

**A Comparative Study of Physical Properties of Selected Virgin and
Recycled Fibers and Yarns**

By

ASWATHY. C. V

(20PTF004)

A Thesis submitted to the

Avinashilingam Institute for Home Science and Higher

Education For Women Coimbatore -641043

In Partial Fulfilment of the Requirement for the

Degree of Master of Science in

TEXTILES AND FASHION APPAREL

MAY 2022

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Certified as Bonafide Research Work


Signature of the Head of the Department


Signature of Supervisor

DECLARATION

I declare that the dissertation entitled “**A Comparative Study of Physical Properties of Selected Virgin and Recycled Fibers and Yarns**” submitted by me for the degree of Master of science (M.Sc.,) is the record of work carried out by me during the period from 2021 to 2022 under the guidance of **Dr. U. RATNA**, M.Sc., M.Phil., Ph.D., Assistant Professor (SG), Department of Textiles and Clothing, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore-642 043 and has not formed the basis for the award of any Degree, Diploma, Associate ship, Fellowship, Titles in this University or any other similar institution of higher learning.



Signature of the Candidate

CERTIFICATE FROM THE SUPERVISOR

I certify that dissertation entitled “**A Comparative Study of Physical Properties of Selected Virgin and Recycled Fibers and Yarns**” submitted for the degree of Master of science (M.Sc.) Textiles and Fashion Apparel by **Aswathy. C. V** is the record of project work carried out by her during the academic year 2021 to 2022 under my guidance and supervision and this work has not formed the basis for the award of any Degree, Diploma, Associate ship, Fellowship, Titles in this University or any other similar institution of higher learning.



Signature of the HOD



Signature of the Supervisor with Designation



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1. INTRODUCTION

Textile industry is one of the largest industries around the world. It is the second largest employer providing sector after the agricultural sector. The industry provides one of the most basic needs of the people and it maintains a sustained growth for improving the quality of life (Moses and Ammayappan, 2006). The industry is very complex compared to other sectors. Because it begins with the production of fibers like cotton, flax, jute and other fibrous plants. later these are processed into yarns and fabrics. By using various manufacturing process like weaving and knitting, these yarns are made into fabrics for industrial and consumer purposes. These fabrics can be converted into finished clothes with a finished appearance and particular function. So, the industry has many faces and it plays significant role in the economies of developing country. It is known to be the first sector of the industrialization process (Toprak and Anis, 2017).

Textiles and apparel industry is the most ancient and well-established industry. But the arrival of advanced technologies and industrialization resulted in a huge production of textiles and it is associated with some forms of pollution and wastes (Jain and Gupta, 2016). The industry is associated with many environmental problems and considered as one of the most polluting industries in the world. Now the consumption of large amount of water, energy, pesticides lead the textile industry one of the most polluting and waste generating industry (Pratap and Islam, 2017).

Growth in the global population and improved living standards resulted in an increase in the production and consumption of textiles in the last few decades. The fashion cycle demands products with more fresher and modern goods which also results in generating the textile waste (fletcher, 2008). Textile industry had a great importance to the economies of the country related to trade, employment, revenue. The demand for textile is increasing. But there are so many problems insisting in relation to the environmental impact of fiber production, disposing operations etc. (statista, 2018).

Environmental sustainability related issues become more significant in the apparel industry. So, the companies are trying to replace dangerous chemicals with environmentally friendly materials to reduce amounts of waste and consumption of resources through apparel recycling (Jung and Jin, 2014). Moreover, fast fashion retailing leads the consumers towards an increased rate of purchasing and also to the trend of keeping clothes for a short time. The

tremendous growth of the textile industry has brought about prosperity. But it ended up in the arise of many environmental issues (Bianchi and Birtwistle, 2011).

Every year large amounts of textile wastes are disposed in landfills. It creates many economic and environmental problems to the society and also represents wasting of resources (Bhatia et al.,2014). The depletion of natural resources associated with waste production is linked with unsustainable human behavior and attributes (Oke and Kruijsen, 2016). The rise of fast fashion in the textile industry has resulted in the accumulation of high level of wastes (Coskun and Basaran, 2019). The use of harmful toxic chemicals during the manufacturing process results in the release of pollutants during the lifecycle of a textile product. Numerous recent studies pointed how the textile industry affect the fresh water and atmosphere micro system (Kumar, 2014).

In order to overcome the environmental problems caused by the industry, recycling is an effective way. Recycling is the process of recovering the valuable raw materials either by chemical or by mechanical recovering methods. Both the production and consumption of textiles produce waste. Textile production and the generation of waste is directly proportional to each other. Higher the production, then greater the amount of waste produced. Industry adopted many measures to reduce this negative impact on the environment. One of such measurement is recycling. The diversion of old textiles for recycling meets the clothing requirement for 70% of the population in developing countries. Because the recycled wastes are more biodegradable so, the importance of textile recycling is being recognized everyday (Chavan, 2014).

Recycling is a process of collecting the textile wastes from different sources, sorting, processed them based on their conditions and compositions. It involves many processes and different technologies. Mainly the fibers are recycled in two different ways. I.e., mechanical recycling and chemical recycling, but it doesn't create any hazardous waste to the environment and also it helps to reduce the environmental impact by avoiding the use of new material (Bhatia et al., 2014). Recycling is a process which helps to provide employment and avoid the environmental pollution by preventing the dumping of textile waste into the landfills (Hawley, 2006). It reduces the needs for extracting, refining and processing the raw materials which creates environmental pollution.

The textile recycling process has first proposed and practiced by France, Germany, US and other western countries. The bureau of international recycling states that the use of 1

kg of waste can reduce the emission of 3.6 kg of carbon dioxide and can reduce the use of pesticides by 0.3% (Liu et al., 2014). The processing of pre- or post-consumer textile waste to produce new textiles or non-textile product is referred to as recycling of textiles. It can be done by chemical, mechanical or by thermal process (Sahoo et al., 2018). Recycling is the key component of the waste reduction. It will generally reduce the environment impacts, because the need for primary resources is reduced in the recycling process (Sandin and Peters, 2018).

According to the studies conducted by ECOSIGN (2017) found that the recycling of second-hand clothes has reduced the greenhouse gas emission by 53%, pollution associated with chemical processing has been reduced by 45% and the eutrophication of water reduced by 95%. After every need, the consumers and manufacturers throw away the textiles in garbage. Beside wasting money and resources, the materials will take 200+ years to decompose in the landfill. During the time of decomposition process, it will release the methane gas and leach the toxic chemicals and dyes into the ground water and soil. So, the textile recycling can be used to address both the resource scarcity and the problem of cloth wastes in landfill. Reusing the existing textiles will reduce the need for newly manufactured textiles, thus it saves water, energy, dyes and results in less pollution.

A logical approach to avoid the problems of existing textile waste is the adoption of textile recycling process (Ali et al., 2021). The waste produced in the areas like spinning and weaving units can be forwarded to the recycling units for the process of fiber recovery. Every phase of the textile recycling provides employment and opportunities for the small-scale businesses (Zamani et al., 2015). Various studies shows that the global textile industry generated around 92 million tons of textile waste in 2014. In which a minimum amount is reused or recycled and others ends up in landfills (Pensupa et al.,2017). Along with this, the global textile waste is estimated to increase at a rate of 60% in each year between 2013 to 2030, with an addition of 57 million tons of waste in every year and it reaches to 148 million tons of wastes annually (Shirvanimoghaddam et al., 2020).

Due to the increased demand for conserving the environment, several companies are there for recycling the textiles. Recycled fibers can be collected during the pre-consumer steps or after the post-consumer steps. Pre-consumer waste consists the materials like fiber, and cotton industries which are re-manufactured for the automotive, aeronautic, home building, furniture, mattress, coarse yarn, home furnishings, paper, apparel and other industries. Any type of garment or household article which are made from manufactured textiles and they are

no longer needs and decides to discard is referred to as post-consumer waste. These are discarded either because they are worn out, or damaged, or because of out of fashion. Another one is industrial textile waste. It is generated from industrial and commercial textile applications including the wastes from properties like carpets, curtains etc. Usually, the industrial textile waste is dirty. So, the collection and chemical contamination issues render this category as the least likely to be recovered (Chavan, 2014).

The recycled fibers have difference in their properties and efficiency when compared to that of the respective virgin fibers. The textile field is a huge consumption Today due to the problems like increased price for both cotton and man-made fibers, labour demands for increasing wages with decreasing productivity most of the textile mills are in doldrums. So, in order to overcome this problem, it is very essential to recycle the waste to produce area along with food, housing, and mobility, which creates many environmental impacts. By means of recycling, we can reduce some of this impact (Filho et al, 2019).

The textile recycling sector has great potential to contribute to the circular economy (Baruque et al, 2017). Thus, it can reduce the use of new virgin raw materials and can save water, energy and chemicals used in the production chain. Due to the increase in the global fiber production, every year a huge amount of fibrous waste is disposed in landfills. The process of recovering wastes involve both economic and environmental benefits. So, the process of recycling is getting more important day by day. Recycling is an effective way to solve this postindustrial and post-consumer fiber waste (Dahlbo et al., 2017).

Even though the recycled fibers can be used as a substitute for the virgin raw materials by incorporating some value addition. A variety of fibers can be made from this recycled fiber. Most of these recycled fibers are re spun into new yarns or it is manufactured into woven, knitted, or non-woven fabrications or other materials like garment linings, insulation materials, toys etc. The global per capita production of textile fiber is increasing day by day. This growth is associated with many environmental challenges like demand on natural resources, generation of solid wastes etc. but the recycling process have the potential to solve both the problems. However, the demand for textiles made from recycled fibers among the consumers will come only once there is a supply (Niinimaki et al.,2020).

According to many brands, the industry be proactive and should provide the market with recycled products and also must communicate on the availability and the reasoning behind to consumers. The use of certification and labels with criteria of recycled textile fibers can

contribute to the customer awareness on good and less good choices. Now many brands are working with recycled textile products. Some brands believe that increasing the demand for recycled textile products is a joint responsibility.

Now textile sector is looking for new options to make the recycled textiles more visible. For this, governments can speed up the process by creating and providing incentives for those who needed (Watson et al., 2017). Now without any limitations, brand-led recycling is accepted by more users. It has two forms, In the first form, the brands will build some recycling channels and carry out their recycling and reusing related business. In the second form, in order to increase trust of public the recycling companies inform the public where the clothes wastes will go. H&M and The Blue Jeans Go Green Plan are the two examples for two forms of brand led recycling (Lascity et al., 2020). Other than this there are so many international brands which promotes the recycling of wastes clothes. Like American eagle, Madewell, Top shop. North face, Uniqlo, Nortex (Denmark), Lindex (Sweden) etc (Xie et al., 2021).

According to the report published by Brainy Insight on 2022 states that the demand for global recycled textile market is witnessing rapid growth because of the growing awareness about how it affects the environment. Also, the rising demand for low-cost clothing boosted the growth of the market. developing technological innovation in recycling equipment also started contributing to the growth of the market. now many international brands started to collect the used clothes from the consumers for recycling. Khaloom, Chindi, Kishco Group, Anandi Enterprises, Usha Yarns Ltd., Renewcell AB, Hyosung TNC Co. Ltd., Martex Fiber, Otto Garne, and Leigh Fibers Inc., are the main players of the global textile market. They are mainly focusing on the adoption of various strategies like product development, collaboration, technological integration, joint venture, product innovations, mergers & acquisitions, and partnerships etc.

Recycled textile products are available in domestic market. But they are found in the form of wipes, floor mats and rugs. During the recycling process of clothing, fibers are extracted. These are converted into recycled yarns and used in different textile products. Now many textile manufacturers started to produce organic cotton, recycled cotton and recycled polyester. They reuse coloured and mélange yarns from cotton and polyester yarns. Ventures like this reduce the amount of waste that has different applications across key businesses (Soni et al., 2021).

The repurposed yarns are comparatively a new addition to the yarn market. Because these yarns are hand drawn and do not have a uniform count. These yarns are currently available in Bhadohi, Bhagalpur, and Karur. The environmental impact of using recycled yarn is very very less when compared to that of the virgin cotton yarns and also it is an alternative to the pressure on natural resources and environment (Liu et al., 2020).

Now the consumers are more aware of protecting the nature because of the waste generated by the industry (Udara et al.,2019). Every year, a lot of fibrous wastes is disposed in landfills. Besides economic and environmental concerns, it represents wasting of resources. We can use the recycled fibers instead of the virgin fibers. It will help to conserve the natural resources. Before using it is very important to check the properties of the recycled fiber whether it is matching with the properties of the virgin fibers or not. If it is not, then it should be blended with virgin fibers for different end uses. Since only few studies are conducted in the area, hence a study on “A Comparative Study of Physical Properties of Selected Virgin and Recycled Fibers and Yarns” was selected with the following objectives”

Objectives

- To collect the virgin and recycled fibers from recycling industry
- To spin the selected recycled fibers into yarns
- To test and compare the properties of the collected fibers and spun yarns
- Evaluation and tabulation of results

1. REVIEW OF LITERATURE

Review of literature for the present study on “**A Comparative Study of Physical Properties of Selected Virgin and Recycled Fibers and Yarns**” are discussed under the following headings:

2.1. Textile fibers

2.1.1. Introduction

2.2. Classification of textile fibers

2.2.1. Introduction

2.2.2. Natural fibers

2.2.2.1 Cotton

2.2.2.2. Flax

2.2.2.3. Hemp

2.2.2.4. Wool

2.2.2.5. Silk

2.2.3. Man-made fibers

2.2.3.1. Polyester

2.2.3.2. Nylon

2.3. Properties of textile fiber

2.3.1. Fiber Length

2.3.2. Fiber Diameter

2.3.3. Fiber Tensile Strength

2.3.4. Uniformity Ratio

2.3.5. Span Length

2.3.6. Maturity

2.3.7. Micronaire

2.4. Textile Yarns

2.4.1. Introduction

2.5. Classification of Textile Yarns

2.5.1. Filament Yarns

2.5.1.1. Monofilament Yarns

2.5.1.2. Multifilament Yarns

2.5.2. Cabled Yarns

2.5.3. Spun Yarns

2.5.4. Core Spun Yarns

2.5.5. Plied Yarns

2.6. Properties of Textile Yarns

2.6.1. Linear Density

2.6.2. Yarn Twist

2.6.3. Breaking Strength

2.6.4. Elongation Percentage

2.7. Textile Recycling

2.7.1. Introduction

2.8. Need for Textile Recycling

2.9. Methods Of Textile Recycling

2.9.1. Mechanical Recycling

2.9.1.1. Fiber Recycling

2.9.1.2. Thermomechanical Recycling

2.9.1.3. Transforming Agricultural byproducts into Textiles

2.9.2. Chemical Process

2.9.2.1. Monomer Recycling

2.9.2.2. Polymer Recycling

2.10. Recycled Fibers

2.11. Recycled Yarn

2.12. Advantages of Recycling

2.1. Textile fibers

2.1.1. Introduction

Fibers are the main raw materials of the textile industry. So, the industry uses different types of textile fibers. Ability to spun, availability, production cost and properties are the various factors influencing their development and utilization in the textile industry. Fibers are the starting point for all textile products that serve the everyday needs of society (Felgueiras,2021). A textile fiber is a unit of matter, either natural or manufactured, that forms the basic element of fabrics and other textile structures. Fiber is the smallest fundamental unit of textile production or the building blocks used in making of textile yarns and fabrics. Some fibers are short while some are long, some are scaly while some are rough, some are smooth (Houck, 2019).

Textile fibers is an integral component of the modern society and physical structure for human comfort and sustainability. The desire for more better garment and apparels resulted in the development of textile fiber production and textile manufacturing process. The desire for better garment and apparel resulted in the development of textile fiber production and textile manufacturing process (Uddin,2019).

