressed as:

$$\text{Tenacity (g/tex)} = \frac{\text{Breaking force (kg)}}{\text{Fiber mass (mg)}} x15.0 \qquad (4.4)$$

It is possible to convert the tensile strength into the Pressley Index. Since the width of the two pressley clamps is 1.181 cm, one pound equal 453.6 g; thus, tensile strength equal 5.36 P.I.

The following subjective ratings will assist in the interpretation of test data and serve to facilitate comparisons between cottons (Table 4.5.).

Table 4.5. Pressley index

Pressley Index	Tenacity (g/tex)	Rating
8.8 and above	47 and above	Very strong
8.0 - 8.8	43 – 47	Strong
7.1 – 7.9	38 – 42	Average
6.1 -7.0	33 – 37	Weak
6.0 and below	32 and below	Very weak

The Stelometer: The stelometer measures fiber strength and elongation of cotton. Test results are obtained simultaneously using one sample by observing direct reading scales. A flat bundle, Pressley-type sample, is prepared in a special vise which allows the operator to make the test without touching the cotton (Figure 4.5).

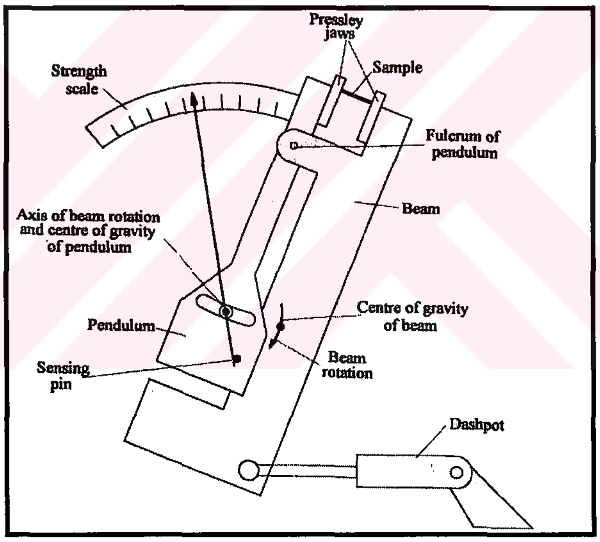


Figure 4.5. Stelometer

The test specimen is mounted between a pair of Pressley clamps which are inserted in slots in the beam and in the pendulum. When the beam is released from its nearly vertical position it rotates, causing the pendulum to rotate too. This rotation produces an increasing tension in the mounted test specimen. This tension is indicated by a detecting pin moving a pointer. When the specimen breaks, the pendulum escapes from the detecting pin and the breaking load may be read off directly from the position of the pointer on a scale graduated from 2 to 7 kg. There is second scale graduated from 0 to 40 % for elongation.

The bundle strength of cotton fibres is also measured as part of the high-volume instrument (HVI). Based on the results, the fibrogram is plotted automatically by this instrument [46].

NCC and conventional white cotton fiber strength which are measured by HVI tester are given in Table 4.6.

Table 4.6. Strength values and classification of the cotton samples

	Name	Fiber Strength(g/tex)	Classification
1	DTN-5	26.7	Strong
2	NDT-10	32.2	Very Strong
3	NDT-11	33.1	Very Strong
4	NDT-13	31.4	Very Strong
5	NDT-15	27.1	Strong
6	Camel	26.5	Strong
7	Nazilli 84 (S)	33.0	Very Strong
8	K.Maraş-Brown	25.5	Average
9	K.Maraş-Green	23.8	Average
10	Erşan-92	34.6	Very Strong
11	Sayar-314	32.3	Very Strong

The fiber strength values of all derived NCC is better than that of its mother "Devetüyü", but the one named as NDT-11 has better strength value from both its mother and father as given in Table 4.6. On the other side, the strength values of NCC, obtained from KARI were measured as "average" class (lower than 26 g/tex), but the strength values of the white cottons are quite high and thay fall into "very strong"class.

Another important fiber parameter is the elongation. The elongation values of the samples are given in Table 4.7.

Table 4.7. Fiber elongation values of the cotton samples

	Name	Fiber Elongation (%)
1	DTN-5	7.2
2	NDT-10	7.7
3	NDT-11	7.7
4	NDT-13	7.5
5	NDT-15	7.7
6	Camel	6.9
7	Nazilli 84 (S)	8.6
8	K.Maraş-Brown	5.8
9	K.Maraş-Green	7.2
10	Erşan-92	8.3
11	Sayar-314	8.0

As known that elongation values of cottons may change between 6–10 %. In the experiments, elongation values of DTN-5, NDT-10, NDT-11, NDT-13 and NDT-15 change from 7.2 to 7.7 % as given in Table 4.7. Elongation values of Camel and Nazilli 84 (S) cotton fibers are measured as 6.9 % and 8.6 % respectively.

4.6.5. Maturity

Whereas the mean girth of a raw cotton is mainly a hereditary characteristic, the degree of development of the cell wall is very largely determined by environment. If, relative to its girth, a fibre has a thick and well-developed wall, it is said to be mature. If, on the other hand, its wall is thin and poorly developed, it is said to be immature. Correspondingly, if a cotton, because of unfavourable growing conditions, contains a considerable proportion of immature fibres, it is referred to as an immature cotton.

The notion that micronaire is a measure of fineness still appears frequently. It is a compound of about two-thirds linear density and one-third maturity. Commercial disagreements are sometimes about a buyer's arguing that a low micronaire reading denotes immaturity, the seller interpreting it as fineness. Maturity of a cotton fiber is the degree to which the lumen has been obliterated by deposition of cellulose. Immaturity of a sample, then, is the percentage of its fibers whose wall thickness is one-hall or less than the diameter of the lumen. In laboratory conditions, a test specimen consists of at least 100 fibers which are mounted on a microscopic glass slide as nearly parallel as possible. The fibers are held in place by a cover glass and flooded with an 18 per cent solution of sodium hydroxide (NaOH), using a pipette. The slide is placed on the mechanical stage of the microscope, which is equipped with the filar micrometer. All the fibers are checked, one by one, and a record kept of the unmature and mature fibers. The total number of immature fibers is divided by the total number of fibers and the quotient expressed as a percentage [31]. But in this study, the maturity of fineness were measured by AFIS tester automically. Maturity ratio and classification are given in Table 4.8.

Table 4.8. Maturity ratio and classification [22]

Maturity Ratio (%)	Classification
1.00 and more	Very Mature
0.95-0.99	Above Average
0.85-0.94	Mature
0.80-0.84	Below Average
0.70-0.79	Immature
Less than 0.69	Uncommon

The maturity values of the samples (obtained from an AFIS instrument) and their places in the classification is given in Table 4.9.

Table 4.9. Fiber maturity ratio and classification of the cotton samples

	Name	Fiber Maturity Ratio (%)	Classification
1	DTN-5	0.89	Mature
2	NDT-10	0.95	Above Average
3	NDT-11	0.94	Mature
4	NDT-13	0.94	Mature
5	NDT-15	0.89	Mature
6	Camel	0.89	Mature
7	Nazilli 84 (S)	0.97	Above Average
8	K.Maraş-Brown	0.91	Mature
9	K.Maraş-Green	0.78	Immature
10	Erşan-92	0.89	Mature
11	Sayar-314	0.88	Mature

The maturity values of all samples are good, except the cotton " K.Maraş-Green" that is immature. However, the cotton named on NDT-10 and Nazilli 84 (S) take place in "Above Average" classification.

Table 4.10 shows all the parameters of the samples obtained from HVI instrument, orijin and attributes of the samples are also given. Similarly, Table 4.11. gives detailed information about the samples obtained from AFIS instrument.

Tablo 4.10. Results of HVI instrument

	Cotton which is planted in Nazilli							Cotton which is planted in Kahramanmaraş			
	Crossing naturally coloured cotton					Male and female cottons which is used for crossing		Orijinal coloured and white cotton			
	DTN-5	NDT-10	NDT-11	NDT-13	NDT-15	Camel	Nazilli-84(S)	K.Maraş Brown	K.Maraş Green	Erşan - 92 White	Sayar -314 White
Spinning Consistency Index(SCI)	119	144	151	157	122	94	160	86	82	176	160
Fineness (micronaire)	4.3	4.4	4.1	4.4	4.2	4.6	4.4	5.0	2.8	3.2	3.8
Strength (g/tex)	26.7	32.2	33.1	31.4	27.1	26.5	33.0	25.5	23.8	34.6	32.3
Fiber Length (mm)	26.55	28.80	29.20	29.90	29.85	25.75	31.60	23.65	22.25	32.25	30.60
Uniformity (%)	82.2	83.5	83.5	86.1	81.2	77.9	84.9	78.9	75.2	84.6	84.6
Short Fiber Index (SFI)	8.9	6.1	5.9	3.5	8.4	14.4	3.5	14.2	19.5	3.8	4.2
Elongation (%)	7.2	7.7	7.7	7.5	7.7	6.9	8.6	5.8	7.2	8.3	8.0
Count Strength Product (CSP)	2010	2140	2202	2212	2126	1900	2318	1768	1879	2484	2337
Fiber Length (%50)	21.98	24.08	23.82	23.74	23.38	18.62	26.53	19.11	15.25	26.14	26.00
Fiber Length (%2.5)	26.67	28.86	28.85	28.57	28.65	24.10	31.02	23.95	21.01	30.90	31.06
Uniformity (%)	82.4	83.4	82.5	83.1	81.6	77.3	85.6	79.8	72.5	84.6	83.7
Strength	27.95	32.25	34.63	30.07	28.45	25.67	31.59	24.91	24.44	33.14	32.48
Elongation(%)	7.0	7.4	7.8	7.4	8.2	7.7	7.9	5.9	6.9	8.7	8.1
Amount	742	685	737	697	770	663	659	443	569	822	668
Crimp (%)	2.416	1.261	0.758	1.347	1.132	1.930	1.339	2.166	2.345	0.385	0.744
Modulus	5.320	6.435	6.348	5.985	4.900	4.451	6.226	5.013	3.126	5.066	5.459
Break Force	10.234	17.365	17.943	14.729	12.521	7.620	19.604	7.099	3.141	16.984	17.953
Work Peak	0.270	0.375	0.375	0.330	0.295	0.245	0.390	0.205	0.140	0.315	0.315
Spinning Factor (%)	8.5 %	6.2 %	7.2 %	6.7 %	8.5 %	16.1 %	3.5 %	13.1 %	23.4 %	3.7 %	4.7 %

Tablo 4.11. Results of AFIS instrument

	Cotton which is planted in Nazilli							Cotton which is planted in Kahramanmaraş			
	Crossing naturally coloured cotton					Male and female cottons which is used for crossing		Orijinal coloured and white cotton			
	DTN-5	NDT-10	NDT-11	NDT-13	NDT-15	Camel	Nazilli-84(S)	K.Maraş Brown	K.Maraş Green	Erşan-92 White	Sayar -314 White
Length (weight)(mm)	24.9	26.5	26.2	25.5	25.5	21.8	27.7	19.2	20.1	28.1	27.5
Length (weight)(%CV)	30.5	27.0	28.0	29.5	30.6	29.8	26.2	37.2	39.2	31.1	31.6
UQL (weight)(mm)	28.7	30.4	30.0	29.4	30.0	25.3	31.5	23.4	24.7	33.5	32.5
SFI (weight) %<12.7	5.9	4.0	4.4	4.9	6.2	7.4	3.0	16.6	16.5	6.1	5.9
Length (number)(mm)	20.1	22.5	22.2	21.1	20.7	18.3	24.1	14.4	15.1	22.5	21.5
Length (number)(% CV)	48.6	41.8	42.5	45.2	48.3	43.5	38.7	58.3	57.5	50.2	53.0
SFC (number) %<12.7	22.8	16.3	17.1	19.2	22.8	21.8	12.9	41.0	39.4	23.2	25.0
Fiber length (%5.0)(mm)	32.0	33.9	33.7	32.8	33.8	28.8	35.8	26.1	28.5	37.1	36.1
Fiber length (%2.5)(mm)	34.3	36.2	36.3	35.3	35.9	31.1	38.2	28.4	31.4	39.7	39.0
Fine (mtex)	169	180	180	180	170	178	193	189	140	154	154
IFC (%)	9.1	6.5	6.3	6.8	7.9	8.3	5.2	7.6	13.0	8.4	9.0
Maturity ratio	0.89	0.95	0.94	0.94	0.89	0.89	0.97	0.91	0.78	0.89	0.88
Weigth (gram)	0.470	0.455	0.485	0.505	0.475	0.495	0.565	0.445	0.430	0.525	0.480
Neps (µm)	560	523	573	610	570	627	584	613	641	581	634
Neps (count/gram)	104	42	78	40	100	96	49	84	179	104	112

CHAPTER 5
EXPERIMENTAL STUDY-YARN

5.1. Spinning Processes

Cotton arriving at the mill is normally dirty and contaminated by bits of leaf, dust and twigs. Impurities will commonly amount to about 2-3 % of the total weight. The cotton has also been compressed tightly in the bale in order to minimize transport costs.

Cotton fibers are subjected to several different processes prior to the actual formation into yarns. These processes vary depending upon

a) the size and quality of the yarn required and
b) the ultimate end-use specifications for the product that is to be made from the yarn.

In general, the processes may be divided into the following;

a) bale selection for blending (usually called the mix, or laydown),
b) conditioning,
c) opening and blending,
d) cleaning,
e) carding,
f) drawing,
g) combing,
h) roving (prior to ring spinning),
i) spinning (rotor, ring and other).

Before the actual spinning of the cotton can be carried out, the fibres are subjected to several preliminary processes. First, cotton from the bale is put into a machine called an opening hopper, in which several spiked rollers are revolving at high speed. The spikes tear the tightly-packed cotton apart, loosening the fibres and allowing many of the impurities to shift out.

Next, the cotton passes to similar machines in which it is beaten to free it from impurities that remain. Another machine continues the cleaning process, delivering the cotton eventually in the form of 'laps', which are continuous sheets of fibre about 102 cm wide and 2.5 cm thick. At this stage, the cotton is like an enormous roll of 'cotton wool' [8]. As the raw fiber passes through these processes, it is successively called "lap," "sliver," "roving," and finally "yarn."

The purpose of these procedures is to open, or fluff, the fibers, clean them of any impurities, and mix and blend them into even strands in preperation for spinning process. The spinning process is a matter of reducing the prepared strands to the proper size and twisting them in such a way so that they will bind together and thus form yarns suitable for further processing into knitted or woven fabrics and other products [15].

5.2. Methods and Equipment Used in This Study

Contrary to the cotton fibers are processed to several different stages prior to the actual formation into yarns which are described before, after the samples of each cotton are taken and tests performed using the HVI and AFIS instruments, the smallest quantity of cotton has been processed through the laboratory equipment of Uster MDTA 3 (Microdust and Trash Analyser, 3rd generation).

The Uster MDTA 3 is a new piece of technical laboratory equipment which makes possible both a gravimetric and visual assessment of trash, dust and fiber fragments [52]. It is applied in the textile laboratories of spinning mills for examination of cotton and synthetic fibers, in the preparation process. The purpose of this device is to form a sliver out of the individualized and cleaned cotton fibers. This sliver can be processed directly on a rotor spinning unit into a yarn. But in this study, all cotton fibers are processed on a ring spinning unit.

This equipment simulate the whole preparation stage of the spinning process (opening, cleaning, carding, doubling). The rotorring 3 is connected to the Uster MDTA 3 in place of the fiber collection box (Figure 5.1.). The fibers are directly transported from the opening roller of the MDTA 3 into the rotating rotor of the Rotorring 3. The surface of the opening roll is covered with card wire to efficiency comb out the fiber beard presented by the feeding system. At this point, small dust particles and fiber fragments are seperated from the fibers and extracted by a vacuum to be suctioned off into the dust channel. By means of two filters of different permeabilities, these particles are separated into dust and fiber fragments. The larger trash particles are seperated from the fibers by means of a mote knife and an air baffle, and extracted by means of centrifugal force. The trash is collected in a plastic bag for easy weighing and visual assessment. The remaining fibers are transported by vacuum into fiber box.

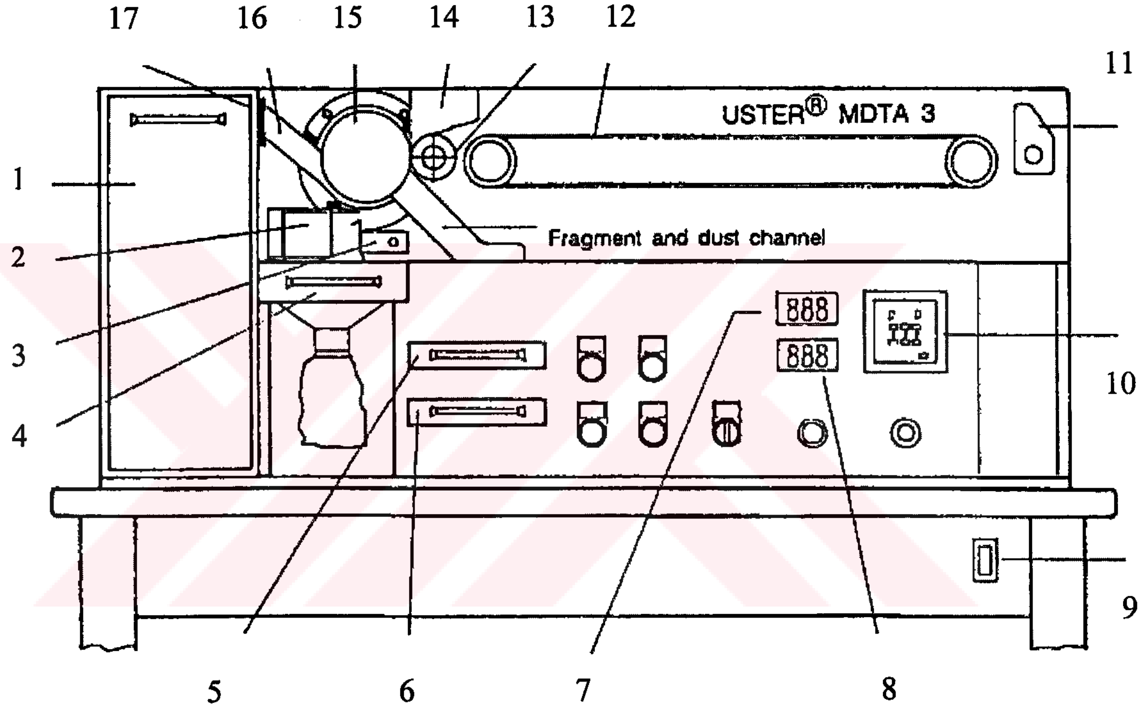


Figure 5.1. Front view and partial section of the Uster MDTA 3 1-Fiber box 2-Trash knife 3-Air baffle plate 4-Trash drawer 5-Fragments drawer 6-Dust drawer 7-Neg air pressure indicating fiber box 8-Neg air pressure indicating fragment and dust channel 9-Main swicth 10-Timer 11-Sliver support 12-Supply belt 13-Feed roll 14-Feed table 15-Bealer 16-Seal 17-Fiber channel

The rotor has a diameter of 300 mm. The produced sliver has therefore a length of 1 meter. To produce a sliver weight suitable rotor spinning, a sample of 3 to max. 10 grams of raw material has to be fed to MDTA 3. The redoubling effect of the rotor (the fibers are deposits in many layers in the rotor groove due to the rotation of the rotor) even out weight variations in the fed fiber tufts.

Other spinning stages are continued in industrial scale equipment. After the sliver are formed, they may go directly to the rotor spinning machine if they are to be ring spun, they are transferred to the roving machine for further processing prior to ring spinning. Roving is an intermediate stage preparatory to ring spinning. Here the sliver is again passed through a set of drafting rolls that draw the fibers down to the proper size required, and the machine then inserts a small amount of twist so that the fibers will cling together.

Spinning is the process of twisting the fibers into a cohesive structure so that the fibers will bind together and have as much strength as possible. The goal is to produce a yarn of a given size that is smooth, even, and free of irregularities or other defects. Two different ways of doing this are employed in the textile industry. They are ring spinning and rotor spinning. Most of the spinning in this country is done on "ring spinning frames." In ring spinning, the roving bobbins are placed on the machine and the roving is passed through a set of drafting rolls that draws the roving down to the size required for the yarn.

5.3. Yarn Analysis

Yarn analysis encompasses the following tests:

a) yarn number,
b) twist,
c) strength,

Other tests, such as determination of evenness and hairness, are performed on yarns but are not confined to yarns exclusively [45]. All yarn test results which are taken from Uster III and Uster Tensorapid are given at the end of this section (Table 5.2 and Table 5.3).

Uster statistics for yarn analysis: The Uster statistics are quality references which permits a classification of fibers, slivers, rovings, and yarns with regard to world production. The Uster statistics are first and foremost a practical quide to "good textile practices" in the field of yarn manufacturing.