Textile fiber is a material mainly made from natural or synthetic sources. The fibers are transformed to make various products such as yarns, knitted, woven or non-woven fabrics and carpets. A growing textile industry always in search of new materials, whether these are resources of textile fibers or the other functional materials. Textile fibers can be obtained naturally from animals and various parts of plants, while a lot of synthetic or semi synthetic textile fibers are being produced in the laboratories that are developed at industrial scale later (Shabbir.et. al,2018).

2.2. Classification of textile fibers

2.2.1. Introduction

The fibers can be mainly classified into two. They are

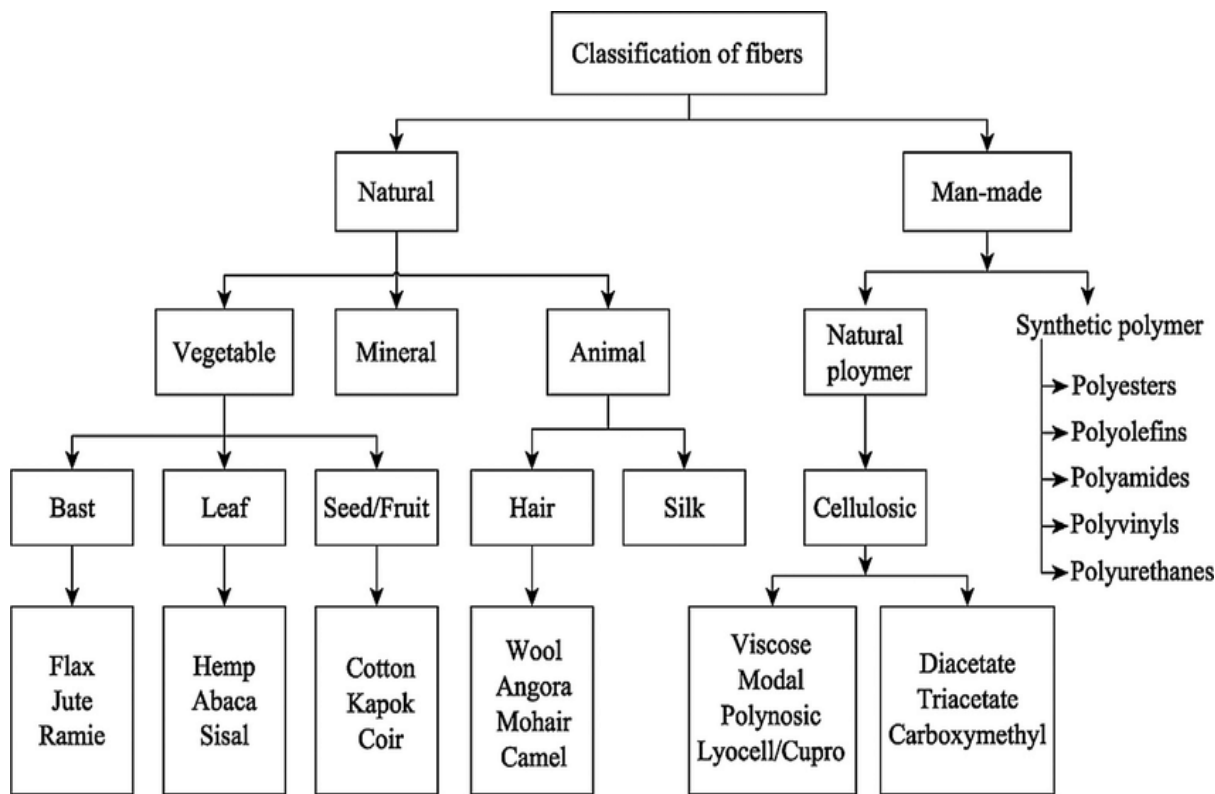


Figure-1

Classification of Textile Fibers (Jiang et al.,2020)

All the fibers which come from the natural sources like animal, plants are called as natural fibers. The natural fibers can be further classified into protein fibers, cellulosic fibers and mineral fibers. The fibers which are made by man through various chemical process and differ in composition and properties when compared to natural fibers are called as manmade fibers. It can be further classified into two. They are synthetic fibers and regenerated fibers. The fibers which are made by chemical synthesis is referred to as synthetic fibers and those which are regenerated from any natural polymer sources are referred to as regenerated fibers (Woodings, 2002).

1.2.2. Natural fibers

The fibers present in nature in the fiber form is referred to as natural fiber. It can be further classified into cellulose based, protein based and mineral based fibers. The fibers obtained from plant or vegetable source is termed as cellulose based. These fibers may be from the plant stalk, leaf or seed. The most commonly used cellulosic fibers are cotton, jute, hemp, flax and kapok. In cotton fiber, the cellulose is present almost in its pure form (Kalia et al., 2011).

Plant fiber is made up of cellulose, which is embedded in the matrix, it is a polysaccharide made up of polymeric carbohydrate molecules. It is a naturally occurring molecule and the base of plant structure (Bunsell, 2018). Cellulosic fibers are used for various textile applications due to their sustainable nature. The chemical composition is depending on their sources like seed, fruit, cane, leaf etc. Mechanical made flammability properties of these fibers vary according to their mechanical composition. Most of the natural fibers are utilized due to their low cost, biodegradability, abundance, recyclability, non-hazardous nature etc. (Salmeia et al., 2016)

1.2.2.1. Cotton

Cotton is an important cash crop and most used natural fiber. Actually, it is a seed fiber develops in the seedpod of the plant. It contains a combination of properties like durability, low cost, visual appearance, easy care etc. Cotton can be growing in any place where the temperature is too hot and adequate rainfall. China is the major producer of cotton around the world. The chemical composition of a typical cotton fiber is as follows,

Cellulose- 94.0%

Protein - 1.3%

pectic substance – 1.2%

wax - 0.6%

ash - 1.2%

other substances - 4% (Ramachandran, 2015)

It is a hollow soft, cool and absorbent fiber. It is known as a breathable fiber. The cotton fiber is strong and have good absorbent properties towards dyes also it can withstand against high temperature and abrasions. They have the capacity to hold water 24-27 times more than their own weight. Cotton fibers can be blended with other fibers like polyester, linen, wool to get the best properties of each fiber (Hosseini and Valizadeh, 2011). Cotton is a highly elongated thickened single cell of the epidermis. Polymers of the fiber cell wall helps to define the quality of the cotton fiber (Haigler et al., 2012). The cell wall determines industrially important parameters related to quality of cotton fiber (Wakelyn et al., 2007)

2.2.2.2. Flax

Flax plant can be grown as a winter crop under sub-tropical conditions and summer crop under temperate conditions. Flax (*Linum usitatissimum* L.) is an industrial plant. Its domestication started about 10,000 years ago (Quillen, 2014). Flax was first introduced in United States to produce fiber for clothing purposes. Every part of the plant is used directly or after processing for commercial purpose. The stem provides good quality fibers with high strength and durability (Singh et al. 2011). Now the use of flax fiber reinforcement in composites gained so much popularity due to the increasing requirement for developing sustainable materials. They are cost-effective and provides specific mechanical properties compare to other of glass fibers (Yan et al., 2014). Flax fiber is a soft, lustrous, and flexible fiber. It is stronger, compared to the cotton fiber and less elastic and can blends properly with wool, silk, cotton, etc. The best grades of flax fiber are used for linen fabrics like damasks, lace, and sheeting. Coarser grades are used to manufacture twines and ropes (Singh et al., 2011).

2.2.2.3. Hemp

Hemp is a sustainable and high yielding crop and can be used for a variety of applications (Carus et al., 2013). Hemp is a natural bast fiber and it is inexpensive. Hemp fiber have high stiffness compared to the other glass fibers. They are multicellular and situated in the cortex tissue of the stem, and encircle the core cambium and the xylem layer (Thamae et al., 2009). It has great potential to be used as a reinforcement in composite materials. Hemp fibers is one of the strong members of the bast natural fibers family, derived from the hemp plant under the species of *Cannabis*. Nowadays, hemp fibers have wide acceptance as reinforcements in composite materials due to their account of their biodegradability and low density compared to artificial fibers (Varghese and Mittal, 2018).

2.2.2.4. Wool

A wool is normally referred to the fleece of sheep, the fleeces from other animals can also be used as textile fibers. The hair of Camel and goat are known as mohair but it is highly priced and their market size is very low. Actually, Wool is a protein called keratin, which has a polypeptide chain with amino acid side chains. It is referred to an outgrowth of the epidermis of the sheep. The surface of the fiber has minute overlapping scales and it is extending lengthwise and pointing to the end remote from the root or cuticle. Wool basically grows in tufts, or near the follicles in the skin of the animal (Lord, 2003).

2.2.2.5. Silk

Animals produce silk fibers, but the most widely used silk fiber is made from the cocoon of the *Bombyx mori* larvae (Colombon and jauzein, 2018). Silk fibers are pliable, and have moderate tensile strength, and very tough. But they can withstand a large number of repetitive bending cycles before they got rupture (Wang and wang, 2009). They have visco-elastic behaviour (Babu, 2015). Silk fibers (*B. mori*) can be spun out from silkworm cocoons which consists of fibroin in the inner layer and sericin in the outer layer. Each raw silk fiber has a lengthwise striation, which consist of two fibroin filaments of 10–14 μm each and it is embedded in sericin. Silk fibers are biodegradable in nature and highly crystalline. They have a higher tensile strength compared to glass fiber or synthetic organic fibers, and have good elasticity, and resilience. Silk fiber is stable up to 140°C and the thermal decomposition temperature is usually greater than 1500°C.

Those fibers which are mined from the earth is called as mineral fibers. One of the mainly used mineral fiber is asbestos. It has high thermal stability and tensile strength (Nayak, 2016).

2.2.3. Man-made fibers

The term man-made fiber points to the manufacturing process of the fiber, not the chemical composition. Fiber made by chemical process and they are unknown by nature are referred to as mam made fibers or synthetic fibers. About 81% of all man-made fibers are made up of polyester. Polyamide has the second share, that is 8%. Other materials make up 11% (Gad and Shalaby, 2017).

Synthetic fibers like polyester, acrylic, nylon is made using organic compounds derived from the crude oil. Polymer of desired properties is formed by reacting specific monomers. Fiber is formed by melt spinning or dry spinning techniques. Polyester is one of the strong and toughest fiber and have high breaking tenacity (Peterson, 2014).

2.2.3.1. Polyester

The structure of polyester fiber is defined as a combination of both crystalline and non-crystalline regions. The most important polyester is polyethylene terephthalate (PET). It is referred to as simple polyester. Derived from the condensation reaction between ethylene glycol and terephthalic acid. Polyester fibers have the ability to deposit electrostatic charges on the surface, have the tendency to form pilling effect and have low moisture absorption. They

are resistant to the action of acids, alkalis and organic solvents. But high concentrations may be affected (Grishanov, 2011).

2.2.3.2. Nylon

Polyamide (PA) or “nylon” fibers were developed by Du Pont in the US and I.G. Farben in Germany in the year 1938. These fibers are based upon amide groups (CO-NH) contained within the chain of a carbon atoms and making up the backbone of atoms linked by strong covalent bonds. Nylon 66 and nylon 6 are the most commonly used nylon fibers. The chains are being void of aromatic compounds, and tend to fold and lead to fibers which have low modulus and high extension at break. It is one of the most stretchable and elastic textile materials. It is hydrophilic in nature. Nylon is mainly preferred for tubular bandages and compression hosiery for treatment of venous leg ulcers (King et al., 2013).

2.3. Properties of Textile Fiber

2.3.1 Fiber Length

It is the most important property of a textile fiber. Sufficient fiber length is required for processing the fiber into products (Li and Dai, 2006). All-natural fibers are staple fibers and have a limited length. For cotton the fiber length value is 30 mm, and 80 mm for wool. Man-made fibers are produced as continuous filaments of unlimited length but can be cut into small lengths and becomes man-made staple fibers. Length of the fiber affects strength of the yarn because longer fibers provide greater number of contact points between individual fibers where the friction forces develop and hold together the fibers (Grishanov, 2011).

2.3.2. Fiber Diameter

Fiber diameter equal to the linear density of textile material it is an important geometric parameter for determining the end uses of fiber. The size of the fiber diameter has a great influence on the hand feel, style and the processing of yarn and textile materials. Smaller the fiber diameter then greater the fiber friction and yarn forming strength. mainly there are two methods for measuring fiber diameter. The first is based on the processing of whole fiber image, and the second is collecting single fiber image for processing (Wang et al., 2019).

2.3.3. Fiber Tensile Strength

The ability to resist such breaking under stress is an important property. (Bajpai, 2018). Tensile strength of textile fibers is commonly determined by single fiber tensile tests, which is little challenging and it is prone to the measurement of errors (Islam et al., 2019).

2.3.4. Crimp

Crimp is defined as the undulations or succession of waves or curls in a strand, formed naturally during fiber growth or mechanically, or chemically. It is considered as the degree of deviation from linearity of a non-straight fiber. Fiber crimp is referred to the waviness of a fiber expressed as waves or crimps per unit length (Singha and Singha, 2013).

2.3.5. Uniformity Ratio

Uniformity Is referred to the measure of degree of uniformity of fibers in a sample. It is expressed as an index of the mean/upper-half-mean length ratio. Fiber uniformity is related to spinning efficiency, yarn uniformity, and yarn strength. It is the ratio of the mean length divided by the upper half mean length. It is a measure of the uniformity of fiber length (Azzouz et al., 2007).

2.3.6. Span Length

The percentage span length t% indicates the percentage of fibers that extends a specified distance or longer. The 2.5% and 50% are the most commonly used by industry The distance exceeded by a stated percentage of fibers from a random point in drafting zone is referred to span length of the fiber (Azzouz et al., 2007).

2.3.7. Maturity

The Maturity Ratio is a cotton maturity parameter which, according to ASTM D-13, determines the degree of wall thickening. To define the degree of wall thickening, the coefficient of fiber circularity was introduced, which is defined as the ratio of the wall cell area and the area of a circle of the same perimeter as the fiber cross section (Frydrych et al., 2010).

2.3.8. Micronaire

In the micronaire method, predetermined mass of cotton fibers is placed in the specimen holder and it is compressed to a fixed volume. The resistance to air flow is measured and expressed as a micronaire reading. Micronaire is an indicator of both the fineness and

maturity of cotton fiber. Low micronaire value has been used as a predictor of problems during the processing period. High micronaire fibers are usually coarser (Montalvo, 2005).

2.4. Textile Yarns

2.4.1. Introduction

Yarn can be defined as a long continuous and very flexible fibrous strand that can be mechanically manipulated in many ways to form a wide variety of textile structures including woven fabrics, knit fabrics, braids, ropes, and cords. In this chapter, the focus will be on yarn classification (Elmogahzy, 2019).

2.5. Classification of Textile Yarns

On the basis of structure, yarns can be classified into

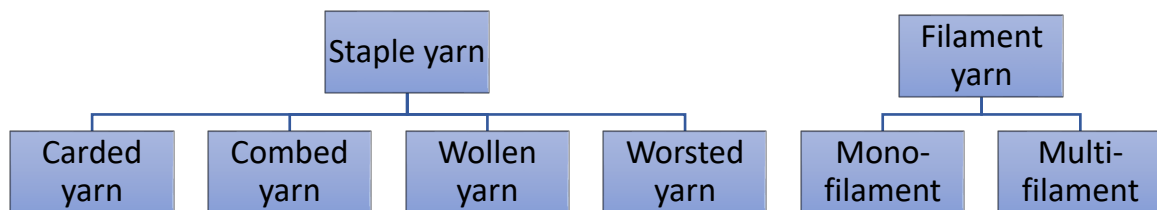


Figure-2

Classification of Yarns

<http://www.apparel-merchandising.com/2011/09/what-is-yarn.html>

2.5.1. Filament Yarn

Filament yarn consists the fibers with each end being endless. The continuous and endless fiber is referred to as filament. In spun yarn, the whole yarn is continuous, but staple fiber is discontinuous. The effect of twist on the filament yarn properties like strength, diameter, and abrasion resistance is similar to that the staple spun yarn (Li, 2020).