The Uster statistics regularly serve as the platform for yarn contracts and product specification in the framework of commercial transaction. This practice is commonly accepted by the manufacturers, merchants, and processors of yarns. Many sales yarn spinners, weavers, and knitters have formulated quality requirements based on the

Uster statistics. Buyers and salesmen involved in the traditional commodity type trade or in direct purshasing and salesmen involved in the traditional commodity type trade or in direct purchasing and sales are certainly among enthusiastic users of the Uster statistics. They appreciate the statistics as a means of categorizing many different qualities by face value. An distinct yet popular belief prevails in the international markets for reasonably priced yarns that largely correspond to the 25th percentile of the Uster statistics to be in high demand.

The Uster statistics should not be interpreted as saying 5 % is "good". In the contrary, the 5 % line might be indicative of high cost, high price, luxurious- even a tendency to price oneself out of the market. By the same taken, 95 % should not imply "poor"- it might be indicative of a very attractive price and just the right quality for the target markets. A "good" spinner is actually one who is in a position to achieve an acceptable quality level from a less expensive fiber- the genuine mastery of spinning. The trouble starts when the Uster statistics are referred to in order to corroborate complaints about a low rating in certain quality categories. This complaint may be directed at the "good" spinner who produces a reasonably priced yarn from a reasonably priced fibers. Yarn price, however, is directly proportional to fiber quality and fiber quality in turn dictates yarn quality to a great extent. Consequently, pushing yarn quality towards better values would simply cannibalize the price advantage. The Uster Statistics should be employed as what they really are global survey of yarn quality as produced in every part of the world. Whether or not these qualities are produced economically from adequate raw materials and effered at a legitimate price is certainly beyond the scope of the statistics [53,54].

5.3.1. Yarn number

Several yarn numbering systems are now being used in the textile industry, but efforts are being made to adopt one universal system. The basis of all numbering systems is the relationship between weight and length of the yarn. The two basic methods being used are:

a) the indirect, based on a length per unit weight, and
b) the direct, based a weight per unit length.

Direct methods of measurement rely on the measurement of fixed lengths of yarn. A specified length of yarn is measured, and this length is weighed. The measures used are tex or denier. In all these measures, the higher the number, the heavier the yarn.

Tex is the preferred SI unit for linear density but it is not yet in common use throughout the textile industry. The Tex system has been proposed as the universal yarn numbering system in an effort to eliminate many systems now in use [45]. Other direct systems can be converted (Table 5.1).

Table 5.1. Count conversion chart

Given ⇨ / To determine ⇩	Ne_c	Tex	Denier	Nm	Ne_w
Ne_c		$\frac{590.5}{Tex}$	$\frac{5314.9}{Den}$	$\frac{Nm}{1.693}$	$\frac{Ne_w}{1.5}$
Tex	$\frac{590.5}{Ne_c}$		$\frac{Den}{9}$	$\frac{1000}{Nm}$	$\frac{885.8}{Ne_w}$
Denier	$\frac{5314.9}{Ne_c}$	$Tex \times 9$		$\frac{9000}{Nm}$	$\frac{7972.3}{Ne_w}$
Nm	$Ne_c \times 1.693$	$\frac{1000}{Tex}$	$\frac{9000}{Den}$		$Ne_w \times 1.13$
Ne_w	$Ne_c \times 1.5$	$\frac{885.8}{Tex}$	$\frac{7972.3}{Den}$	$\frac{Nm}{1.13}$	

Indirect methods of measurement rely on the measurement of fixed weights of yarn. The numbering system establishes a number of hanks (skeins) of yarn that make up either a pound or a kilogram of yarn weight. Pounds are used for measurements in the English system and kilograms for measurements in the metric system. In these measurement, the larger number, the finer yarn. The size of the hanks used is different for each kind of fiber.

5.3.2. Yarn twist

Twist, the spiral arrangement of the fibers around the axis of the yarn, is produced by rotating one end of a fiber strand while the other end is held the constituent fibres together stationary, thus giving strength to the yarn. The effects of the twist are twofold: as the twist increases, the lateral force holding the fibres together is increased so that more of the fibres can contribute to the overall strength of the yarn. Secondly as the twist increases, the angle that the fibres make with the yarn axis increases, so preventing them from developing their maximum strength which occurs when they are oriented in the direction of the applied force. The overall result is that there is a point as twist is increased where the strength of the yarn reaches a maximum value. Higher twist yarns are more expensive because yarn yield is lower. The strength, dyeing, finishing properties, the feel of the finished product etc. are all dependent on the twist in the yarn [20]. However, the ideal amount of twist varies with the yarn thickness: the thinner the yarn, the greater is the amount of twist that has to be inserted to give the same effect. Yarn can be classified by amount of twist as, very low twist, medium twist, hard twist and crepe twist [4].

5.3.3. Yarn strength

Strength is one of the tensile properties of textile materials, comprising their resistance to stretching or pulling forces. In use and care textile products are subjected to many different forces: stretching, twisting, bending, shearing, and compression. Acceptable levels of tensile properties depend on the end use for which the textile was produced. The level of tensile force that a seat belt or parachute fabric is expected to withstand is higher than that expected for apparel fabrics. Minimum strength levels can be used in selecting fabrics in product development or in evaluating retail products. The recommended breaking strength of fabrics for men's heavy-weight work clothing is more than twice that required for men's dress shirt fabrics, and should be considered in product selection. Tensile strength tests are the most common tests and these are carried out using either a single strand or a skein containing a definite number of strands as the test specimen.

Tensile strength of single strands of yarn: During routine testing, both the breaking load and extension of yarn at break are usually recorded for assessing the yarn quality. Most of the instruments record the load-elongation diagram also. Various parameters such as initial elastic modulus, the yield point, the tenacity or elongation at any stress or strain, breaking load, breaking extension etc can be obtained from the load-extension diagram.

Skein strength or lea strength: The skein breaking strength was the most widely used measure of yarn quality in the cotton textile industry. The measurement of yarn quality by this method has certain drawbacks. Firstly, in most of the subsequent processing, such as winding, warping or weaving, yarn is used as single strand and not in the form of a skein except occasionally when sizing , bleaching, mercerizing or dyeing treatments are carried out on hanks. Secondly, in the method used for testing skein strength, the rupture of a single strand at a weak place affects the result for the whole skein. Further, this method of test does not give an indication of the extensibility and elastic properties of a yarn, the characters which play and important role during the weaving operations. However, since a large size sample is used in a skein test as against that in a single strand test, the sampling error is less. The skein used for strength test can be used for determination of the linear density of the yarn as well [48].

Yarn strength measurement by Zellweger Uster Tensorapid: Among the more modem instruments there are some with digital reading systems, whose signal is sent to a computer to perform the statistical processing of the data (mean and CV): in this case, obviously, one does not perform a global weighing, but the single specimens are weighted separately, to obtain the frequency distribution. Zellweger Uster Tensorapid measures the yarn strength automatically.

As it is shown in Table 5.10, we have demonstrated that there is an unacceptable correspondence between the properties of yarns spun by small and large-scale methods, the latter providing yarns of slightly superior quality. In this study all cotton samples both NCC and white conventional cottons are firstly processed to sliver form in MDTA 3 without mixing, cleaning, opening, carding, combing. Consequently the properties of yarns produced by the small-scale test produce don't provide a close indication of yarn produced under large scale or production condition. However, the parameters of these yarns provides important information about the quality of the yarns since all sample cottons were converted into yarn form under the same conditions. Zellweger Uster Tensorapid strength measurement of others yarn results are given in Table 5.2.

Table 5.2. Strength values of the yarns

	Name	Rkm (kgf/Nm)	Uster Quality
1	DTN-5	11.57	% 95
2	NDT-10	11.25	% 95
3	NDT-11	12.89	% 95
4	NDT-13	14.31	% 95
5	NDT-15	10.55	% 95
6	Camel	8.46	% 95
7	Nazilli 84 (S)	12.71	% 95
8	K.Maraş-Brown	7.23	% 95
9	K.Maraş-Green	11.61	% 95
10	Sayar-314	12.05	% 95
11	Erşan-92	17.76	% 28

According to Uster Statistics 2001 of Ne 20/1 ring spun yarn made of 100 % cotton for knitted fabrics is defined as: RKM= 18 for 25^{th} percentile quality parameter. As can be seen in Table 5.2. all of the sample yarns are below 18.5 RKM value. However, these numerical values may not be an important indicator, as mentioned previously that the cotton samples were not converted into yarn by following the standart procedures. On the other hand, these samples may be compared with each other. If the numerical values are examined, it will seen that derived NCC yarn DTN-5, NDT-10 and NDT-15 are higher than Camel but lower than conventional white cotton yarn Nazilli 84 (S), but the yarn of NDT-13 has a higher strength than the yarn of Nazilli 84 (S).

Table 5.3. Elongation values of the yarns

	Name	Elongation (%)	Uster Quality
1	DTN-5	5.97	% 5
2	NDT-10	5.17	% 63
3	NDT-11	6.12	% 5
4	NDT-13	6.04	% 5
5	NDT-15	6.69	% 5
6	Camel	4.83	% 95
7	Nazilli 84 (S)	5.60	% 5
8	K.Maraş-Brown	4.71	% 95
9	K.Maraş-Green	7.08	% 5
10	Sayar-314	5.11	% 73
11	Erşan-92	6.35	% 5

According to the statistics 2001 of Ne 20/1 ring-spun yarn made of 100 % cotton yarn for knitted fabrics is measured at elongation 6 % for 25th percentile quality parameter of Uster statistics. In this case, some of the samples have elongation values which are quite close on higher than this standart value. For example, yarn made of DTN-5 has %5.97 elongation, and yarns produced from NDT-11, NDT-13 and NDT-15 have elongation values higher than standart value. This is interested point that the elongation values of sample yarn produced from DTN-5, NDT-11, NDT-13 and NDT-15 are higher than the sample yarns produced from Nazilli 84 (S) and Camel cottons which were used for crossbreeding.

5.3.4. Hairiness

Yarn hairiness is in most circumstances an undesirable property, giving rise to problems in fabric production. Therefore it is important to be able to measure it in order to control it. Fiber hairs surrounding a textile yarn may adversely affect the operations which follow spinning, such as weaving and knitting, and may influence the characteristics of the finished product [46]. Measurement of yarn hairiness has become an essential and routine test in the textile industry. However, it is not possible to represent hairiness with a single parameter because the number of hairs and the length of hairs both vary independently.

Hairiness of the yarns are given in Table 5.4.