2.5.1.1. Monofilament Yarn

It consists a single solid filament diameter range from 0.1 – 2.0 mm. Its cross-sectional shape can be varied according to the end use. It has smooth or structured surface. They have bending rigidity and they are also resistance to abrasive damage. Their diameter depends upon the application (Alagirusamy and Das, 2011).

2.5.1.2. Multifilament yarns

They are composed of a bundle of individual filaments. The unit for expressing the size of yarn is *denier* or *tex*. *Denier* means the weight in grams of 9000 m of filament or yarn, but *tex* is the weight in grams of 1000 m (Ebnessajad, 2015). Multifilament yarns consists a multitude of fine, continuous filaments with some twist in the yarn to facilitate handling. Sizes range from 5–10 denier. The Individual filaments in a multifilament yarn size range about 1–5 denier. Because of the large surface area, multifilament yarn can be heat-treated more homogenously during drawing process. It can be drawn more effectively compared to monofilaments. they have high specific strength and modulus. Because of the small diameters of the filaments in multifilament yarns, the bending stiffness is lower than that of monofilaments. It leads to more flexible end-products. By using multifilament yarns, denser fabrics can be obtained by yielding smaller pores (Algirusamy and Das, 2011).

2.5.2. Cabled Yarn

Two or more plied yarns are twisted together to form cabled yarn. As a result, opposite twist direction cause plies to grip each other and thereby it maintains adherence. They are strong and hard (Varinder, 2004).

2.5.3. Spun Yarn

Spun yarns are made by placing a series of individual fibers or filaments together to form a continuous overlapping fiber, bound together by twist (Grishanov, 2011). Spun yarns and filament yarns are different in terms of aesthetics, structure and performance. Spun yarns

are hairy, less lustrous and softer in terms of handle when compared to the filament yarns. Spun yarns have the tendency to pill more than filament yarns. They are usually preferred for apparel production like lingerie, hosiery and fabrics that are required to be windproof (Wilson, 2011).

2.5.4. Core Spun Yarn

It is referred to another type of compound yarn made from a readily separable core surrounded by fibers or fiber strands. Different combinations of the core spun yarn type include filament core/staple-fiber wrap, staple-fiber core/filament wrap and staple-fiber core/staple-fiber wrap. Ring spinning, air-jet spinning, and friction spinning are the spinning systems used for producing these types of yarns (Elmogahzy, 2019).

2.5.5. Plied Yarn

Plied yarns are made by twisting two or more single yarns together. During plying, the yarns are twisted in the direction which is opposite to the single yarn twist to give a torque-balanced yarn (Jayaraman, 2003). Plied yarns are mainly used for the purposes other than sewing threads. They are durable, flexible, and have low twists may be used to give a soft hand. Acrylic and wool yarns are plied for the hand knitting market because of the soft hand that can be created. Aramid yarns can be plied into various complex structures to give strength to ropes and load-bearing strands. Plying is widely used within the specialty markets, but the process is too expensive (Lord, 2003).

2.6. Properties of Textile Yarns

2.6.1. Linear Density

It measures the coarseness of yarn in unit of decitex or mass per unit length (King et al., 2013). It is an expression of yarn fineness. It is expressed by measuring the mass of a known length of yarn or by measuring the length of a known mass of yarn. The two basic methods for finding the linear density of any textile strand are known as direct system (mass/length) and indirect system (length/mass) (Hari, 2020).

2.6.2. Yarn Twist

Yarn twist binds the fibers together and contributes to the strength of an industrial yarns. Twist contributes strength, elongation, diameter, torque, lustre and softness. Elongation increases with increase in the number of twists. Also, twist can increase the yarn stiffness but

the softness will decrease. Usually Twist level is measured in turns per inch (TPI) or turns per meter (TPM) (Ozkaya et al., 2010).

2.6.3. Breaking Strength

Breaking strength is referred to as the maximum force observed during a test. In which the specimen is stretched until it breaks and it is measured in pounds (Tyagi, 2010).

2.6.4. Elongation Percentage

It is referred to the ratio of elongation to the initial length. It is expressed on percentage (Hearle and Morton, 2008).

2.7. Textile Recycling

2.7.1. Introduction

Textile recycling represents the re-use of textile raw materials. The efficiency of recycling largely depends on the design of easy-to-recycle products. Limited resources are one of the essential forces which drive towards the recycling. The need for textiles is rising, but the raw materials and energy are becoming more expensive and the raw materials are declining (Voncina, 2016).

Textile recycling routes are classified as either mechanical, chemical or, thermal. Sometimes often consist of a mix of mechanical, chemical and thermal processes (Roos et al., 2019).

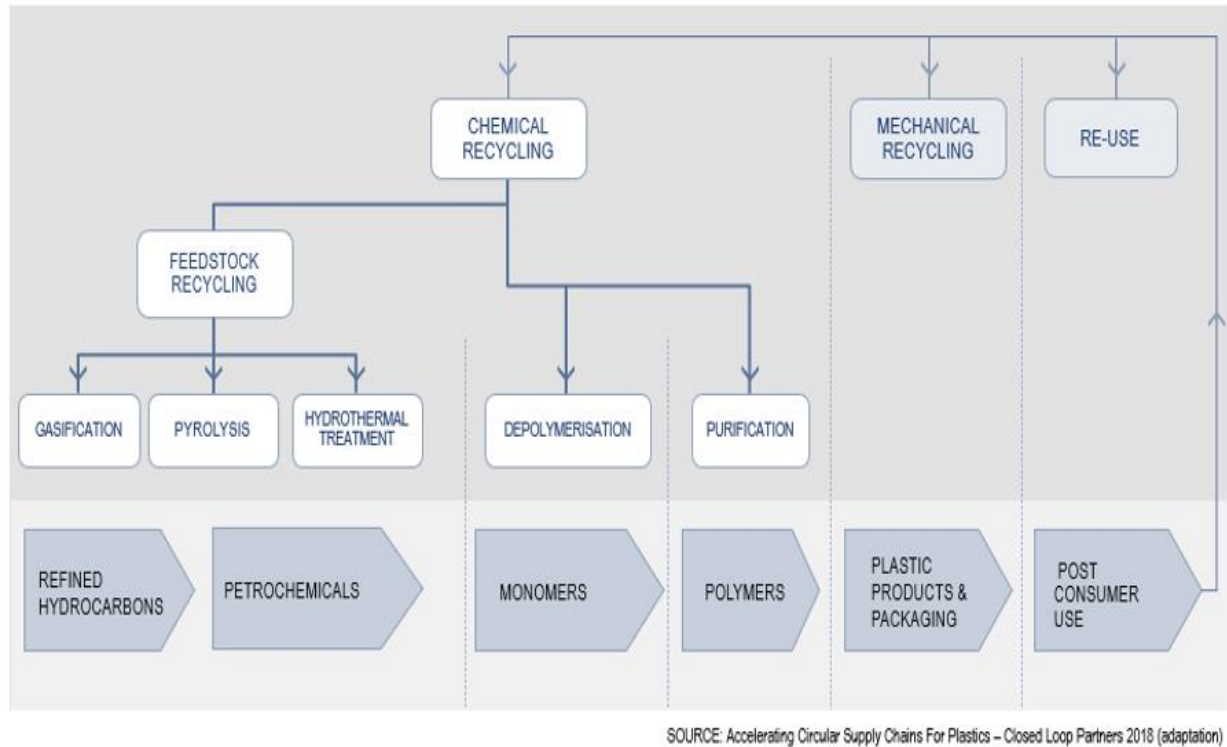


Figure-3
Recycling Process

The next strategy after prevention and reuse is recycling. According to Directive 2008/98/EC (European Parliament and Council of the European Union, 2008) recycling is a recovery operation in which waste materials are reprocessed into products, materials or substances for the original or other purposes. This includes the reprocessing of organic material, but does not include energy recovery.

2.8. Need for Textile Recycling

The increased population, industrialisation, and improved living standards leads to an increase in the global fiber consumption and generates a huge amount of unwanted textiles wastes. Textile reuse and recycling are more sustainable methods when compare to incineration and landfilling. In addition, it is very essential to promote consumer awareness for an environmentally friendly consumption behaviour on textile products (Juanga et al., 2022).

Today recycling is essential not only because of the shortage of raw materials but also to control pollution. So many ways are there to reduce the pollution. But the most effective way is to recycle the waste before it is discharged. Now the recycling industry is developed. Textile recycling industry is able to process 93% of the product without the formation of any hazardous waste or by products (Sule and Bardhan, 2001).

The recycling of textile products has been identified as a solution to the problems like environmental pollution, noise pollution etc. The size of the market is not enough to accommodate the material that would come from the comprehensive recycling of clothes and the use of virgin materials (Roos et al., 2016).

A study conducted by sandin and peters (2018) clearly states that, reuse and recycling reduce the increasing environmental impacts by avoiding the use of natural resources. Thereby it saves the environment and it also avoid the dumping of textile wastes into the landfills.

2.9. Methods of Textile Recycling

2.9.1. Mechanical Recycling

One of the most established recycling methods for textile materials is mechanical recycling. Compared to other process it is a low-cost process, but its results in decreased quality of the products. (Roos et al., 2019). Mechanical recycling can be categorized into different methods on the basis of degree of breakdown undergone by the recovered materials like fiber, fabric, polymer, and monomer recycling. The applications of mechanical recycling in the wiper, fiber material, and prespun fiber industries produce new fabrics for products (Michaud et al., 2010).

In mechanical process it breaks down the fabric and retains the fibers by cutting, tearing, shredding or carding. So, there are chances for reducing the fiber length and which affect the spinnability and yarn strength. So, the fibers will have a shorter length than the original fibers, and also some dust will be generated (Lindstrom et al., 2020).

2.9.1.1. Fiber Recycling

It is a form of mechanical recycling. In this process, the fabric is taken and the fiber is preserved (Rittfors, 2020). The most common method to process any type of textile fiber is shredding or cutting. Before shredding, the parts like zips, buttons are need to be removed. During the shredding process, the fibers are shortened and therefore the production of new yarn often necessitates blending the recycled fiber with virgin fibers to achieve the required strength and quality. It is one of the limits of mechanical recycling process. For Cotton, semi closed-loop recycling process is preferred. Where the recycled fiber is mixed with virgin cotton fiber and made into new yarn and for wool closed-loop process is adopted. So, mixing with virgin fibers is not needed (Ellen MacArthur Foundation, 2017).

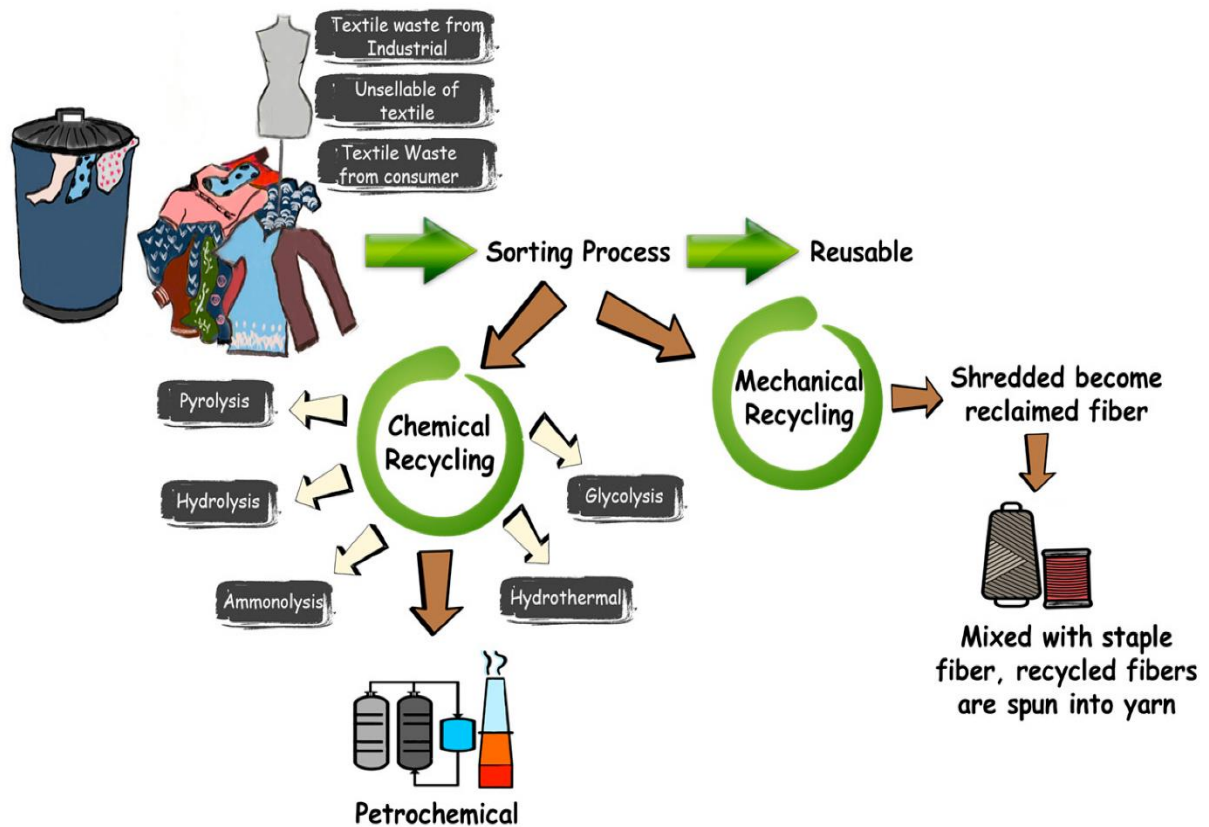


Figure-4

Fiber Recycling Process (Damayanti et al., 2021)

2.9.1.2. Thermomechanical Recycling

Thermomechanical recycling process melts the synthetic fibers before it is re-spun into new fibers. This process is mainly used for pure synthetic fibers like nylon 6, thermoplastic polyurethane, elastane and polyamide 6 (Kunchimon et al., 2019). This process is also known as thermal recycling (Niinimäki et al., 2020).

2.9.1.3 Transforming Agricultural by Products into Textiles

Recycling agricultural by-products and waste into fibers for textiles is can be enabled by the development of new technologies. Spinnova in Finland is an example. It patented a mechanical process which is inspired by the spider web to use the fiber suspension and rheology for the production of cellulose converted into textile fibers ‘using technologies currently available in the pulp and paper industry’ (Salmela et al., 2016).

2.9.2. Chemical Process

Chemical recycling is referred to as the conversion of high molecular weight polymers to low molecular weight compounds. The compounds produced by this method can be utilized as reactants for the manufacture of other chemicals and polymers (Grover et al., 2021). Chemical process can be classified into monomer and polymer recycling. Current methods for polymer recycling often degrade the polymer chain, and leading to a loss of quality in the recycled fiber, but monomer recycling transforms the end-of-use materials into virgin-quality fibers (Guo et al., 2021).

2.9.2.1. Monomer Recycling

It is the process in which polymer chain is disassembled to obtain intact monomers. Then the monomers can be transformed into new virgin polymers through polymerisation. This technique has been adopted to transform the different types of textile wastes into fibers ECONYL fiber is an example (Ellen MacArthur Foundation, 2017). The European RESYNTEX project transforms protein-based wastes into amino acids and peptides through chemical degradation and they are used to produce adhesives.

2.9.2.2 Polymer Recycling

Polymer recycling has been used for cellulose-based, synthetic and blends of fibers. Here the fiber is taken using mechanical processes like shredding and followed by chemical dissolution with specific dangerous solvents. Then the polymer remains preserved and the fibers are regenerated and spuned (Sherwood, 2020).

2.10. Recycled Fibers

A variety of products can be made from reprocessed fiber because most of this fiber is re spun into new yarns or manufactured into woven, knitted or non-woven fabrications or upholstery materials. Other methods include garment linings, household items, furniture upholstery, insulation materials, automobile carpeting and toys (Wang, 2006). Recycled fibers can be manufactured from a variety of textile wastes. But the quality and process ability of such fibers depend up on the kind of waste. Pure sorted high-quality fibers are achieved from spinning fiber waste. There are many ways to incorporate the recycled fibers in the textile and non-textile products. Yarn is an example of how the recycled fibers can be used. Yarns made from recycled fibers can be used to produce fabric for garment making and household textiles as well as for simple technical applications (Bhatia et al., 2014).

The use of recycled fibers will conserve non-renewable resources, reduce the dumping of wastes into landfill by giving a second life to the garment and also recycling process requires less energy and waste and has a lower climate impact when compared to the virgin fibers. The quality of the recycled fiber differs on the basis of fiber and the process used for recycling. Depending on the fiber, it needs to be mixed with virgin fibers in order to achieve the required material property and performance (Rengel, 2017).

2.11. Recycled Yarns

Spinning wastages can be converted into a value-added product. Blends of fiber reclaimed from yarn waste, rags/fabric clippers. These fibers were converted to open end yarn. Those fibers which are reclaimed from yarn waste had superior properties compared to the fiber from rags in terms of the properties of fiber like fiber length, uniformity percentage, and floating fiber percentage. Which are found to be 8% and 8.95% and 12% respectively. Yarn produced from blended waste yarn have low yarn irregularities and better tensile strength properties than that of rag waste blended yarn. Also, the cost of yarn produced from fibers extracted from rag is cheaper than the yarn-waste (Jamshaid et al., 2021).

Recycled yarns are usually made by twisting the pre-consumer textile waste yarns and fibers. It is composed of mixed fibers i.e., synthetic, cellulosic and protein. These are a mixture of cotton, polyester, silk, rayon etc. These recycled yarns are widely used in durries and floor coverings. Others include floor cushion covers, wall tapestry etc. Repurposed yarns are made by short length waste yarns, so they are not strong. Virgin yarns are mostly used as warp in combination with the repurposed yarns to make the products. (Mitra and Agrawal, 2020).

2.12. Advantages of Recycling

- Recycling and reusing of fabrics, fibers, and waste materials is an efficient way to promote the sustainability in the garment business. According to a U.S. Environmental Protection Agency, textile industry is one of the main sources of greenhouse gas emissions. So many efforts are taken to promote textile recycling in order to minimize the emission of greenhouse gas. Textile recycling is the only way to slow the generation of textile waste.
- Recycling of textile waste has several environmental benefits. Like it reduces the requirement for landfill space and reduce the emission of greenhouse gases emitted by the discarded textiles. Also, the recycled textile materials are less expensive (Grover et al., 2021).

- Recycling of textile materials will reduce the environmental impact. Because it reduces the use of virgin textile fibers and avoid processes. Along with this, recycling is more sustainable when compared landfilling. Applying ecological footprint to a textile tailoring plant shows that the resources category has the highest ecological footprint, and it is followed by the energy consumed (Herva et al., 2008).
- Recovery of resources can provide significant environmental profit by replacing the products from primary resources (Zamani et al., 2018).
- Many countries are already facing water scarcity due to the excessive use of water for agricultural and industrial needs. The requirement of water by humans has doubled since 1960 (WWF 2008). Thus, it saves energy because less energy is required to manufacture brand new products and industries burn fewer fossil fuels (CO₂ emissions), Prevents the destruction of natural habitats (Cuc and Vidovic, 2011).

3. EXPERIMENTAL PROCEDURES

Experimental procedures pertaining to the study on “**A Comparative Study of Physical Properties of Selected Virgin and Recycled Fibers and Yarns**” are discussed under the following headings.

3.1. Selection of Raw Material

3.1.1. Selection of Fibers

3.1.2. Selection of Yarns

3.2. Evaluation of Fibers

3.2.1. HVI Parameters

3.3. Evaluation of Yarns

3.3.1. Linear Density of Yarns

3.3.2. Yarn Strength

3.3.3. Yarn Twist

3.4. Thermo Gravimetric Analyzer

3.1 Selection of Raw Material

3.1.1. Selection of Fibers

The recycling method used to process any type of textile fiber is shredding or cutting. Parts like zips and buttons are removed before shredded into smaller pieces. The recycled fibers are collected through fiber recovery of textile waste. Disintegration of textile into loose fibers is referred to as fiber recovery (Piribauer and Bartl, 2019). The wastages were passed through pre opener which opened the fibers using harsh beating of fibers. Trash was removed in this process. Then it was passed through a recycling machine. Then the material was made into compacted form in order to deliver it to next process. A web of fibers was delivered at the end which was then compressed to make bales of fibers (Jamshaid et al., 2021)

Virgin and recycled cotton, polyester fibers were collected from Ramesh Industries Coimbatore and Palkudiar Threads, Suler .



Plate- 1
Raw Cotton



Plate- 2
Recycled grey Cotton



Plate- 3
Recycled yellow Cotton



Plate - 4
Recycled black Cotton



Plate- 5
Recycled red Cotton



Plate- 6
Recycled orange yellow cotton

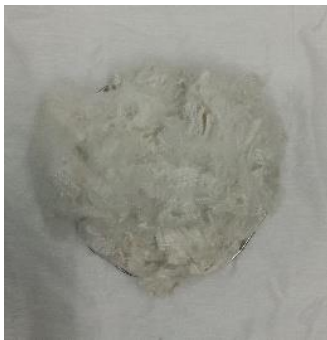


Plate- 7
100 % polyester



Plate- 8
**Recycled fiber +
polyester blend**



Plate- 9
**Recycled fiber +
polyester/ viscose blend**

3.1.2. Selection of Yarns

The shredded textile is then torn to produce a sliver and spun into new yarns. In order to obtain sufficient strength and quality, it was mixed with some virgin fibers. Cotton adopts a semi closed-loop recycling process because where the recycled fiber was mixed with virgin cotton fiber and spun into new yarn. Wool adopts a closed-loop process without the need of mixing in virgin fibers when the textile is recycled for the first time (Ellen MacArthur Foundation, 2017).

Cotton and recycled dyed cotton yarns were spun in OE spinning machine. The recycled dyed yarns are manufactured using recycled fibers. After fiber recovery the recovered fibers are spun into yarns. Here 30s count yarn was produced because of it is commonly used.

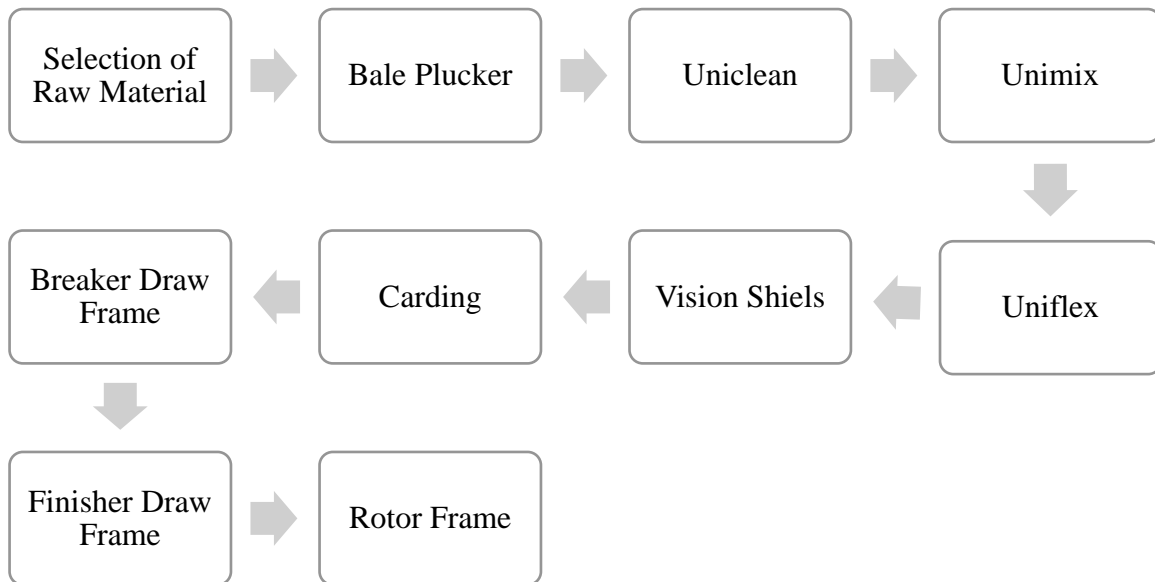


Figure-5.

Flow chart of Yarn Manufacturing (Uddin et al., 2016)



Plate 10
30s Grey cotton yarn



Plate 11
30s dyed blue recycled and blended cotton yarn



Plate- 12
Recycled Yarn Production



Plate- 13
Converting sliver to yarn



Plate- 14

Single jersey Knitting machine

3.2. Evaluation of Fibers

The properties of each fiber are different. To identify the quality and efficiency of each fiber, it is very essential to find out certain physical properties of the fiber.

3.2.1. HVI Parameters

ASTM Standard D 5867 is used to measure certain physical properties of the cotton fiber. This test methods cover the color, trash content, micronaire, length, length uniformity, strength and elongation of cotton fibers using the spin lab system HVI 900 SA2 or the motion

control. HVI 3500 and HVI 40002 are a set of instruments which are connected to a common computer. First appropriate routine for testing cotton fiber was selected from the menu displayed on the computer. Then the specimen was placed on the sample window and energize the instrument by pressing the appropriate switch that will make a plate to apply pressure to the specimen. The specimen should be held until the visual monitor advises that the measurement is complete. Calculations are carried out by the internal programmed microprocessor (Morais, 2020).



Plate- 15

High Volume Instrument

3.3. Evaluation of Yarns

The chief raw material for fabric production is yarn. The quality of yarn affects the quality of fabric. So, it is very necessary to test the certain parameters of yarn.

3.3.1. Linear Density of Yarns

Fineness of a yarn is usually expressed in terms of linear density or count. IS 1315 (1977) is a method for determination of linear density of yarns spun on cotton systems. This method is applicable to single, plied and cabled yarns (King et al.,2013).



Plate- 16
Lea Strength and Count Tester



Plate- 17
Wrap Reel

Cotton Count System

Special Yarn Count of Balance - Prepared skein of 109*73 m (120 yd) on the wrap reel was placed or hanged on the balance and read off the linear density of yarn from the scale provided.

Pan Balance — Reel out the skeins of 10973 m (120 yd) on the wrap reel and determined their mass in grams individually on the balance correct to 1 mg.

Tex System

Special Yarn Count Balance — Prepared skein of 100 m on the wrap reel was placed or hanged on the balance and read off the linear density of yarn from the scale provided.

Pan Balance— Reel out the skeins of 100 m on the wrap reel and determined their mass in grams, individually on the balance correct to 1 mg (King et al., 2013).

3.3.2. Yarn Strength

A Strength is a measure of the steady force needed to break a material and it is measured in pound. IS:1671- 1977 is a test method for the determination of yarn strength parameters of yarn spun on cotton systems using cotton count and tex systems. Lea tester was used to measure the strength. The tensile property of yarn can be defined as the maximum force required to break or disintegrate the material. This parameter is very important in the production of yarn, because it directly affects the strength of the fabric made with yarn. Count strength product was used to measure the quality of cotton yarn from the point of view of judging the yarn strength. For testing the yarn strength, first the dial reading was set to be zero and ensure that the elongation pointer coincides with the zero mark. Using wrap reel samples were prepared. Then weighed the leas using an electronic balance to calculate the lea count. The lea was clamped between upper and lower jaw and engage the lower jaw in screw mechanism and the motor was switched on. Lowe jaw started transverse at a constant rate of 12" per minute. Upper jaw pulled the arm which moves over the quadrant. If one or two strands break, the remaining strands slip which is indication of end point of the test. Then the pointer movement over the dial stops and can note down the elongation scale reading and dial reading calibrated in kgs/lbs (Gopalakrishnan, 2020).

$$\text{Count} = \frac{64.8}{\text{Lea weight}}$$

$$\text{Standard deviation} = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$$

$$\text{Coefficient of variation} = \frac{S.D}{\bar{x}} \times 100$$



Plate- 18.
Tensile Tester

3.3.3. Yarn Twist

The spiral deposition of components of a yarn is referred to as twist. It is generally expressed as the number of turns per unit length of yarn. The twist is very essential to keep the component fibers together in a yarn. It is tested by using single yarn twist twister. The instrumentation is fully automatic. First the yarn is gripped in the fixed clamp. After being led through the rotating jaw. Then the yarn is pulled through until the pointer lies opposite a zero line on a small quadrant scale. Then the jaw is closed. At this stage, the specimen is under a small tension and it has a nominal length. As the twist is removed the yarn extends and the pointer reaches a vertical position. Eventually all the twist is taken out but the jaw is kept rotating in the same direction until sufficient twist has been inserted to bring the pointer back to the zero mark again. When the pointer coincides with the mark the dial reading is noted and the twist per inch can be calculated (Ozkaya et al., 2010).

$$\text{Twist (turns per meter)} = \frac{\text{Twist factor}(Kt)}{\sqrt{\text{tex}}}$$

3.4. Thermo Gravimetric Analyzer

Thermogravimetry (TG), the technique in which the mass of water retted/treated sample is monitored against time or temperature, is performed with a Thermogravimetric Analyser (TGA) or thermobalance. Thermogravimetric analysis (TGA) is a thermos analytical technique where thermobalance (a combination of an electronic microbalance with a furnace and appropriate temperature controller) measures changes in sample mass. This technique can be used to study the material weight loss due to e.g., decomposition, oxidation, or loss of volatiles, such as moisture in a set temperature range, giving typically a temperature (or time)/mass (or mass percentage) plot. Although TGA plots of composite materials can sometimes be hard to interpret, TGA is often used for determining their compositional analysis, using adequate standard samples or reference plots. In addition, TGA represents a useful tool to obtain information regarding thermal and oxidative stability, life expectancy, decomposition profile, moisture, and volatiles content. Thermogravimetric analysis (TGA) is one of the powerful techniques used for the measurement of thermal stability of materials. In this method, changes in the weight of a specimen are measured according to the temperature. Moisture and volatile contents of the sample can also measure by this method. (Ebnesajjad, 2006). TGA is measured using EXSTAR/6300 device.

4. RESULTS AND DISCUSSION

The results of the study on “**A Comparative Study of Physical Properties of Selected Virgin and Recycled Fibers and Yarns**” are discussed as follows.

4.1. Results of Fiber Tests

4.1.1. Mean Micronaire of Fibers

4.1.2. Maturity of Fibers

4.1.3. Span Length of Fibers

4.1.4. Uniformity Ratio of Fibers

4.1.5. Short Fiber Index of Fibers

4.1.6. Breaking Tenacity of Fibers

4.1.7. Elongation Percentage of Fibers

4.2. TGA Tests Results

4.2.1. TGA Results of 100% Polyester Fiber

4.2.2. TGA Results of Recycled Fiber + Polyester Blend

4.2.3. TGA Results of Recycled Fiber + Polyester/ Viscose Blend

4.3. Results of Yarn Tests

4.3.1 Linear density of Yarn Spun on Cotton Systems

4.3.2. Lea breaking strength of Yarn

4.3.3. Twist per inch of Yarn

4.1. Results of Fiber Tests

4.1.1. Mean Micronaire of Fibers

The test results and Loss/Gain value obtained for the micronaire of raw cotton and recycled colored cotton fibers are given in Table- I, and the comparison of results are represented in the graph is given in Figure 6.