Table 5.4. Hairiness values of the yarns

	Name	Hairness value (-)	Uster statistics
1	DTN-5	8.58	% 76
2	NDT-10	7.64	% 39
3	NDT-11	8.12	% 60
4	NDT-13	8.16	% 60
5	NDT-15	8.69	% 77
6	Camel	8.30	% 70
7	Nazilli 84 (S)	7.26	% 21
8	K.Maraş-Brown	9.10	% 83
9	K.Maraş-Green	8.85	% 79
10	Sayar-314	9.16	% 84
11	Erşan-92	9.24	% 85

According to the Uster Statistics 2001, an 20 Ne % 100 cotton packages, carded ring spinning yarn for knitted fabrics are measured at hairiness value 7.3 for 25th percentile quality paramater and 10 for 95th percentile quality parameter by Uster tester. As indicated previously that the direct comparison of hairiness of these samples with the standart value is no so logical, however their hairiness may be compared with each other.

Hairiness values of the yarns produced from derived NCC change between 7.64 to 8.69 that limits correspond to a wide range of spectrum. However, these values are close to hairiness values of yarns produced from their mother and father (Camel and Nazilli 84 (S)). On the other hand, the hairiness from the cotton cultivated at K.Maraş region have much more higher with respect to the others.

5.3.5. Evenness

Yarn evenness can be defined as the variation in weight per unit length of the yarn or as the variation in its thickness. It is generally known as 'Irregularity' or 'Unevenness' (in practice they are called Um % or CVm % value). There are a number of different ways of assessing it. Irregularity can adversely affect many of the properties of textile materials. The most obvious consequence of yarn evenness is the variation of strength along the yarn. An irregular yarn will tend to break more easily during spinning, winding, weaving, knitting, or any other process where stress is applied.

A second quality-related effect of uneven yarn is the presence of visible faults on the surface of fabrics. If a large amount of irregularity is present in the yarn, the variation in fineness can easily be detected in the finished cloth. Fabric construction geometry ensures that the faults will be located in a pattern that is very clearly apparent to the eye, and defects such as streaks, stripes, barre or other visual groupings develop in the cloth. Such defects are usually compounded when the fabric is dyed or finished, as a result of the twist variation accompanying them. Other fabric properties, such as abrasion or pill-resistance, soil retention, drape, absorbency, reflectance or luster, may also be directly influenced by yarn evenness. Thus, the effects of irregularity are widespread throughout all areas of the production and use of textiles, and the topic is an important one in any areas of the industry [48].

5.3.5.1. Coefficient of variation CVm %

Shortly, it is the coefficient of variation. The percentage CV gives an overall number for yarn irregularity and hence most widely used of the measurement that the instrument makes. The upper limit of CV which is acceptable for yarn varies with different types of yarn. Different spinning systems, counts and end uses have different upper limits and knowledge of these can only be gained from experience of what is acceptable in a given application. Uster produces a volume of 'statistics' which lists the measured values of unevenness for the main types of yarn and for a range of counts for each type, so that measured values can be compared with expected values. Graphical representation are given below (Figure 5.2.).

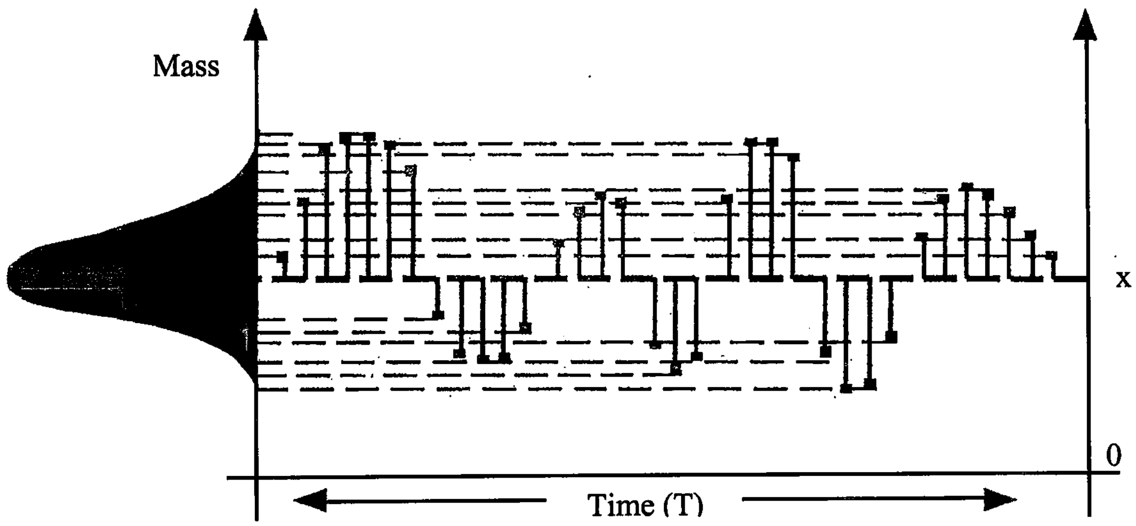


Figure 5.2. Graphical representation of mass variations

Coefficient of variation (CVm) which belong to the NCC and conventional white cottons are given in Table 5.5.

Table 5.5. Coefficient variation of the yarns

	Name	Coefficient variation (CVm)	Uster statistics
1	DTN-5	24.21	% 95
2	NDT-10	21.12	% 95
3	NDT-11	20.52	% 95
4	NDT-13	23.07	% 95
5	NDT-15	23.46	% 95
6	Camel	22.10	% 95
7	Nazilli 84 (S)	19.90	% 95
8	K.Maraş-Brown	31.08	% 95
9	K.Maraş-Green	22.30	% 95
10	Sayar-314	26.62	% 95
11	Erşan-92	26.40	% 95

According to the statistics 2001, an 20 Ne % 100 cotton packages, carded ring spinning yarn for knitted fabrics are measured at coefficient of variation(CVm) value 14 for 25^{th} percentile quality paramater and 17 for 95^{th} percentile quality parameter by Uster tester.

If the numerical values of samples are compared with each other, it will be seen that CVm values of DTN-5, NDT-13 and NDT-15 are higher than Camel and Nazilli 84 (S), but NDT-10 and NDT-11 have lower CVm values than Camel, higher than Nazilli 84(S). However, the yarn obtained from the cotton of K.Maraş-Brown has the highest value, but K.Maraş-Green has very low hairness. Conventional white cotton yarns produced from Sayar-314 and Erşan-92 fibers CVm values are about 26.5.

5.3.5.2. Imperfection

Spun yarns contain certain extremes of variations besides the normal irregularity referred to as imperfection. They are also referred to as frequently occurring yarn faults.

In addition to measuring the overall variability of yarn thickness the Uster tester also counts the larger short-term deviation from the mean thickness. These are known thin places, thick places, and neps.

Imperfections are caused either due to poor raw material quality or due to imperfect process parameters. A reliable estimation and analysis of these imperfections will therefore help in achievement of optimum processing conditions and also provide some reference for the purchase of good quality raw material.

The imperfections are detected when the measured value of the mass variations oversteps the concerned sensitivity level. Standard sensitive levels for imperfections are as follows;

a) Thin places : -50%
b) Thick places : +50%
c) Neps : +200% (+280% for open-end yarns).

Thin places: It is the faults that occur by thinness of yarn and causes breakage on weaving operation. A yarn showing mass variations as given in Figure 5.3.

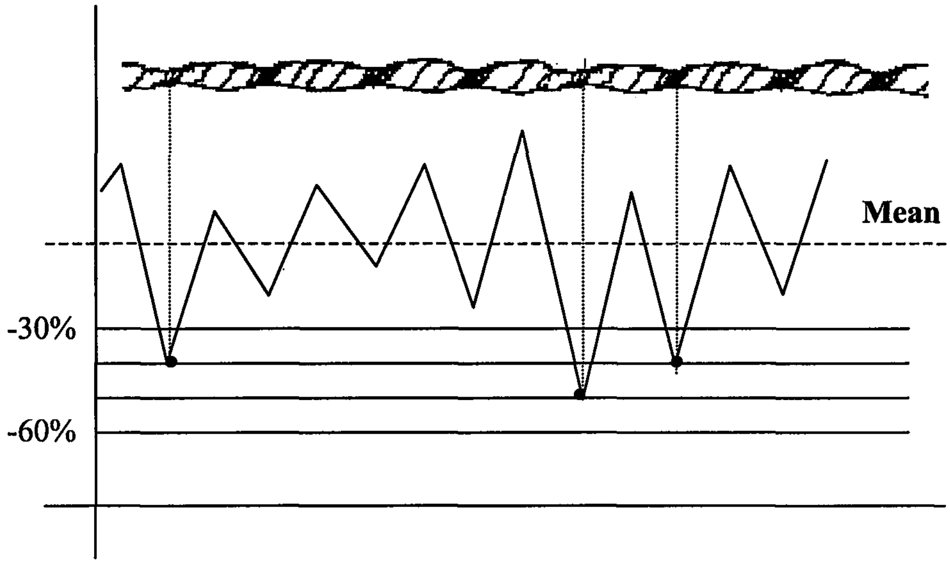


Figure 5.3. Mass variations showing thin places

In a yarn, a thin place overstepping a lower sensitivity level will also be overstepping the higher sensitivity levels. Therefore, when this yarn is tested in a evenness tester, the imperfection indicator would record the number of thin places as 1 at a sensitivity level of –50% and 3 at a sensitivity level of –40%. Thin places at a sensitivity level of – 50 % of cotton yarns are given in Table 5.6.

Table 5.6. Thin places (-50 %) of the yarns

	Name	Thin places (-50 %)	Uster statistics
1	DTN-5	718	% 95
2	NDT-10	98	% 95
3	NDT-11	58	% 95
4	NDT-13	435	% 95
5	NDT-15	228	% 95
6	Camel	350	% 95
7	Nazilli 84 (S)	70	% 95
8	K.Maraş-Brown	3220	% 95
9	K.Maraş-Green	640	% 95
10	Sayar-314	951	% 95
11	Erşan-92	610	% 95

According to the statistics 2001, an 20 Ne % 100 cotton packages, carded ring spinning yarn for knitted fabrics are measured at thin places (-50 %) value 4.2 for 25th percentile quality paramater and up to 24 for 95th percentile quality parameter by Uster tester.

Thin places of derived NCC yarns DTN-5, NDT-10, NDT-11, NDT-13, NDT-15 and also Camel used for crossbreeding have found between 58 and 718. As could be seen in Table 5.6. fluctuations are extremely high. The numerical thin places values of NDT-11 is lower than Nazilli 84 (S), but thin places values of DTN-5 and NDT-13 are higher than Camel and Nazilli 84 (S). The highest thin places value (3220) belongs to K.Maraş-Brown.

Thick places: It is the faults that occur by thickness of yarn (Figure 5.4.). The length threshold level for detection of thick places is 4 mm. A mass increase is recorded as a thick place only if its length exceeds 4 mm. A mass increase with length below 4 mm is classified as a nep.

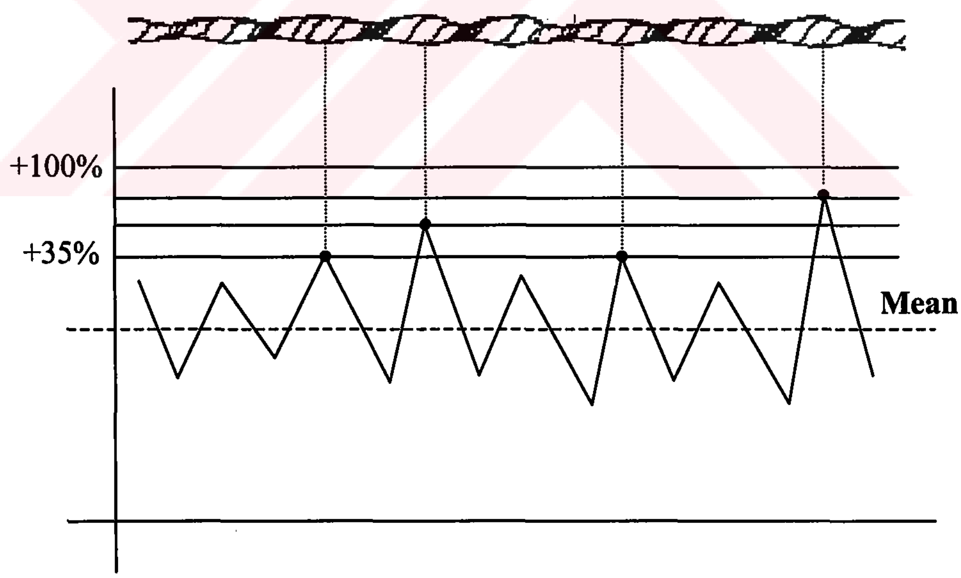


Figure 5.4. Mass variations showing thick places

Thick places of cotton yarns measured from Uster HVI instruments are given in Table 5.7.

Table 5.7. Thick places (+ 50 %) of the yarns

	Name	Thick places (+50 %)	Uster statistics
1	DTN-5	899	% 95
2	NDT-10	554	% 95
3	NDT-11	432	% 95
4	NDT-13	815	% 95
5	NDT-15	580	% 95
6	Camel	936	% 95
7	Nazilli 84 (S)	478	% 95
8	K.Maraş-Brown	2020	% 95
9	K.Maraş-Green	920	% 95
10	Sayar-314	1280	% 95
11	Erşan-92	905	% 95

According to the statistics 2001, an 20 Ne % 100 cotton packages, carded ring spinning yarn for knitted fabrics are measured at thick places (+50 %) value 78 for 25^{th} percentile quality paramater and up to 400 for 95^{th} percentile quality parameter by Uster tester.

Thick places values of derived NCC yarn NDT-10, NDT-11 and NDT-15 are very close to the values of the conventional white cotton yarn's Nazilli 84 (S). However the yarn obtained from DTN-5 and NDT-13 cottons given thick place as much as twice of Nazilli 84(S). The highest thick places values are measured at K.Maraş-Brown with 2020 values.

Neps: A nep is a thick place not exceeding a length of 4 mm. The mass increase is measured over a reference length of 1 mm and this increase, if oversteps the selected sensitivity level, then a nep will be registered (Figure 5.5.) [45].

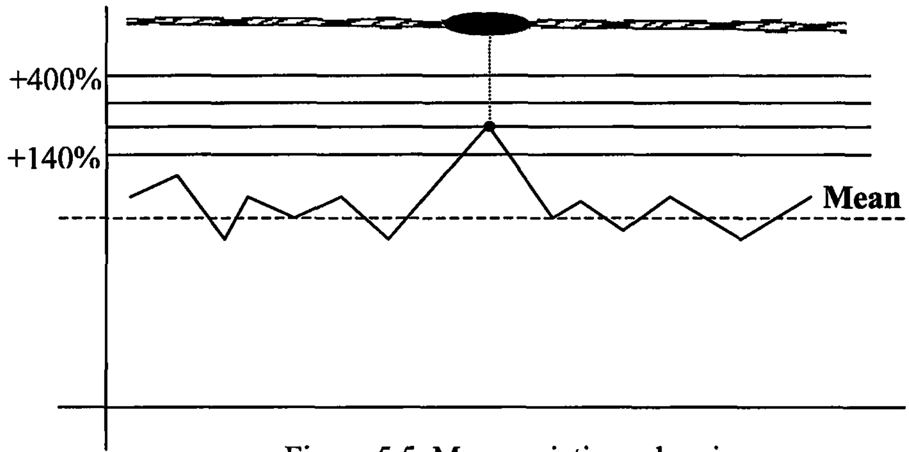


Figure 5.5. Mass variations showing neps

Neps can be divided, fundamentally, into two categories

a) Raw material neps: The raw material neps in cotton yarns are primarily the result of vegetable matter and immature fibers in the raw material. The influence of the raw material with wool and synthetic fibers in terms of nep production is negligible.
b) Processing neps: Processing neps are produced at ginning and also in cotton, woolen and worsted carding. Their formation of neps is influenced by the type of card clothing, the setting of the card flats, workers and stripters, and by the production speed used [53,54].

Neps can influence the appearance of woven or knitted fabrics quite considerably. Furthermore, neps of a certain size can lead to processing difficulties, particularly in the knitting machine sector of the industry. Consequently, the avoidance of neps in the production of spun yarns is a fundamental textile technological problem, whose solution is facilitated considerably by the application of the Uster.

Neps values belong to sample yarns are given in Table 5.8.

Table 5.8. Neps values (+200%) of the yarns

	Name	Neps (+ 200 %)	Uster statistics
1	DTN-5	325	% 82
2	NDT-10	230	% 70
3	NDT-11	185	% 58
4	NDT-13	405	% 92
5	NDT-15	211	% 66
6	Camel	266	% 76
7	Nazilli 84 (S)	158	% 51
8	K.Maraş-Brown	1800	% 92
9	K.Maraş-Green	400	% 86
10	Sayar-314	435	% 94
11	Erşan-92	349	% 85

According to the statistics 2001, an 20 Ne % 100 cotton packages, carded ring spinning yarn for knitted fabrics are measured at neps (+50 %) value 103 for 25th percentile quality paramater and up to 430 for 95th percentile quality parameter by Uster tester.

The neps value of yarns produced from derived NCC are, in general, higher than neps of yarn of Nazilli 84(S), but their average value is close to the neps value of yarn of Camel cotton. On the other side, the neps of yarns produced from K.Maraş-Green, Sayar-314 and Erşan-92 has an average value of 400, but the other yarn of K.Maraş-Brown given maximum neps of 1800.

After fiber parameters are evaluated, the second step of this study is investigate physical and mechanical properties of NCC yarns and compare these results with conventional white cotton yarns. All of the NCC and conventional white cotton yarns are produced by Sanko Textile in Gaziantep according to Table 5.9 under the same conditions. All of the cotton yarns are measured by Uster Evenness Tester III and Uster Tensorapid Tester for strength and elongation. Table 5.10. shows test results.

Table 5.9. Ring spinning cotton yarn specification

Number of Roving	1.10
Twist of Roving	55
Number of Yarn	20/1
Twist of Ring	742
Rpm of spindle	6800 rpm
Production Range	9.3 m/min
Ambient conditions	20 ± 2 °C / 65 ± 2 R.H.

Tablo 5.10. Mechanical properties of sample yarns

	Cotton yarn which is planted in Nazilli							Cotton yarn which is planted in K.Maraş			
	Derived naturally coloured cotton yarn					Male and female cotton yarn which is used for crossing		Orijinal coloured and white cotton yarn			
	DTN-5	NDT-10	NDT-11	NDT-13	NDT-15	Camel	Nazilli-84(S)	K.Maraş Brown	K.Maraş Green	Sayar-314 White	Erşan-92 White
Um (%)	18,77	16,30	16,06	17,71	17,96	17,2	15,275	24,15	17,27	20,37	20,66
CVm (%)	24,21	21,12	20,52	23,07	23,46	22,1	19,90	31,08	22,30	26,62	26,40
Index (-)	3,31	2,89	2,81	3,16	3,22	3,0	2,725	4,26	3,05	3,64	3,62
Thin Places (-50 %)	718,0/km	98,0/km	58,0/km	435,0/km	228,0/km	350/km	70/km	3220,0/km	640,0/km	951,0/km	610,0/km
Thick Places (+50 %)	899,0/km	554,0/km	432,0/km	815,0/km	580,0/km	936,0/km	478,75/km	2020,0/km	920,0/km	1280,0/km	905,0/km
Neps (+200 %)	325,0/km	230,0/km	185,0/km	405,0/km	211,0/km	266,0/km	158,75/km	1800,0/km	400,0/km	435,0/km	349,0/km
Hairness	8,58	7,64	8,12	8,16	8,69	8,30	7,265	9,10	8,85	9,16	9,24
B-Force (gf)	341,8	332,3	380,8	422,7	265,2	249,9	375,3	213,7	342,8	531,6	562,1
Elongation (%)	5,97	5,17	6,12	6,04	6,69	4,83	5,60	4,71	7,08	5,11	6,35
Rkm (kgf*Nm)	11,57	11,25	12,89	14,31	10,55	8,46	12,71	7,23	11,61	12,05	17,76

CHAPTER 6
EXPERIMENTAL STUDY - FABRIC

6.1. Fabric Analysis

In addition to finer content and yarn structure, the several fabric physical properties affect final performance. These properties are explained shortly in the following section.

6.1.1. Color fastness

Color is one of the most important factors in consumer acceptance of textiles. When a consumer shops for a new garment, color typically weighs heavily in the purchase decision. Most often, this means whether or not the color is pleasing. However, in some cases, it means whether or not the color matches another item that the consumer already has.

Retention of color is equally important to consumers and is often a determining factor in the serviceability of a textile item. Consumers may discard an satisfactory item because it has faded or has changed color in some other way. A textile that resists loss of color is said to be colorfast.

Poor colour fastness in textile products is a major source of customer complaint. The fastness of a colour can vary with the type of dye, the particular shade used, the depth of shade and how well the dyeing process has been carried out. Dyes can also behave differently when in contact with different agents, for instance dyes which may be fast to dry-cleaning may not be fast to washing in water. It is therefore important to test any dyed or printed product for the fastness of the colours that have been used in its decoration. There are a number of agencies that the coloured item may encounter during its lifetime which can cause the colour either to fade or to bleed onto an adjacent uncoloured or light coloured item. These factors vary with the end use for which the product is intended. For instance carpets and upholstery are cleaned in a different way from bed linen and clothing and therefore come into contact with different materials. The agencies that affect coloured materials include light, washing, dry-cleaning, water, perspiration and ironing.