Table I
Mean Micronaire of Fibers

Raw cotton	Recycled grey cotton		Recycled yellow cotton		Recycled black cotton		Recycled red cotton		Recycled orange yellow cotton	
	Value (µg/in)	Loss/Gain %	Value (µg/in)	Loss/Gain %	Value (µg/in)	Loss/Gain %	Value (µg/in)	Loss/Gain %	Value (µg/in)	Loss/Gain %
4.1µg/in	4.5	9.75	4.1	0	4.3	4.87	4.3	4.87	5.9	43.9

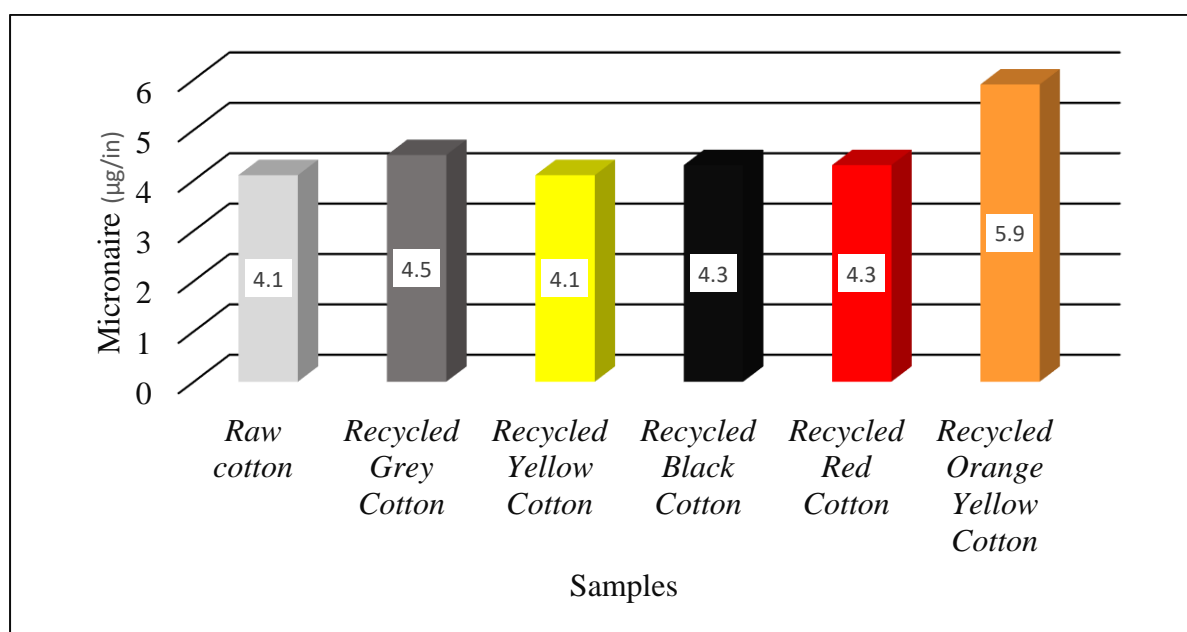


Figure-6
Mean Micronaire of Fibers

From Table I it is evident that the Cotton and textile manufacturers prefer a micronaire range of 3.8 to 4.5, and a fiber length of 1 1/8 inch or longer. Thicker or thinner fibers cause problems in both spinning and uniform dyeing of yarn. Once fibers are fully elongated, the fibers begin to thicken from the inside out. Carbohydrates produced through photosynthesis allow cellulose to be added to the cotton fiber walls, thus increasing both thickness and strength.

Cotton with high micronaire ratings can be associated with drought or water stress. Dry hot weather can cause a cotton plant to shed upper bolls early in the season, leaving only the bottom bolls. A cotton plant will produce the same amount of carbohydrates to be distributed among the fewer bolls, the result is higher micronaire.

From Table 1 it is found that the mean micronaire value of raw cotton is 4.1µg/inch. But in case of recycled orange yellow colour cotton, it is increased to 43.9%. The value is almost similar for raw cotton and recycled coloured cotton except recycled yellow orange cotton fibers. According to the results that are compared in above graph given in Figure 6 shows that the micronaire value is very high for recycled orange yellow cotton. Short fibers can also lead to high micronaire. When fiber elongation is limited micronaire often increases. Cotton varieties that typically produce shorter fiber are coarser and have higher micronaire rating than cotton varieties with longer fiber length.

4.1.2. Maturity of Fibers

The test results and Loss/Gain value obtained for the maturity of raw cotton and recycled colored cotton fibers are given in Table- II, and the comparison of results are represented in the graph is given in Figure 7.

Table II
Maturity of Fibers

Raw cotton	Recycled grey cotton		Recycled yellow cotton		Recycled black cotton		Recycled red cotton		Recycled orange yellow cotton	
	Value (M)	Loss/Gain %	Value (M)	Loss/Gain %	Value (M)	Loss/Gain %	Value (M)	Loss/Gain %	Value (M)	Loss/Gain %
0.85%	0.86	1.17	0.85	0	0.85	0	0.84	1.17	0.86	1.17

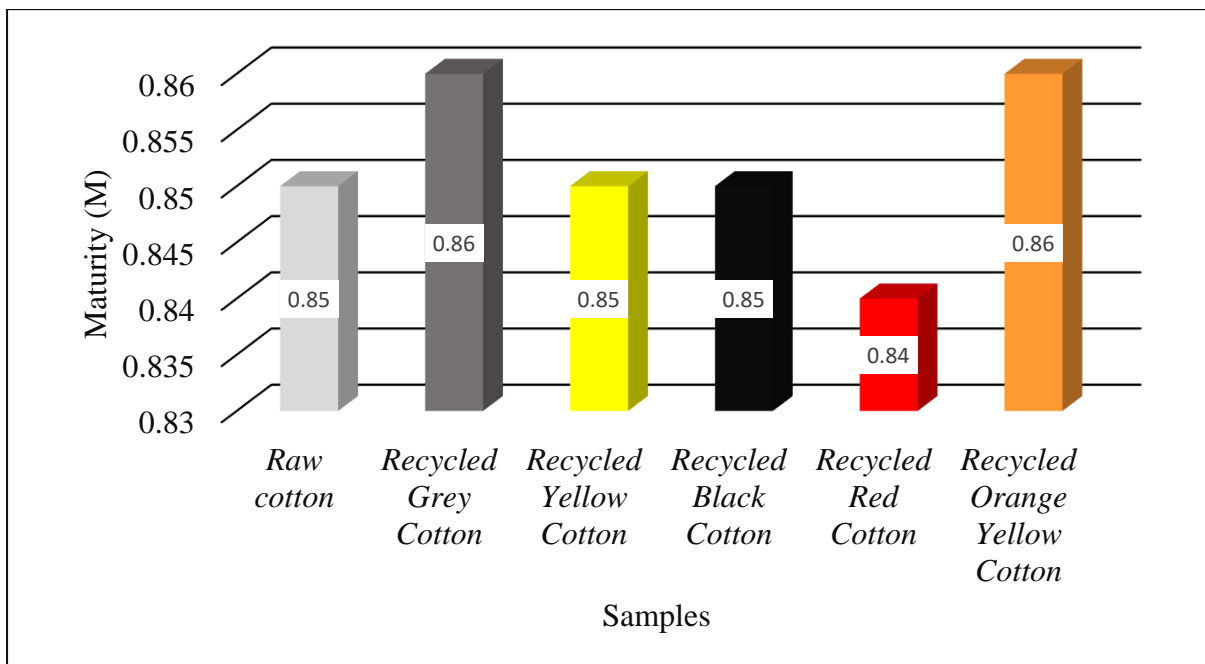


Figure-7
Maturity of Fibers

From Table II it is evident that the maturity value of raw cotton is 0.85. but in case of recycled grey, red, and orange yellow coloured cotton it is almost similar. According to the results that are compared in above graph given in Figure 7 shows that the Maturity is almost similar for all fibers. The maturity of cotton fiber has a big concern to a cotton spinner. The

maturity of cotton fibers plays a decisive role in resulting in yarn properties to be spun. It is a significant characteristic of cotton fibers. The maturity of cotton fiber is an indicator that expresses "the degree of development of cotton fiber". The maturity of fibers tells us how much development has been taken place in the fibers.

The cotton fibers do not have regular development within the sample or the fibers obtained from the same seed too. This difference among the maturity of various fibers appears because of the variations in the degree of the secondary thickening or deposition of cellulose in fibers. Maturity generally has a greater effect on fabric appearance and defects than any of the other fiber properties. It is commonly measured by the double compression airflow test, although single fiber measurements are used for more detailed information, including maturity distribution and the presence of immature and dead fibers. A small percentage of immature or 'dead' fibers may not significantly affect the average maturity but could significantly affect the yarn and fabric appearance, notably in terms of neppiness and white flecks which can comprise only about 0.5% (by weight) of fibers. The lighter appearance of dyed immature fibers is mainly due to their flat and ribbon-like non-uniform shape and the shorter path-length the light takes through the thinner dyed wall, rather than due to a lower dye uptake, with the difference in light reflectance characteristics from the 'flat' fiber surfaces also playing a role.

4.1.3. Span Length of Fibers

The test results and Loss/Gain value obtained for the 2.5% span length of raw cotton and recycled colored cotton fibers are given in Table- II, and the comparison of results are represented in the graph is given in Figure 8.

Table III
Span Length of Fibers

Raw cotton	Recycled grey cotton		Recycled yellow cotton		Recycled black cotton		Recycled red cotton		Recycled orange yellow cotton	
	Value (Mm)	Loss/Gain %	Value (Mm)	Loss/Gain %	Value (Mm)	Loss/Gain %	Value (Mm)	Loss/Gain %	value (Mm)	Loss/Gain %
29.4Mm	22.3	24.14	22.0	25.17	22.5	23.46	22.0	25.17	22.2	24.48

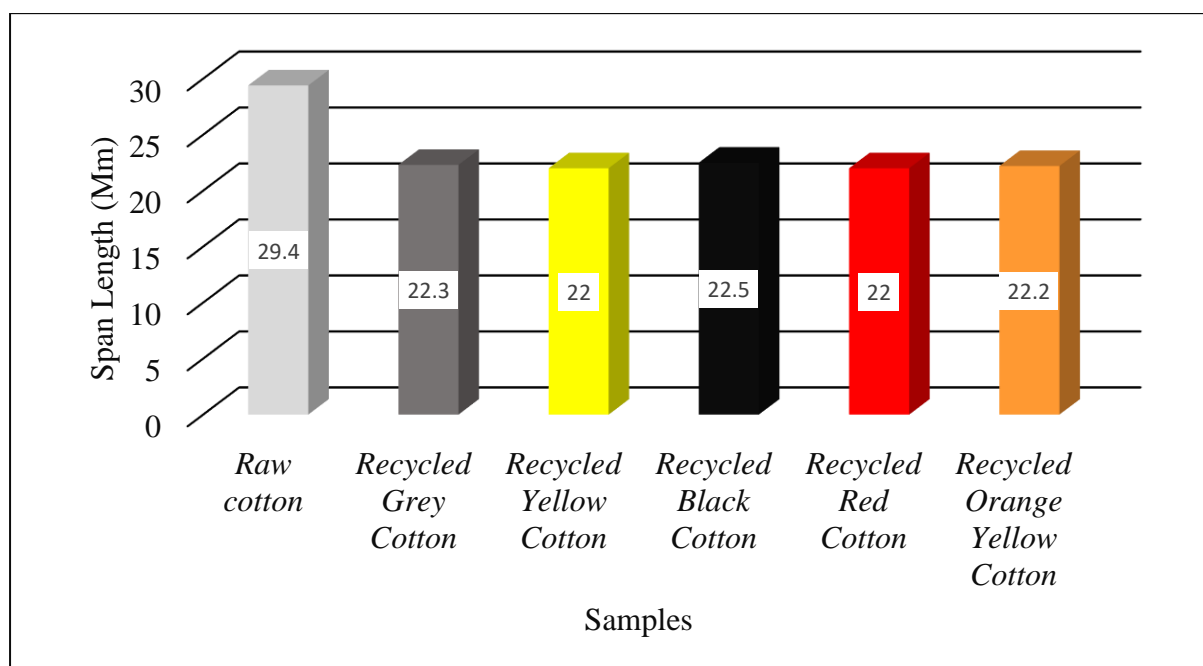


Figure-8
Span Length of Fibers

From Table III it is clear that the 2.5% span length of raw cotton is 29.4Mm. which is higher when compared to recycled coloured cotton fibers. The fiber length is the most important and critical characteristic of cotton fiber. It plays a decisive role to determine the cost of any cotton variety. The fiber length directly influences many yarn parameters like the tensile strength, elongation, evenness and hairiness of the yarn to be spun. It is defined as the distance spanned by 2.5% of fibers in the specimen being tested when the fibers are parallelized

and randomly distributed and where the initial starting point of the scanning in the test is considered 100%. The spinner chooses the correct fiber length to achieve desired yarn parameters to be spun. These yarn parameters directly affect the fabric to be woven. A cotton lint consists of many fibers. These fibers have different- different lengths individually. Many groups of lengths lie in the cotton lint. Since the cotton lint has many groups of fiber length, it gets very difficult to find the exact fiber length of any cotton.

4.1.4. Uniformity Ratio of Fibers

The test results and Loss/Gain value obtained for the uniformity ratio of raw cotton and recycled colored cotton fibers are given in Table- IV, and the comparison of results are represented in the graph is given in Figure 9.

Table IV
Uniformity Ratio of Fibers

Raw cotton	Recycled grey cotton		Recycled yellow cotton		Recycled black cotton		Recycled red cotton		Recycled orange yellow cotton	
	Value (%)	Loss/Gain %	Value (%)	Loss/Gain %	Value (%)	Loss/Gain %	Value (%)	Loss/Gain %	Value (%)	Loss/Gain %
45.5%	42.0	7.69	42.0	7.69	41.8	8.13	42.1	7.47	43.0	5.49

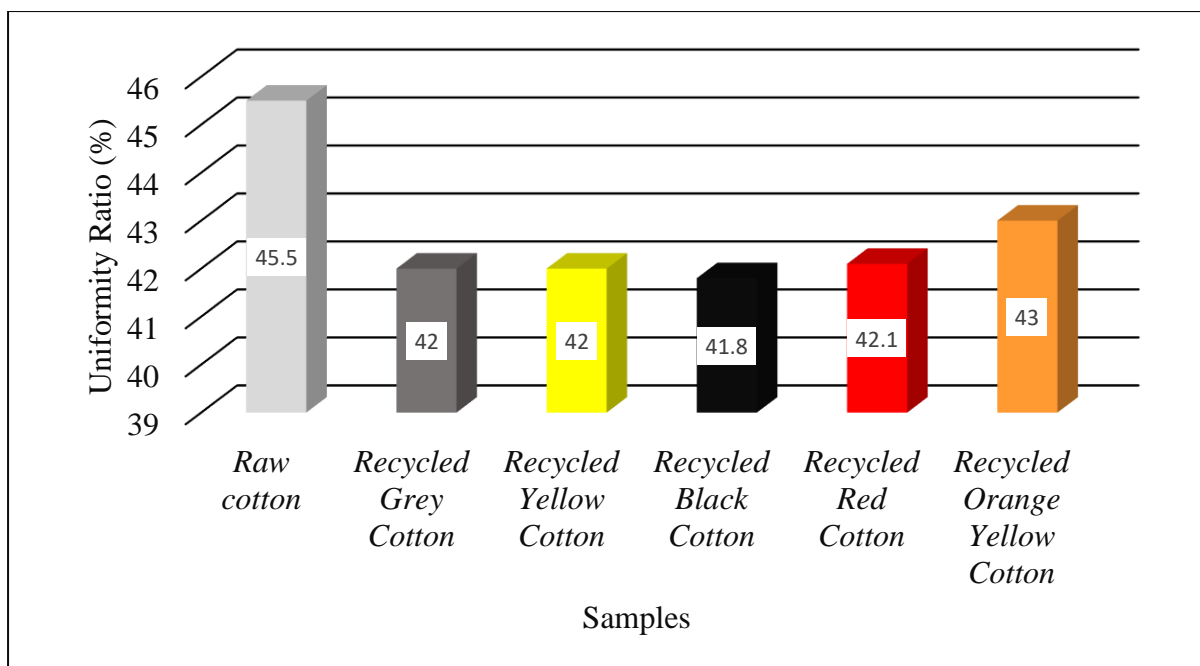


Figure-9

Uniformity Ratio of Fibers

From Table IV it is clear that the uniformity ratio of raw cotton fiber was found to be 45.5%. Cotton fiber length characteristics are probably the best criterion for ring spinning performance and spinning limits and often also of yarn strength. An increase of 1 mm in fiber length increases yarn strength by some 0.4 cN/tex or more. The staple length, upper half mean length (UHML) and 2.5% span length all provide similar, but not identical, measures of the length of the bulk of the long fibers in a sample, and approximate the length of the fibers when carefully detached from the seed by hand.