6.1.2. Measurement of colorfastness

Many different conditions that a fabric encounters in use can cause it to change. These conditions include moisture, light, heat, and abrasion. There are a number of test methods that deal with colorfastness, differentiated by the treats and conditions to which the textiles are exposed. These tests provide exposure to various agents and treatments that can potentially alter textile color, including water, perspiration, light, laundering, bleaching, drycleaning, and crocking. Color change resulting from these treatments can be assessed visually or instrumentally. Currently, most colorfastness tests specify the use of visual evaluation tools, such as gray scales, that provide numerical ratings that correspond with apparent levels of color difference between specimens. Although visual evaluation procedures are carefully conducted under standard. Some tests are for end-use conditions, while others focus on in-production conditions that the fabric may inter in processing. Several of the standard colorfastness tests that are widely used are given below.

Gray scales: In order to give a more objective result a numerical assessment of each of these effects is made by comparing the changes with two sets of standard grey scales, one for colour change and the other for staining [49]. There are two standard gray scales for evaluating color differences. Each gray scale consists of nine steps of color difference represented by stationary pairs of gray chips. Gray scale ratings are determined by comparing the difference between an unexposed specimen and an exposed specimen with the difference observed between the two members of a stationary pair of chips on the gray scale. The original (unexposed) specimen and its corresponding exposed specimen are placed side by side. The gray scale is then placed beside the edges of the test specimen and the unexposed specimen. Finally, the perceived visual difference between the unexposed and exposed specimens is compared with the perceived differences represented between the pairs of chips on the gray scale. A rating is assigned based on this comparison of perceived differences in value. The nine steps are designated as follows: 5, 4-5, 4, 3-4, 3, 2-3, 2, 1-2, and 1. A gray scale rating of 5 indicates no color difference between two specimens (good colorfastness). The opposite extreme, maximum color difference between two specimens (poor colorfastness), is indicated by a rating of 1. At the end of the test, samples must be evaluated by using gray scale as shown in Table 6.1.

Table 6.1 Colorfastness classification according to gray scale

Colorfastness degree	Classification
5	No colour change (good colorfastness)
4	Slight colour change
3	Moderate colour fastness
2	Severe colorfastness
1	Very severe colour change (poor colorfastness)

6.1.2.1. Colorfastness to crocking

Crocking is the transfer of color from a colored textile to another fabric surface through the process of rubbing. The extent of crocking may be influenced by moisture, as many textiles transfer more color when wet. The test (ISO 105/X12) requires a crockmeter that has a base for mounting the fabric specimen and an arm with a small plastic finger. The finger is covered with a standard white fabric called a crock square and is rubbed against the test fabric for a specified number of cycles. Color transfer to the standard fabric is then evaluated using the standarts. The gray scale for staining can be used [44].

The performance tests of fabrics made from cottons (Erşan-92, Sayar-314, K.Maraş-Brown and K.Maraş-Green) obtained from KARI are not done because some of these fibers were not suitable for fabric construction due to low strength and high amount of neps. Therefore they are not included in this chapter. So, the samples includes the fabrics which are made of derived naturally coloured fibers (children) and orijinal naturally coloured fibers (parents). Colorfastness to dry crocking of the samples are given in Table 6.2. All the samples have very good dry colorfastness, that means, no color change of the samples were observed.

Table 6.2. Colorfastness to crocking (DRY) of the knitted fabrics

	Name	Colorfastness to crocking (DRY)	Classification
1	DTN-5	5	Good colorfastness
2	NDT-10	5	Good colorfastness
3	NDT-11	5	Good colorfastness
4	NDT-13	5	Good colorfastness
5	NDT-15	5	Good colorfastness
6	Camel	5	Good colorfastness
7	Nazilli 84 (S)	5	Good colorfastness

Wet crocking colorfastness of these samples were also performed and these test results are given in Table 6.3. The wet crocking colorfastness of fabric made of Nazilli 84 (S) fibers (white cotton) has very good colorfastness value "5", however, all of the other sample fabrics exhibit slight color change as shown in the Table 6.3.

Table 6.3. Colorfastness to crocking (WET) of the knitted fabrics

	Name	Colorfastness to crocking (WET)	Classification
1	DTN-5	4	Slight color change
2	NDT-10	4-5	Slight color change
3	NDT-11	4	Slight color change
4	NDT-13	4	Slight color change
5	NDT-15	4-5	Slight color change
6	Camel	4	Slight color change
7	Nazilli 84 (S)	5	Good colorfastness

6.1.2.2. Colorfastness to laundering and hypochlorite

As most consumers know, fabric can change color in home laundering using washing machines, or even in hand laundering. This can be a result of the effects of the water, detergent, bleach, or other laundry additives, and is also related to temperature and agitation, as well as the stability of the dye. This test simulate commercial laundering at different temperatures with different levels of detergents by using laundering machine according to ISO 105/ C06 standarts.

A standard fabric or multifiber swatch is attached to the test fabric. These are placed in canisters with a standard detergent solution and steel balls to provide agitation. Water temperature is controlled during the test. After the cycle, the fabric being tested is evaluated for color change either instrumentally, or using the gray scale for color change. At the end of the tests, these results are obtained.

Table 6.4. Colorfastness to laundering (Staining) of the knitted fabrics

	Name	Colorfastness to laundering (Staining)	Classification
1	DTN-5	4	Slight color change
		4-5(polyester)	Slight color change
2	NDT-10	4-5	Slight color change
3	NDT-11	5	Good colorfastness
4	NDT-13	5	Good colorfastness
		4-5 (polyester)	Slight color change
5	NDT-15	5	Good colorfastness
6	Camel	5	Good colorfastness
7	Nazilli 84 (S)	5	Good colorfastness

Staining colorfastness to laundering of fabrics which are knitted from NDT-11, NDT-13 (except polyester fabric in multifiber test material) and NDT-15 fibers are shared same colorfastness with fabric produced from Camel fibers. DTN-5 has the lowest value "4" for secondary cellulose acetate (dicel), bleached unmercerized cotton, nylon 6.6, acrylic (courtelle), wool worsted fabrics in multifiber test material. Not only DTN-5 but also NDT-13 is in "slight colorfastness" for polyester fabrics in multifiber test material according to gray scale. The white cotton, Nazilli 84 (S) has good colorfastness classification with "5" value.

Colour change of colorfastness to laundering of samples are given in Table 6.5.

Table 6.5. Colorfastness to laundering (Colour change) of the knitted fabrics

	Name	Colorfastness to laundering (Colour change)	Classification
1	DTN-5	5	Good colorfastness
2	NDT-10	5	Good colorfastness
3	NDT-11	5	Good colorfastness
4	NDT-13	5	Good colorfastness
5	NDT-15	5	Good colorfastness
6	Camel	5	Good colorfastness
7	Nazilli 84 (S)	4	Slight color change

All of the sample fabrics which were knitted from DTN-5, NDT-10, NDT-11, NDT-13, NDT-15 and Camel fibers don't change the colour during laundering process. The most significant alteration was colour inherent of NCC fabric's colour were not faded when laundering, but more stronger, intenser and saturated. However, when the sample produced from conventional white cottons Nazilli 84 (S), it was observed that the sample has slight color change with "4" value.

Hypochlorite colorfastness method (ISO EN 20105 N01/ April 1999) is used to determine the colorfastness to sodium hypochlorite bleach, commonly called "chlorine bleach," in home laundering of textiles which are expected to withstand frequent laundering. Results of this test method may be used in combination with other testing for establishing care instructions. If a chlorine bleach contains ingredients other than the sodium hypochlorite, it is the total effect of these chemicals on the color change that is being evaluated. Specimens are laundered under appropriate conditions of temperature, chlorine bleach solution and specimens are evaluated for color change. At the end of the colorfastness to hypochlorite tests, these results are given in Table 6.6.

Table 6.6. Colorfastness to hypochlorite (colour change) of knitted fabrics.

	Name	Colorfastness to hypochlorite (Colour change)	Classification
1	DTN-5	2-3	Moderate colorfastness
2	NDT-10	2	Severe colorfastness
3	NDT-11	2	Severe colorfastness
4	NDT-13	1-2	Poor colorfastness
5	NDT-15	2	Severe colorfastness
6	Camel	1-2	Poor colorfastness
7	Nazilli 84 (S)	3	Moderate colorfastness

According to colorfastness to hypochlorite of NCC fabrics which were knitted from NDT-10, NDT-11, NDT-15 fibers have severe colorfastness classification with "2" value. NDT-13 has the classification of 1-2 poor colorfastness. According to the grey scales, all these cotton fabrics colour change of hypochlorite colorfastness are not acceptable by textile industry and customer. Besides these results, Nazilli 84 (S) has moderate colorfastness with "3" value.

6.1.2.3. Colorfastness to perspiration

ISO 105/ E04 perspiration colorfastness test requires a device called a perspirometer, which applies pressure to the specimen as it is heated to body temperature alter being wetted in a simulated perspiration solution. The fabric being tested, along with a multifiber test strip attached, is soaked in an acidic and alkaline perspiration solution that includes sodium chloride, lactic acid, anhydrous disodium hydrogen phosphate, and histidine monohydrochloride in proportions specified in the standart test method. After being wetted out, the specimens and attached test cloths are heated under pressure for a specified time period. The heat and pressure serve to accelerate the test. The solution should be made up freshly for each use according to the test method.

The tested fabric may be evaluated for color change using the gray scale for color change, or instrumentally, and the standard white fabric or multifiber test strip is evaluated using the gray scale for staining, the chromatic transference scale, or instrumentally. Acid perspriation colorfastness test results according to staining are given in Table 6.7.

Table 6.7. Colorfastness to acid perspriation (staining) of the knitted fabrics

	Name	Colorfastness to acid perspriation(staining)	Classification
1	DTN-5	5	Good colorfastness
		4-5 (Nylon 6.6)	Slight color change
2	NDT-10	5	Good colorfastness
		4-5 (Nylon 6.6)	Slight color change
3	NDT-11	5	Good colorfastness
		4-5 (Nylon 6.6)	Slight color change
4	NDT-13	5	Good colorfastness
		4-5 (Nylon 6.6)	Slight color change
5	NDT-15	5	Good colorfastness
		4-5 (Nylon 6.6)	Slight color change
6	Camel	5	Good colorfastness
		4-5 (Nylon 6.6)	Slight color change
7	Nazilli 84(S)	5	Good colorfastness
		4-5 (Nylon 6.6)	Slight color change

As seen from the above table all of the samples have good colorfastness according to secondary cellulose acetate (dicel), bleached unmercerized cotton, polyester (terylene), acrylic (courtelle), wool worsted of multifiber test material, however nylon 6.6 is in slight color change that is in the acceptable limits of textile industry.

Colorfastness to acid perspriation according to color change is given in Table 6.8. Colour change of acid perspriation colourfastness of NCC knitted fabrics which are constructed from DTN-5, NDT-10, NDT-11, NDT-13, NDT-15 and Camel fibers have same classification "Good colorfastness". But the sample fabrics which is constructed from conventional white cotton fibers Nazilli 84 (S), exhibits slight color change which may be negligible for textile industry.

Table 6.8. Colorfastness to acid perspriation(colour change) of the knitted fabrics

	Name	Colorfastness to acid perspriation (Colour change)	Classification
1	DTN-5	5	Good colorfastness
2	NDT-10	5	Good colorfastness
3	NDT-11	5	Good colorfastness
4	NDT-13	5	Good colorfastness
5	NDT-15	5	Good colorfastness
6	Camel	5	Good colorfastness
7	Nazilli 84 (S)	4-5	Slight color change

Colorfastness to alkaline perspriation (staining) of the knitted fabrics are given in Table 6.9. The results show that all the samples exhibit the same behaviour. The alkaline perspriation of samples for secondary cellulose acetate (dicel), bleached unmercerized cotton, polyester (terylene), acrylic (courtelle) and wool are in "Good colorfastness" classification. However all the samples again show slight color change for nylon 6.6 of multifiber test material.

Table 6.9. Colorfastness to alkaline perspriation (staining) of the knitted fabrics

	Name	Colorfastness to alkaline perspriation(staining)	Classification
1	DTN-5	5	Good colorfastness
		4-5 (Nylon 6.6)	Slight color change
2	NDT-10	5	Good colorfastness
		4-5 (Nylon 6.6)	Slight color change
3	NDT-11	5	Good colorfastness
		4-5 (Nylon 6.6)	Slight color change
4	NDT-13	5	Good colorfastness
		4-5 (Nylon 6.6)	Slight color change
5	NDT-15	5	Good colorfastness
		4-5 (Nylon 6.6)	Slight color change
6	Camel	5	Good colorfastness
		4-5 (Nylon 6.6)	Slight color change
7	Nazilli 84(S)	5	Good colorfastness

As seen in Table 6.10, all NCC knitted fabrics which are constructed from DTN-5, NDT-10, NDT-11, NDT-13, NDT-15, Camel and conventional white cottons knitted fabrics's (Nazilli 84(S)) colour change of alkaline perspriation colorfastness are in "Good colorfastness" according to gray scale.

Table 6.10. Colorfastness to alkaline perspriation(colour change) of the knitted fabrics

	Name	Colorfastness to alkaline perspriation (Colour change)	Classification
1	DTN-5	5	Good colorfastness
2	NDT-10	5	Good colorfastness
3	NDT-11	5	Good colorfastness
4	NDT-13	5	Good colorfastness
5	NDT-15	5	Good colorfastness
6	Camel	5	Good colorfastness
7	Nazilli 84 (S)	5	Good colorfastness

6.1.3. Pilling resistance

Pilling is a condition that arises in wear due to the formation of little 'pills' of entangled fibre clinging to the fabric surface giving it an unsightly appearance. Pills are formed by a rubbing action on loose fibres which are present on the fabric surface. Pilling was originally a fault found mainly in knitted woollen goods made from soft twisted yarns. The introduction of man-made fibres into clothing has aggravated its seriousness. The explanation for this is that these fibres are stronger than wool so that the pills remain attached to the fabric surface rather than breaking away as would be the case with wool [55].

The initial effect of abrasion on the surface of a fabric is the formation of fuzz as the result of two processes, the brushing up of free fibre ends not enclosed within the yarn structure and the conversion of fibre loops into free fibre ends by the pulling out of one of the two ends of the loop.

The greater the breaking strength and the lower the bending stiffness of the fibres, the more likely they are to be pulled out of the fabric structure producing long protruding fibres. Fibre with low breaking strength and high bending stiffness will tend to break before being pulled fully out of the structure leading to shorter protruding fibres.

The next stage is the entanglement of the loose fibres and the formation of them into a roughly spherical mass of fibres which is held to the surface by anchor fibres. As the pill undergoes further rubbing, the anchor fibres can be pulled further out of the structure or fatigued and eventually fractured depending on the fibre properties and how tightly they are held by the structure. In the case of low-strength fibres the pills will easily be detached from the fabric but with fabrics made from high-strength fibres the pills will tend to remain in place. This factor is responsible for the increase in the propensity for fabrics to pill with the introduction of synthetic fibres.

The use of higher twist in the yarn, reduced yarn hairiness, longer fibres, increased inter-fibre friction, increased linear density of the fibre, brushing and cropping of the fabric surface to remove loose fibre ends, a high number of threads per unit length and special chemical treatments to reduce fibre migration will reduce the tendency to pill. The presence of softeners or fibre lubricants on a fabric will increase pilling. Fabrics made from blended fibres often have a greater tendency to pill as it has been found that the finer fibres in a blend preferentially migrate towards the yarn exterior due to the difference in properties.

Fabric pilling is a complex phenomenon comprised of different stages and influenced by several factors. Factors influencing fabric pilling are;

a) fiber type and cross-sectional shape,
b) yarn type and construction,
c) fabric type and construction.
d) fabric finishes also play an important role inpilling by affecting some of these textile parameters.

6.1.3.1 Pilling tests

After rubbing of a fabric it is possible to assess the amount of pilling quantitatively either by counting the number of pills or by removing and weighing them. However, pills observed in worn garments vary in size and appearance as well as in number. The appearance depends on the presence of lint in the pills or the degree of colour contrast with the ground fabric. These factors are not evaluated if the pilling is rated solely on the number or size of pills. Furthermore the development of pills is often accompanies by other surface changes such as the development of fuzz which affect the overall acceptability of a fabric. It is therefore desirable that fabrics tested in the laboratory are assessed subjectively with regard to their acceptability and not rated solely on the number of pills developed. Counting the pills and/or weighing them as a measure of pilling is very time consuming and there is also the difficulty of deciding which surface disturbances constitute pills. The more usual way of evaluation is to assess the pilling subjectively by comparing it with either standard samples or with photographs of them or by the use of a written scale of severity. Most scales are divided into five grades and run from grade 5, no pilling, to grade 1, very severe pilling. Standart test methods are given below;

a) ICI pilling box.
b) Random tumble pilling test.
c) Pilling test Swiss standard.
d) Martindale pilling tests.

The pilling test of the samples were performed on martindale pilling tester. As mentioned previously pilling of fabrics is a complex phenomenal because several factors affect the result and these factors may be classified in to three main groups as:

a) fiber properties,
b) yarn properties,
c) fabric properties.

However, in this study, the yarn and fabric properties of the samples are same because all the yarns were produced as same yarn count (Ne 20) and all the fabrics have same structure (plain knitted fabrics). As a result, differences between pilling degree of samples are due to fiber properties as given in Table 4.7. and Table 4.8.

First of all, the number of turns the pilling machine that correspond to maximum pilling of the samples were determined. This number is divided into five intervals to examine the evaluation of pilling of samples. The corresponding intervals were determined as 25, 50, 75, 100, 125 and 150 turns of the machine. Table 6.11. shown the numerical values of pilling of samples for the determined intervals of the pilling machine. These numerical values were converted to graphs given in Figure 6.1, that shows the pilling degree of samples produced from DTN-5, NDT-10, NDT-13, NDT-15 fibers. The results show that every one of these samples produce a different numbers of pills. However, the samples which are produced from NDT-11 and NDT-13 have minimum number of pills when compared to the others, because the fiber properties of these samples are better than other derived NCC. However fabrics knitted from DTN-5 cotton fibre produces 8 pills/ cm^2 after 100 turns of martindale piling instruments because of low fiber and yarn quality.

Pilling degrees of samples produced from Devetüyü and Nazilli 84 (S) fibers are given in Figure 6.2. that shown that the fabric produced from Nazilli 84 (S) exhibit low pilling with respect to the other fabric as expected, because the fiber properties of this sample is much better than the other as mentioned previous chapters.

As it is shown in Table 6.11, all of the sample fabrics reached maximum number of pills at the end of 100 turns of instruments. The reasons of this results is the effect of fiber, yarn quality and also fabric structure.

Table 6.11 Test results and classifications of knitted fabrics

Number of turns	DTN-5 Pilling/cm^2(Class)	NDT-10 Pilling/cm^2(Class)	NDT-11 Pilling/cm^2(Class)	NDT-13 Pilling/cm^2(Class)	NDT-15 Pilling/cm^2(Class)	Camel Pilling/cm^2(Class)	Nazilli 84 (S) Pilling/cm^2(Class)
25	3 pieces (4)	1 pieces (5)	0 pieces (5)	0 pieces (5)	2 pieces (5)	0 pieces (5)	0 pieces (5)
50	5 pieces (4)	3 pieces (4)	3 pieces (4)	2 pieces (5)	4 pieces (4)	3 pieces (4)	2 pieces (4)
75	7 pieces (2)	5 pieces (3)	4 pieces (3)	4 pieces (4)	5 pieces (3)	5 pieces (3)	3 pieces (4)
100	8 pieces (2)	7 pieces (2)	5 pieces (2)	5 pieces (3)	6 pieces (3)	8 pieces (2)	6 pieces (2)
125	7 pieces (2)	5 pieces (2)	3 pieces (2)	3 pieces (3)	5 pieces (2)	5 pieces (2)	4 pieces (2)
150	7 pieces (2)	4 pieces (2)	2 pieces (2)	2 pieces (3)	5 pieces (2)	3 pieces (2)	3 pieces (2)