Excessive fiber length variation (e.g., CV of fiber length, uniformity ratio or uniformity index) tends to increase manufacturing waste and to adversely affect processing performance, including spinning performance and yarn quality. The inverse of length uniformity also provides a measure of floating fibers within the drafting zone, although the short fiber content (SFC) is a better indicator of the floating fibers. An increase in SFC increases spinning end breaks, processing waste (including comber noils), fly and optimum roving twist, and causes deterioration in yarn and fabric properties, notably yarn strength and evenness.

An increase of 1% (absolute) in SFC can decrease ring spun yarn strength by 1% or more. Fabric strength and abrasion resistance also tend to deteriorate with an increase in SFC. uniformity index is measured on high volume systems, on its own it does not provide an

accurate measure of SFC. A uniformity index of above 83% and uniformity ratio above 48% are desirable, although it depends upon the spinning system and yarn count.

4.1.5. Short Fiber Index of Fibers

The test results and Loss/Gain value obtained for the short fiber index of raw cotton and recycled colored cotton fibers are given in Table- V, and the comparison of results are represented in the graph is given in Figure 10.

Table V
Short Fiber Index of Fibers

Raw cotton	Recycled grey cotton		Recycled yellow cotton		Recycled black cotton		Recycled red cotton		Recycled orange yellow cotton	
	Value (%)	Loss/Gain %	Value (%)	Loss/Gain %	Value (%)	Loss/Gain %	Value (%)	Loss/Gain %	Value (%)	Loss/Gain %
7.4%	24.5	231.0	24.0	224.3 2	23.8	221.6 2	24.1	225.6 7	24.3	228.3 7

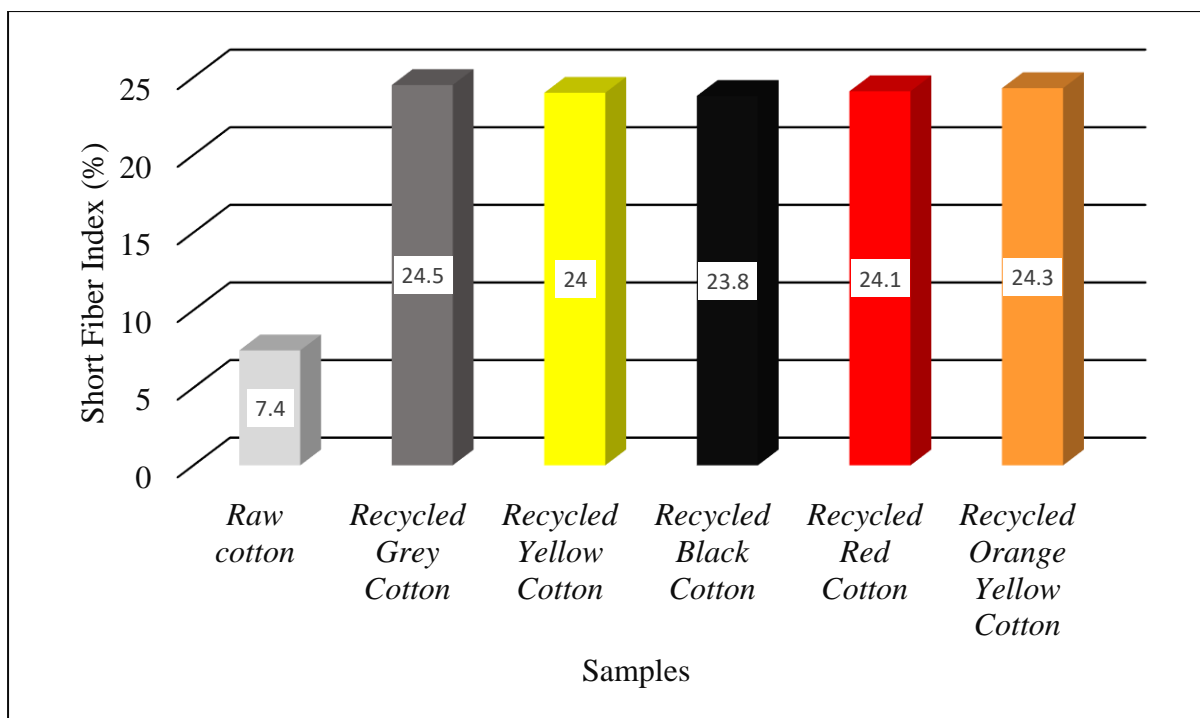


Figure- 10

Short Fiber Index of Fibers

From the above Table V, it is clear that the short fiber index of raw cotton fiber is 7.4%. whereas all the recycled cottons short fiber index has increased by more than 200%. The maximum value is seen in recycled orange yellow cotton as 228.37% and least increase is noted in recycled black cotton as 221.22%. The proportion of short fibers has a very substantial influence on the yarn parameters namely end breaks, strength, IPI values, hairiness and uniformity. Production losses due to reduced speeds is another major factor to be considered. Besides this, a large proportion of short fibers also lead to considerable fly contamination (among other problems), straining personnel, the machines, the work- room, the air-conditioning, and also leads to extreme drafting difficulties. Unfortunately, the proportions of short fibers have increased substantially in recent years in cotton available from many sources. Hence it could be concluded that, after recycling the short fiber index has increased to a great extent. Care must be taken to test as many incoming bales as possible for SFC(n) and set limits for the rejection of the supply based on this parameter.

4.1.6. Breaking Tenacity of Fibers

The test results and Loss/Gain value obtained for the breaking tenacity of raw cotton and recycled colored cotton fibers are given in Table- VI, and the comparison of results are represented in the graph is given in Figure 11.

Table VI

Breaking Tenacity of Fibers

Raw cotton	Recycled grey cotton		Recycled yellow cotton		Recycled black cotton		Recycled red cotton		Recycled orange yellow cotton	
	Value (G/Tex)	Loss/Gain %	Value (G/Tex)	Loss/Gain %	Value (G/Tex)	Loss/Gain %	Value (G/Tex)	Loss/Gain %	Value (G/Tex)	Loss/Gain %
25.1 G/Tex	24.0	4.38	23.8	5.17	23.3	7.17	23.9	4.78	24.1	3.98

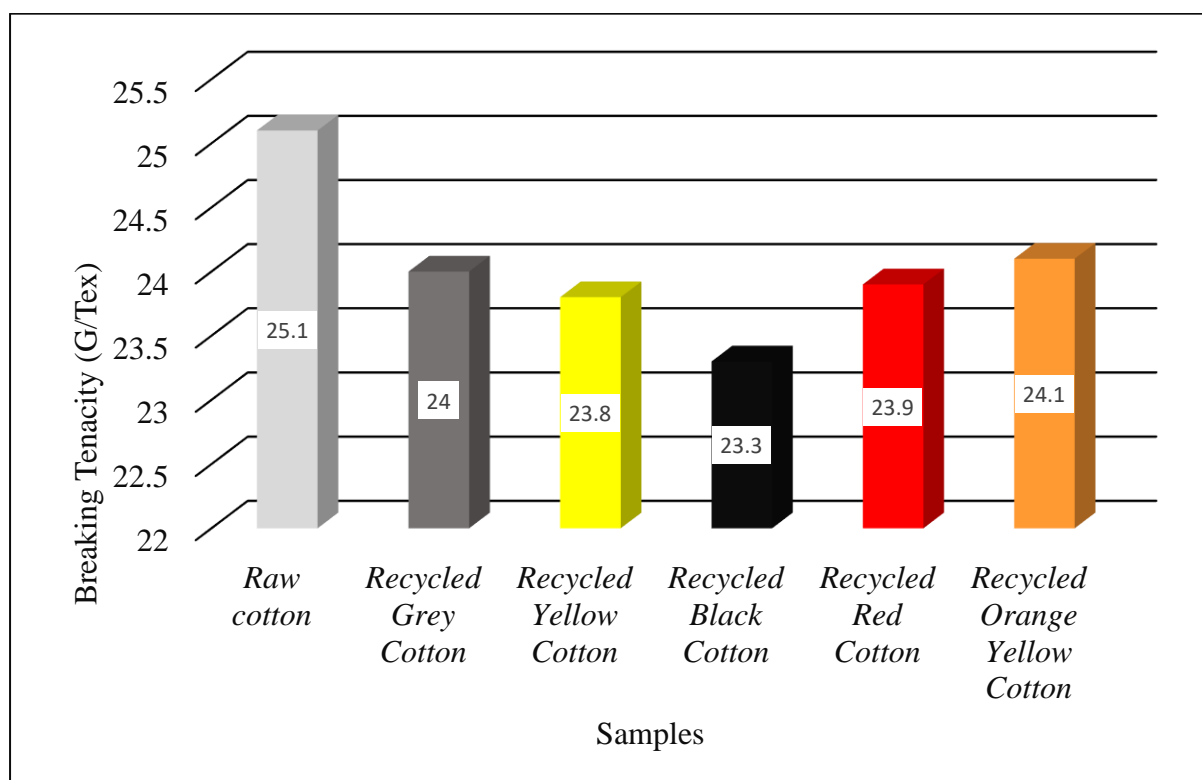


Figure- 11

Breaking Tenacity of Fibers

From Table VI it is clear that, the breaking tenacity of raw cotton is 25.1 G/Tex. It is almost similar for all the recycled coloured cotton fibers. While the tensile properties of cotton fibers in the bundle forms have been studied extensively in the past several years, little research has been performed with the single cotton fibers. It is natural to expect that the changes in the

mechanical properties of cotton fibers brought about by the machine actions during the manufacturing processes would exert indelible effects on the characteristics of the resulting textile products, e.g., fabrics and garments. The modes and extents of machine actions or damages inflicted upon cotton fibers during the ginning and the subsequent processes are numerous, complex and indeterminate, to be quantified or identified. Investigations on this important issue have not been successful due to lack of means for testing the tensile properties of a large number of cotton fibers before and after each stage of processing. Yet, it is readily conceivable that the rapid and repeated loading of cotton fibers may leave irreversible effects on cotton fibers.

4.1.7. Elongation Percentage of Fibers

The test results and Loss/Gain value obtained for the elongation percentage of raw cotton and recycled colored cotton fibers are given in Table- VII, and the comparison of results are represented in the graph is given in Figure 12.

Table VII
Elongation Percentage of Fibers

Raw cotton	Recycled grey cotton		Recycled yellow cotton		Recycled black cotton		Recycled red cotton		Recycled orange yellow cotton	
	Value (%)	Loss/Gain %	Value (%)	Loss/Gain %	Value (%)	Loss/Gain %	Value (%)	Loss/Gain %	Value (%)	Loss/Gain %
6.5%	10.6	63.07	10.1	55.38	9.8	50.76	10.0	53.84	10.2	56.92

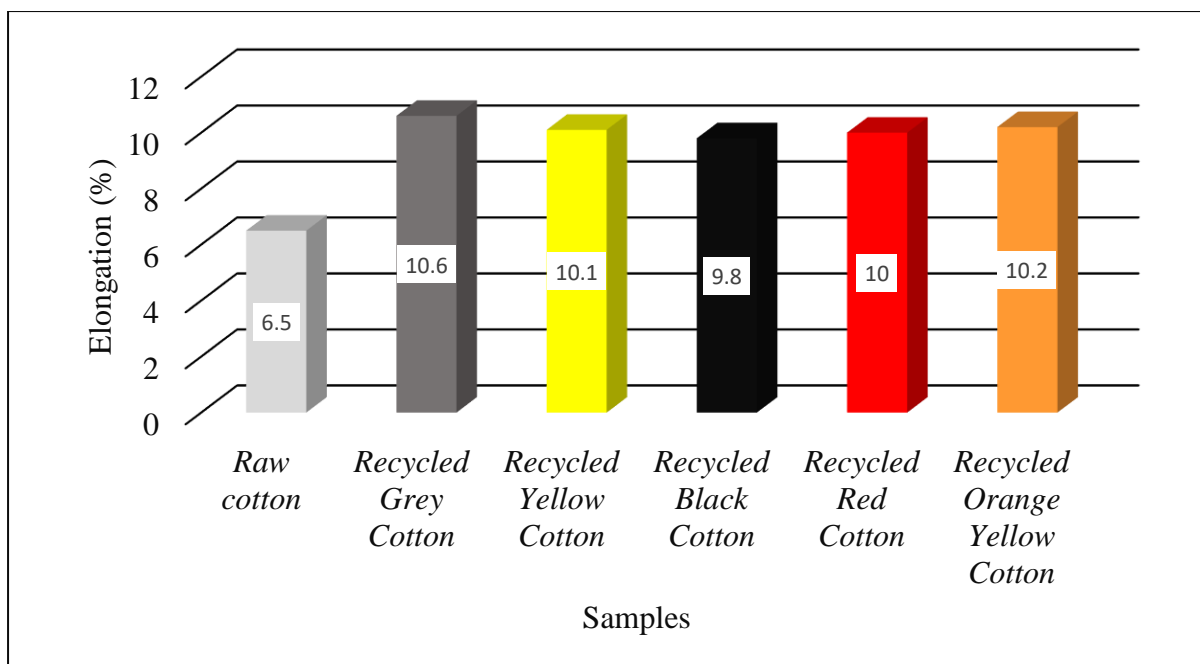


Figure-12

Elongation Percentage of Fibers

From Table VII it was found that the elongation percentage of raw cotton is 6.5%. it is lower when compared to other recycled coloured cotton fibers. The degree of fiber elongation before rupture plays an important role in almost all of the textile manufacturing processes. As mentioned by Benzina et al., (2007), the cotton fibers which do not possess an adequate degree of elongation, as well as tenacity, fail to withstand the stresses applied during ginning and subsequent mechanical processing stages which results in fiber breakage. In addition, fibers with a higher degree of elongation tend to spin more efficiently as they deform more easily during spinning. The total energy required to break a bundle of fibers, such as a yarn, or a single fiber is a product of the breaking strength and the elongation at break.

A yarn that has a low breaking strength and a high degree of elongation before rupture value will require more energy to break than a yarn with high breaking strength and a low elongation value. Several studies suggest using cotton fiber with a higher degree of elongation as a raw material result in an improved tenacity and degree of elongation of the spun yarn. Correspondingly, it was emphasized that the degree of fiber bundle elongation plays an important role in the work of rupture of fiber bundles.

4.2. TGA Tests Results

4.2.1. TGA Results of 100% Polyester Fiber

The test results of TGA obtained for 100% polyester fibers are represented in graph is given in Figure 13 and 14.

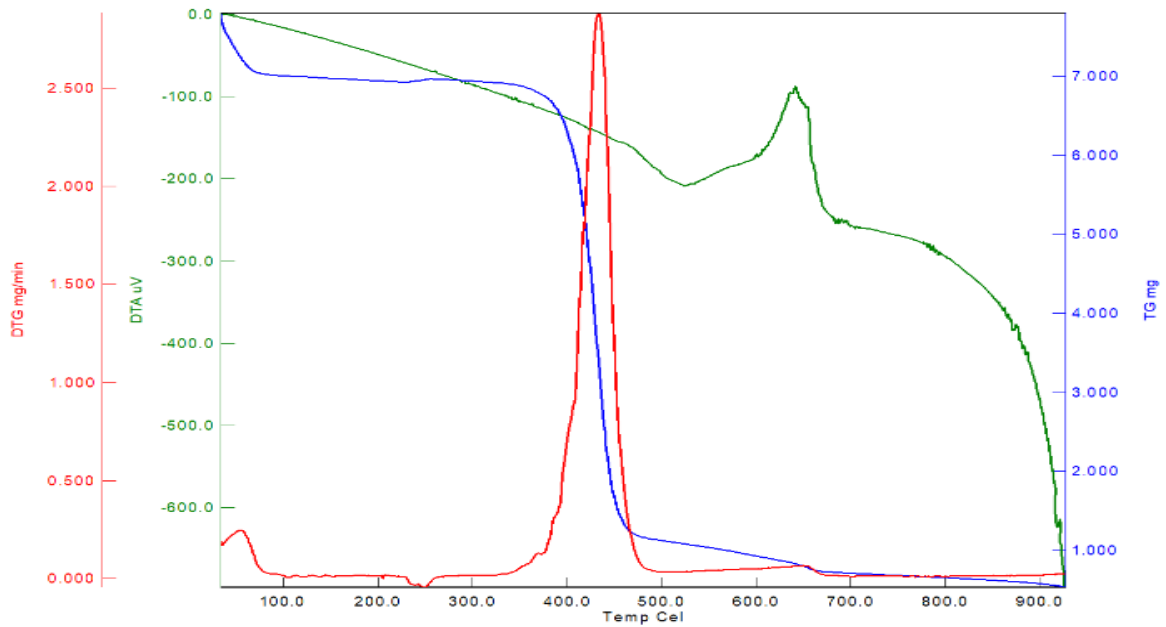


Figure- 13
DTG of 100 % Polyester Fiber

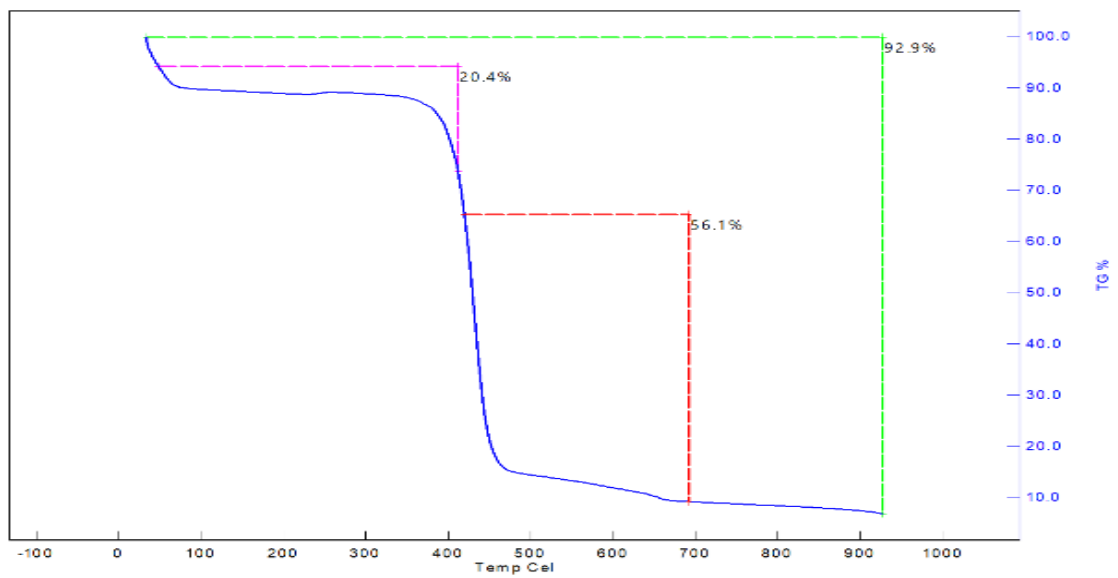


Figure-14
TG% of 100% Polyester Fiber

From Figure 13 and 14, it shows that in the first stage, the 100% polyester fiber was stable upto 220°C. the fiber shows a variation in the curves between 220°C to 310°C. the first degradation started from 310°C with a weight loss of 6.9 mg from 7.817 mg. From fig 18 the % of weight loss was found to be 20.4%

The second degradation started from 480°C. in which there is a weight loss from 480°C. The % of weight loss was found to be 56.1%.

The third degradation was started at 910°C. There was a weight loss from 1.3 mg to 0.5 mg. The % of weight loss was 92.

4.2.2. TGA Results of Recycled Fiber + Polyester Blend

The test results of TGA obtained for Recycled Fiber + Polyester Blend are represented in graph is given in Figure 15 and 16.

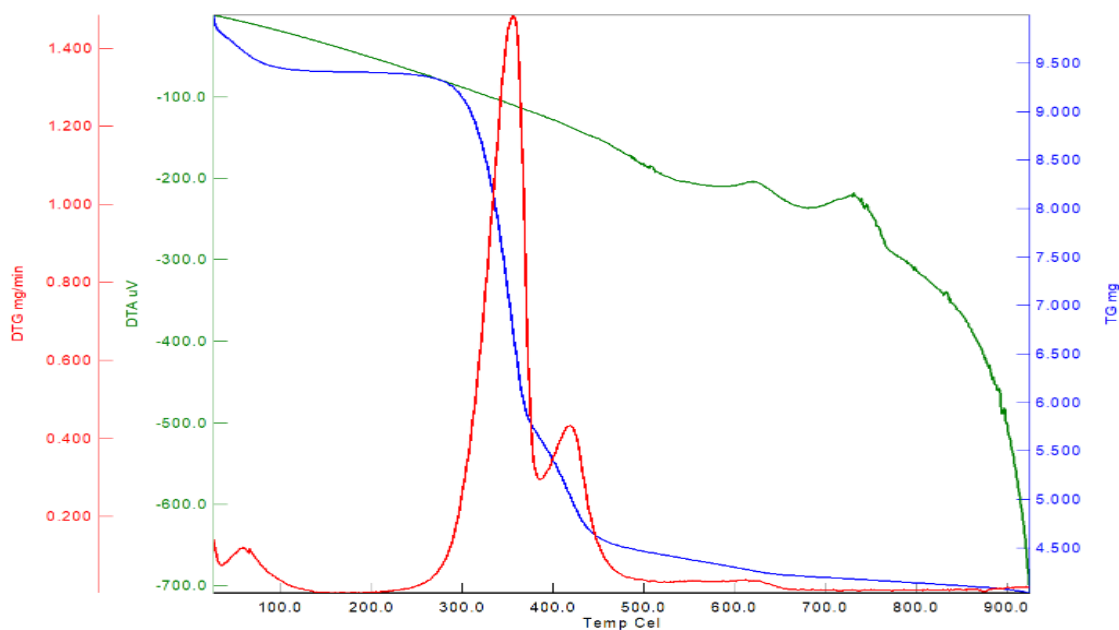


Figure-15.
DTG of Recycled Fiber+ Polyester Blend

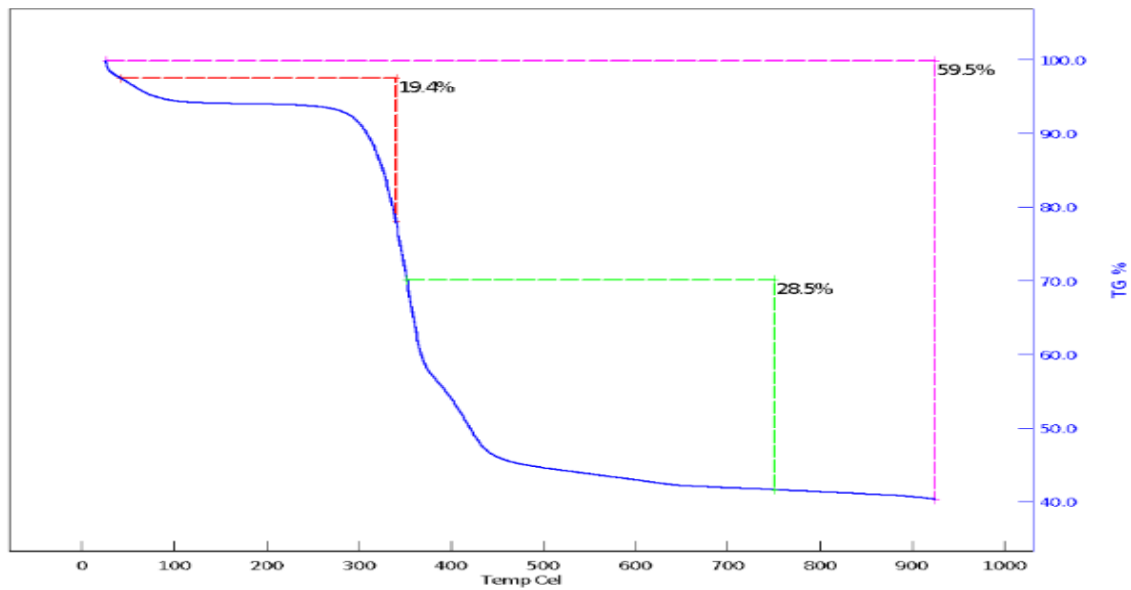


Figure-16
TG% OF Recycled Fiber+ Polyester Blend

From Figure 15 and 16 it was found that the fiber was stable at 0° to 250°C. The first degradation was started between 200° to 300°C. The weight loss of first degradation from the standard sample weight 10.009 mg is decreased to 9.4 mg. The % of weight loss was about 19.4%.

The second degradation was started between 400° to 500°C. It shows that there was a weight loss from 9.4 to 4.6 mg and 28.5% of weight loss

At 910°C the third degradation was started. The weight was reduced to 4.0 mg from 4.6mg and the % of weight loss was found to be 59.5%.

4.2.3. TGA Results of Recycled Fiber + Polyester/ Viscose Blend

The test results of TGA obtained for Recycled Fiber + Polyester/ Viscose Blend are represented in graph is given in Figure 17 and 18.

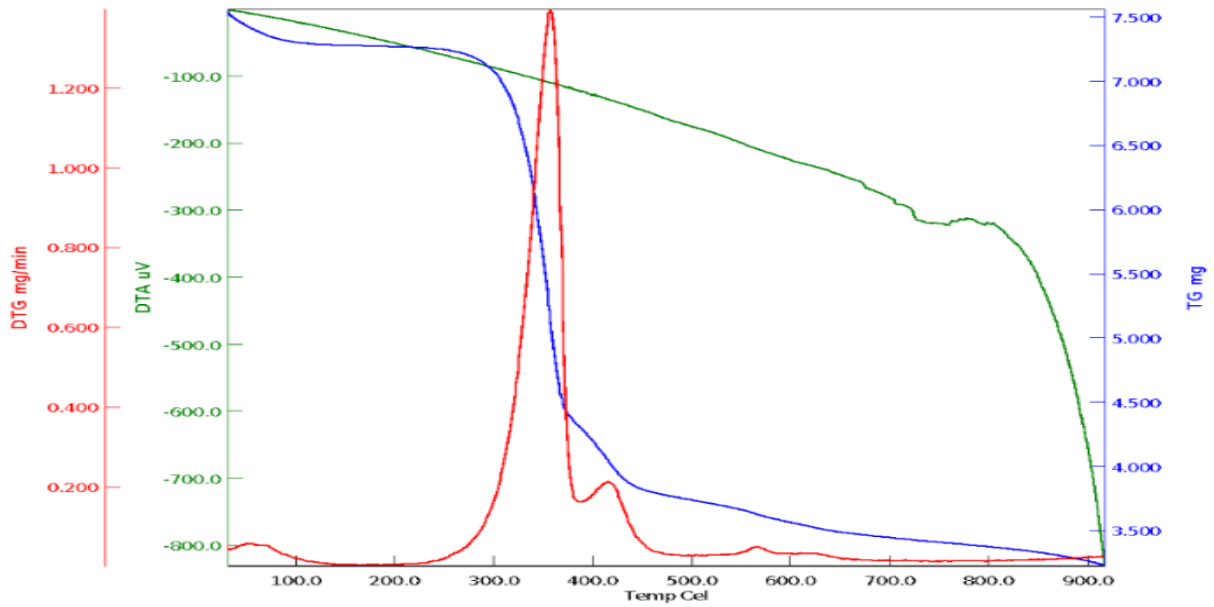


Figure- 17
TG% of Recycled Fiber+ Polyester/Viscose Blend

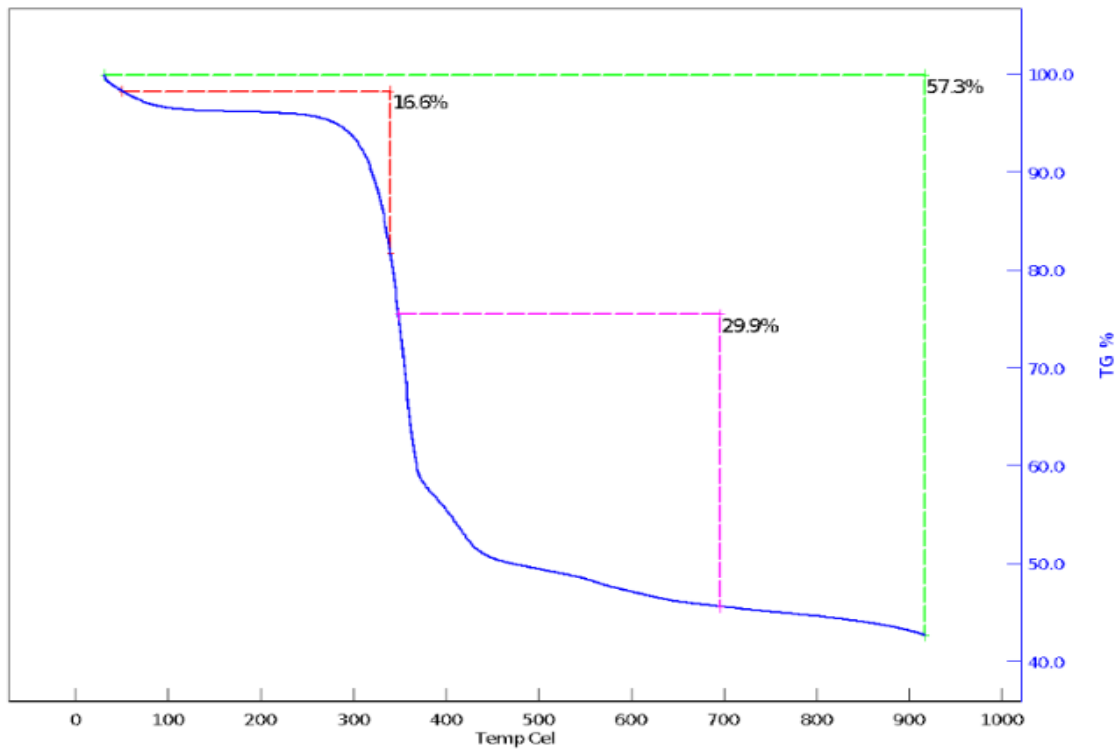


Figure- 18
TG% of Recycled Fiber + Polyester/Viscose Blend

From Figure 17 and 18 it is understood that the fiber has short stability from 0° to 250°C. The first degradation was started between 200° to 300°C. the standard sample weight 10.009 mg was reduced to 7.3 mg. The % of weight was found to be 16.6%.