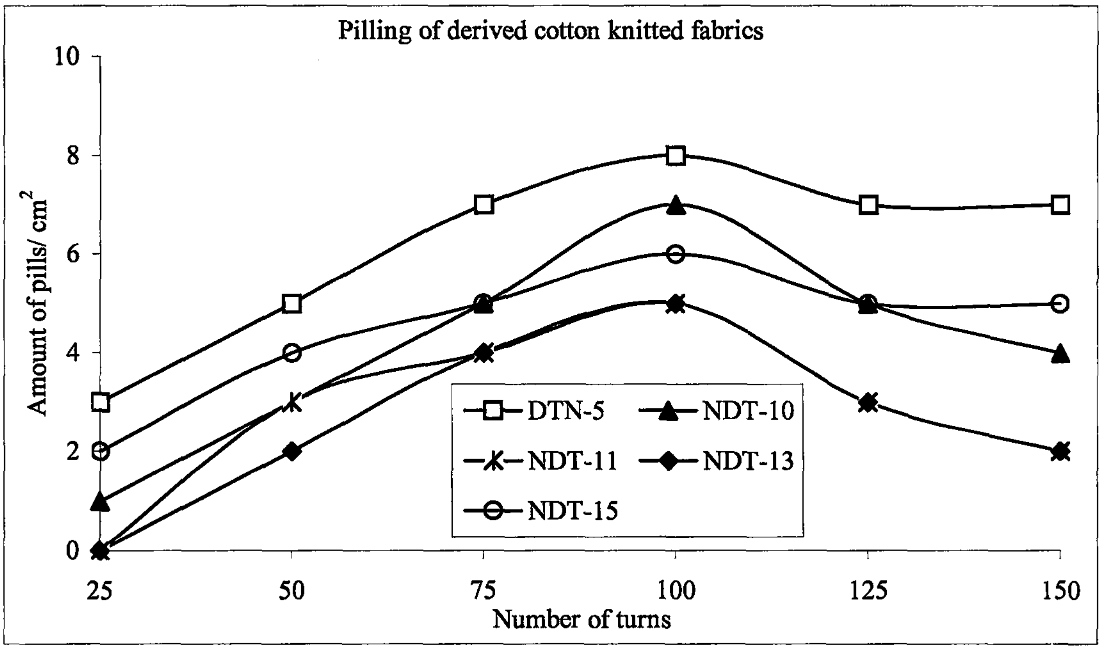


Figure 6.1. Pilling of derived cotton knitted fabrics

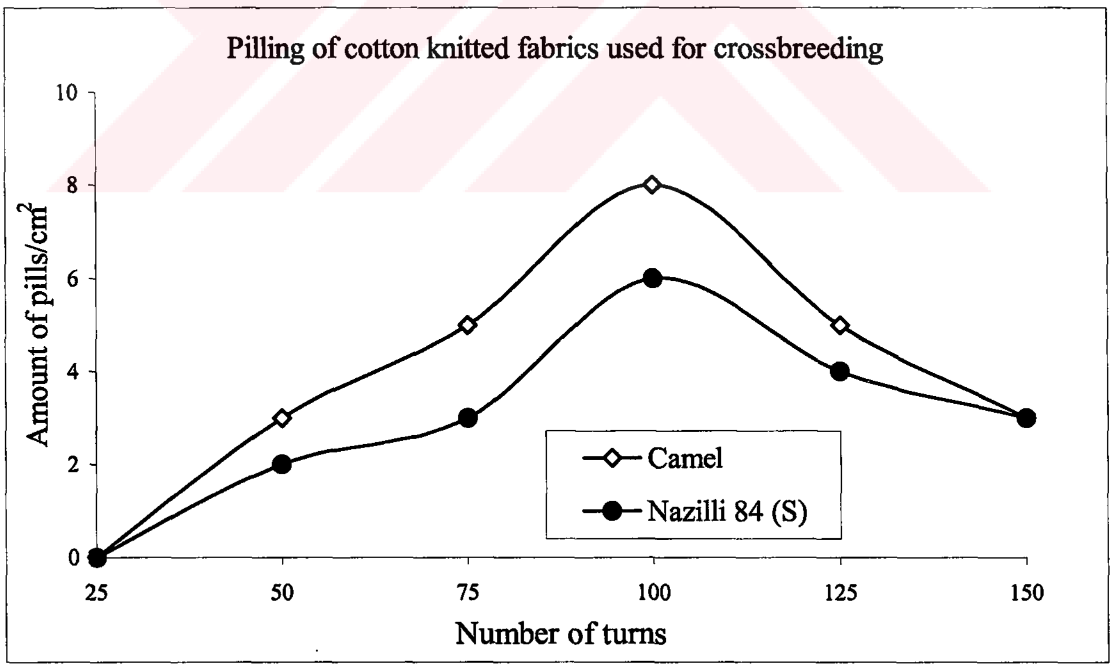


Figure 6.2. Pilling of knitted fabrics used for crossbreeding

CHAPTER 7
CONCLUSION

Textiles are surrounded from birth to death to humanbeings. Most of the people walk on and wear textile products and also sit on fabric-covered chairs and sofas; sleep on and under fabrics; textiles dry body or keep dry body; keep body warm and protect body from sun, fire and imperfection; clothing and furnishing textiles are aesthetically pleasing, and they vary in color, design and texture. The industrial and medical uses of textiles are many and varied. The automative industry uses textiles to make tire cords, upholstery, carpeting head liner, window runners, scat belts, shoulder harness, and many other parts. It is important to understand fibers and their performance because fibers are the primary materials from which most textile products are made. Textile fibers have been used to make cloth for several thousand years. The textile industry uses many different kinds of fibers as its raw materials. The fibers that most commonly used are wool, flax, cotton and silk. Cotton, one of the most popular commercial fibers in the world today, has been used for textile fabrics for the last 4000-5000 years. Cotton was known and used in the earlier years of civilization as well as in modern times not only white colours but also NCC. An alternative to dyed cotton is organically grown NCC that cultivated in different shades of brown and green instead of white. Naturally pigmented cotton has existed for thousands of years in many countries around the world. So it is not new for textile and agricultural industry. But, in many countries white coloured cotton is the only cotton that has been used in textile industry after colouring by chemicals dyes instead of NCC.

NCC can offer unique attributes and selective advantages over common white varieties. Besides some advantages of NCC, it received little attention in the recent past because fibres were not suitable for commercial processing. They must have sufficient length, strength and cohesiveness to be spun into yarns. Textile processes-spinning, weaving, knitting, dyeing and finishing of fabrics-were developed for the natural or man-made fibres. NCC can not be easily processed because they are shorter, weaker and finer than white cotton. Textiles are always changing as fashion and needs of people. New developments in production processes also cause change in textiles, as do government standards for safety, environmental quality, and energy conservation. Recently organic agriculture which aims to less damage on human and environment is becoming more important in developed countries. For this reason, researchers have started working on cotton genetics material of naturally coloured cotton fibers. With advanced genetic breeding technology, however, naturally coloured cotton fibers in various shades of green and brown have been successfully processed on conventional textile machines. There has been growing interest in the use of NCC in niche markets where chemically dyed textiles have traditionally been used. Despite some recent commercial and economical disappointments, the softness and beauty of NCC helps it keep a hold on niche markets. Although the color range of naturally coloured cotton is limited and these fibers appear to be weaker than their conventional white counterparts the need for a naturally coloured textile whih does not require man-made dyes, appears to be growing among certain user groups. There are a growing and researching number of organization that cultivate coloured cotton internationally. Each of these companies also markets apparel and consumer products made from pigmented cotton. There are some government and commercial entities interested in these fibers.

Coloured cotton has been used for the production of a variety of woven and knitted fabrics. If current limitations of NCC were overcome, many new fabrics could be developed. Scientist can only be speculated about the possibility of developing new colors eventually. In the meantime, breeders continue to improve existing coloured cultivars, while researchers continue to develop and refine processing methods suitable for these and other fibers. However pigmented cotton also appear suitable for use in certain non-woven fabrics, a category of use previously largely overlooked. Environmentally concious consumers have been demostrated on increasing interest in an array of goods manufactured from NCC. There are presently a variety of consumer products including sheets, towels, t-shirts, and socks made from fibers.

This research benefits investigation of physical and mechanical properties of NCC fibers, yarns and knitted fabrics and compare these results conventional white cottons which are cultivated in same region. The result of study may be investigated in three steps.

First step: The physical and mechanical properties of these sample cottons were measured by HVI and AFIS tester. The details of the samples can be seen in Table 4.7 and Table 4.8, however, they may be broadly classified as;

a) white cottons,
b) naturally coloured cottons (not crossbred),
c) derived naturally coloured cottons (obtained by crossbreeding of above cottons).

The experimental results show that the orijinal NCC (not crossbred) have poor mechanical properties with respect to mechanical properties of an average white cotton produced in Turkey (see Table 2.1). They have low strength, short fiber length, low elongation and more neps, however, they are finer. On the other hand, the white cotton used in the experiments has better mechanical properties than mechanical properties than mechanical properties of an average cotton of Turkey. These two cottons (white and naturally coloured cottons) have been crossbred to produce new generation of coloured cotton (DTN-5, NDT-10, NDT-11, NDT-13 and NDT-15) at NCRI. The experiments performed on these cottons show that, their mechanical properties, such as fiber fineness, length, strength, elongation and maturity are better than orijinal NCC.

Second step: Some amount of sample cotton were converted into 20/1 ring spun yarns at laboratory conditions. Uster Evenness III and Tensorapid tester were used to measure yarn properties of these samples. The results show that most of the properties;

- Um %
- CVm %
- hairness
- thin places
- thick places
- neps
- breaking force
- elongation

of yarns produced from generated naturally cotton fibers are better than the properties of yarns produce from crossbred fibers (mother and father). Especially, the properties of yarn produced from the cotton named NDT-11 are much better than others.

Third step: All these yarns were converted into knitted fabrics and some colorfastness (dry- wet crocking, acid-alkaline perspriation, washing, hypochlorite) and pilling resistance tests were performed at Textile Engineering Department of University of Gaziantep. The performance tests of fabrics made from cotton (K.Maraş-Brown, K.Maraş-Green, Erşan-92 and Sayar-314) obtained from KARI are not done because some of these fibers were not suitable for fabric construction instead of two times heat setting because of their low strength and high amount of neps. Therefore they can not be evaluated in all fabric analysis. The fabric tests include the samples which are made of derived naturally coloured fibers (children) and orijinal naturally coloured fibers (parents) obtained from NCRI. While unlike traditional dyed textile goods (lose color with use and tend to fade), the NCC fabrics have better in color intensity and actually the natural color deepens after washing. Pilling test results shows that the naturally brown and white fabrics were equally well for resistance to pilling.

In addition to these unique characteristics, naturally coloured cottons are becoming increasingly important also because the presence of natural pigments eliminates the need for coloring textile products, thus saving, not only a large amount of energy but also preventing dye chemicals from polluting the environment.

Recommendations

The further study on this subject may be ordered as follows;

a) NCC can be spinned on commercial machinery with large quantity in order to construct woven fabrics and perform some tests.

b) Different spinning processes (ring, open-end, friction, self-twist, vortex and etc.) may be used to produce yarns from NCC fibers and perform other experiments to fabrics which are not tested in this study.

c) NCC may be used for production of non-woven fabrics and some tests may be done.

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