Between 400° to 500°C the second degradation was started. There is a weight loss happened from 7.3 mg to 3.9 mg and the % of weight loss was found to be 29.9%.

At 910°C the third degradation was started. It shows that there was a weight loss of 3.0 mg from 3.9 mg. The % of weight loss was found to be 57.3%.

4.3. Results of Yarn Tests

4.3.1 Linear density of Yarn Spun on Cotton Systems

The test results and Loss/Gain value obtained for the Linear Density of 30s Grey Cotton Yarn and 30s Dyed Blue Recycled and Blended Cotton Yarn are given in Table- VIII.

Table- VIII.

Linear density of Yarn Spun on Cotton Systems

Sl.no.	Linear density	30s Grey Cotton Yarn	30s Dyed Blue Recycled and Blended Cotton Yarn	
			Value	Loss/Gain %
1	Mean value (C.C)	30.4	28.7	5.59
2	C.V % of count	0.6	0.7	16.66

From Table-VIII it is clear that the mean value of linear density of yarn spun on cotton system is 30.4 whereas the mean value for 30s dyed blue recycled and blended cotton yarn has decreased to 5.59 %. The count of yarn is expressed in the form of numerical numbers. Different systems are used in the different regions of the world to express the count of the yarn (linear density of yarn).

4.3.2. Lea breaking strength of Yarn

The test results and Loss/Gain value obtained for the Lea Breaking Strength of 30s Grey Cotton Yarn and 30s Dyed Blue Recycled and Blended Cotton Yarn are given in Table- IX.

Table- IX.

Lea breaking strength of Yarn

Sl.no.	Lea breaking strength	30s Grey Cotton Yarn	30s Dyed Blue Recycled and Blended Cotton Yarn	
			Value	Loss/Gain %
1	Mean value (Lbs)	81.4	43.6	46.43
2	C.V %	2.9	3.8	31.03
3	Count strength product	2475	1251	49.45

From Table- IX states that the mean value of lea breaking strength of cotton yarn is 81.4Lbs. and for dyed blue recycled and blended cotton yarn is decreased to 46.43 %. The table shows that there is wider variation in strength which leads to huge difference in the count strength product of both yarns.

4.3.3. Twist per inch of Yarn

The test results and Loss/Gain value obtained for the Twist Per Inch of 30s Grey Cotton Yarn and 30s Dyed Blue Recycled and Blended Cotton Yarn are given in Table- X.

Table- X.

Twist per inch of Yarn

Sl.no.	Twist per inch	30s Grey Cotton Yarn	30s Dyed Blue Recycled and Blended Cotton Yarn	
			Value	Loss/Gain %
1	Twist per inch (TPI)(Singles)	20.9	18.3	12.44
2	Twist multiplier	3.8	3.4	10.52

From Table-X it is understood that the twist per inch is less in 30s dyed blue recycled and blended cotton yarn i.e.,18.3 for both grey cotton and dyed blue recycled and blended cotton yarn the value is low, even though grey cotton yarn is found to be better. A certain amount of lengthwise contraction occurs in yarns with increase in twist, but the amount is quite small.

5. SUMMARY AND CONCLUSION

Population growth, improved living standards increased the need for textile materials and decreased the life cycle time of textile products contributed to global fiber consumption that generates a significant amount of post-industrial and post-consumer fiber waste. It will create a lot of problems to the environment like dumping of this wastes into landfills, depletion of natural resources etc. Besides economic and environmental concerns, it represents wasting of resources. We can use the recycled fibers instead of the virgin fibers. It will help to conserve the natural resources. Before using it is very important to check the properties of the recycled fiber whether it is matching with the properties of the virgin fibers or not. If it is not, then it should be blended with virgin fibers for different end uses (Fletcher, 2008).

Considering the above facts in mind the present study on “A Comparative Study of Physical Properties of Selected Virgin and Recycled Fibers and Yarns” with the following objectives”

- To collect the virgin and recycled fibers from recycling industry
- To spin the selected recycled fibers into yarns
- To test and compare the properties of the collected fibers and spun yarns
- Evaluation and tabulation of results

Findings of the study

- Mean micronaire value of raw cotton is 4.5 $\mu\text{g}/\text{inch}$. But in case of recycled orange yellow colour cotton, it is increased to 43.9%. The value is almost similar for raw cotton and recycled coloured cotton except recycled yellow orange cotton fibers.
- The maturity value of raw cotton is 0.85M. but in case of recycled grey, red, and orange yellow coloured cotton fiber it is almost similar. The maturity of cotton fibers plays a decisive role in resulting in yarn properties to be spun.
- 2.5% span length of raw cotton is 29.4Mm. which is higher when compared to recycled coloured cotton fibers.
- The uniformity ratio of Raw cotton fiber was found to be 45.5%. A uniformity index of above 83% and uniformity ratio above 48% are desirable, although it depends upon the spinning system and yarn count.

- The short fiber index of raw cotton fiber is 7.4%. whereas all the recycled cottons short fiber index has increased by more than 200%. The maximum value is seen in recycled orange yellow cotton as 228.37% and least increase is noted in recycled black cotton as 221.22%.
- The breaking tenacity of raw cotton is 25.1 G/Text and it is almost similar for all the recycled coloured cotton fibers. It indicates the addition of small amount of polyester or other synthetic fibers in the recycled fibers.
- The elongation percentage of cotton fiber is found to be 6.5%. which is lower when compared to the values of recycled coloured cotton fibers.
- The mean value of linear density of yarn spun on cotton system is 30.4s Ne whereas the mean value for 30s dyed blue recycled and blended cotton yarn has decreased to 5.59 %.
- The mean value of lea breaking strength of cotton yarn is 81.4Lbs and for dyed blue recycled and blended cotton yarn is decreased to 46.43 %. It shows that there is wider variation in strength which leads to huge difference in the count strength product of both yarns.
- The twist per inch is less in 30s dyed blue recycled and blended cotton yarn i.e., 18.3TPI for both grey cotton and dyed blue recycled and blended cotton yarn the value is low, even though grey cotton yarn is found to be better.
- By adding a small amount of synthetic fibers in recycled cotton fiber, strength can be increased. Hence such fibers can be used for making yarn and subsequently fabric of equal strength as such raw cotton.
- The only demerit of recycled cotton is higher short fiber index, which may lead to pilling effect. But by considering the cost effectiveness of using recycled cotton and waste management, it is better.
- In case of TGA, the weight loss of 100% polyester showed 92.9% when compared to recycled fiber + polyester blend. Which showed only 59.5% weight loss at 910°C and recycled fiber + polyester/viscose blend shows 57.3% of weight loss at the same temperature.
- In comparison with 30s grey cotton yarn with 30s dyed blue recycled and blended cotton yarn there is no much variation in count. But there was a wider variation in strength. Which leads to huge difference in the count strength product.

- In case of twist per inch and twist multiplier, as recycled cotton blended yarn are made from recycled blended fiber, there was a higher short fiber index in fiber, which subsequently leads to lesser twist per inch. As the twist per inch is lesser in recycled blended cotton yarn, the smoothness will be better.
- Because of lesser count strength product, recycled blended cotton yarn can be used in fabric where lesser strength can be used like floor mat, table mat, home furnishing, home textile product etc.

Conclusion

Globally textile industry is the largest and fastest growing sector. But increased population, industrialisation is resulted in a huge production of textiles. Now the industry is associated with many environmental problems and known as one of the most polluting industries around the world. The consumption of large amount of natural resources, pesticides, energy are leading the textile industry one of the most polluting and waste generating industry. In order to overcome these environmental issues, recycling is an effective way. By preventing the dumping of wastes into the landfills, reducing the need for natural resources it reduces the negative impact on the environment.

From the above study it is clear that the properties of recycled coloured fibers and dyed yarns are almost similar to that of the properties of virgin cotton fibers and yarns. Recycled yarns can be used in fabrics where low strengths can be used like floor mat, home furnishing products etc. thus we can reduce the environmental impact and can save natural resources. By using recycled fibers, we can reduce the generation of wastes, CO₂ emissions and can save water. By adding some amount of synthetic fibers like polyester into the recycled fibers during the recycling process, we can increase the strength of the fiber. Thus, it can be used to produce garments. Also, by considering the cost and availability recycling is an effective way.

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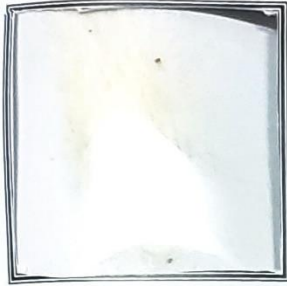
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**APPENDIX I
SAMPLES**



Raw Cotton



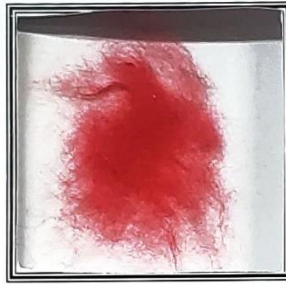
Recycled Grey Cotton



Recycled Yellow Cotton



**Recycled Black
Cotton**



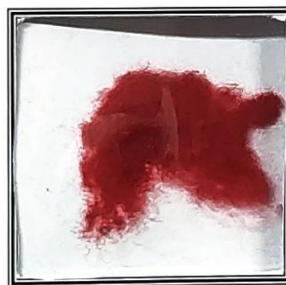
Recycled Red Cotton



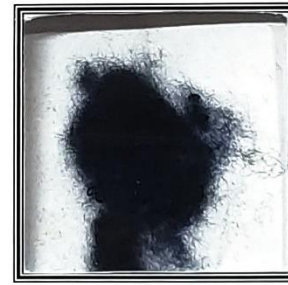
**Recycled Orange-Yellow
Cotton**



100% Polyester



**Recycled Fiber + Polyester
Blend**



**Recycled Fiber + Polyester
/ Viscose Blend**



30s Grey Cotton



**30s Dyed Blue Recycled
and Blended Cotton Yarn**

APPENDIX 2

Textile Committee Textile Results

REGIONAL LABORATORY
TEXTILES COMMITTEE
(Ministry of Textiles, Govt. of India)
"B" Chambers, 97B A, Thadagan Road,
Coimbatore - 641 002.
Tel : 2473054, 2478758 Fax : 2472689 E-mail : rlabco@nic.in, rlabco@rediffmail.com

Format No. : 19/33/00

TEST REPORT

Test report No. : 6850/2021-22 23/02/2022
Name and address of the Customer : Miss. Aswathy C.V.IIInd Year Post Graduate in Textiles & Fashion Apparel
Avinashilingam University
Coimbatore-641043

Sample forwarding letter No. & date : 10/02/2022
Date of receipt of Sample : 10/02/2022
Buyer's Name & Address (Optional) :
Customers sample Ref. :

Sample description : Fibre
Lab Sample No. : CT-6850 to 6855
Date/s of Testing : 10/02/2022 to 23/02/2022

TEST RESULTS

Our sample No-	6850	6851	6852	6853	6854	6855
Sample ID-	Raw Cotton	Recycled Grey Cotton	Recycled Yellow Colour Cotton	Recycled Black Colour Cotton	Recycled Red Colour Cotton	Recycled Orange Yellow Colour Cotton
I. Physical Properties Of Cotton Fibre By High Volume Instrument (Astm D 5867 – 2012) (Ice Mode)						
Mean Micronaire	4.1	4.5	4.1	4.3	4.3	5.9
Maturity	0.85	0.86	0.85	0.85	0.84	0.86
2.5% Span Length (Mm)	29.4	22.3	22.0	22.5	22.0	22.2
50% Span Length (Mm)	13.4	9.4	9.2	9.4	9.3	9.5
Uniformity Ratio (%)	45.5	42.0	42.0	41.8	42.1	43.0
Short Fibre Index	7.4	24.5	24.0	23.8	24.1	24.3
Breaking Tenacity (G/Tex)	25.1	24.0	23.8	23.3	23.9	24.1
Elongation Percentage	6.5	10.6	10.1	9.8	10.0	10.2
Colour (Rd / +B)	72.1/12.6	66.1/10.4	8/40	10/38	10/35	8/37

K. GOWRISANKAR
मुद्रणा अधिकारी (प्रमाणन)
Quality Assurance Officer (LABS)

Head office : Textiles Committee, (Government of India, Ministry of Textiles) P.Balu Road, Prabhadevi Chowk, Prabhadevi, MUMBAI - 400 025. Tel : +91-22-66527519 Fax : +91-22-66527554 E-mail: dlab.tr@nic.in, tlabmumbai@gmail.com

Fiber Test Result

REGIONAL LABORATORY
TEXTILES COMMITTEE
(Ministry of Textiles, Govt. of India)
"B" Chambers, 97B A, Thadagan Road,
Coimbatore - 641 002.
Tel : 2473054, 2478758 Fax : 2472689 E-mail : rlabco@nic.in, rlabco@rediffmail.com

Format No. : 19/33/00

TEST REPORT

Test report No. : 7203/2021-22 02/03/2022
Name and address of the Customer : The Registrar
Avinashilingam University
Coimbatore-641 043
Cell No-8848977426

Sample forwarding letter No. & date : 01/03/2022
Date of receipt of Sample : 01/03/2022
Buyer's Name & Address (Optional) :
Customers sample Ref. : 30s Grey Cotton Yarn

Sample description : Yarn
Lab Sample No. : CT-7201
Date/s of Testing : 01/03/2022 to 02/03/2022

TEST RESULTS

Linear Density of Yarns spun on cotton system (IS 1315:1977 (RA 2014))
Mean Value (CC) : 30.4s Ne
C.V.% of Count : 0.6
Lea breaking strength IS 1671:1977 (RA 2014)
Mean Value (Lbs) : 81.4
C.V.% : 2.9
Count Strength Product : 2475
Twist per Inch (IS 832:1985) (RA 2011)
Twist per Inch (Singles) : 20.9
Direction of Twist (Single yarn) : "Z"
Twist multiplier : 3.8

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30s Grey Cotton Yarn Test Result

REGIONAL LABORATORY
TEXTILES COMMITTEE
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"B" Chambers, 97B A, Thadagan Road,
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Tel : 2473054, 2478758 Fax : 2472689 E-mail : rlabco@nic.in, rlabco@rediffmail.com

Format No. : 19/33/00

TEST REPORT

Test report No. : 7204/2021-22 02/03/2022
Name and address of the Customer : The Registrar
Avinashilingam University
Coimbatore-641 043
Cell No-8848977426

Sample forwarding letter No. & date : 01/03/2022
Date of receipt of Sample : 01/03/2022
Buyer's Name & Address (Optional) :
Customers sample Ref. : 30s Dyed Blue Recycled and blended Cotton Yarn

Sample description : Yarn
Lab Sample No. : CT-7204
Date/s of Testing : 01/03/2022 to 02/03/2022

TEST RESULTS

Linear Density of Yarns spun on cotton system (IS 1315:1977 (RA 2014))
Mean Value (CC) : 28.7s Ne
C.V.% of Count : 0.7
Lea breaking strength IS 1671:1977 (RA 2014)
Mean Value (Lbs) : 43.6
C.V.% : 3.8
Count Strength Product : 1251
Twist per Inch (IS 832:1985) (RA 2011)
Twist per Inch (Singles) : 18.3
Direction of Twist (Single yarn) : "Z"
Twist multiplier : 3.4

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30s Dyed Blue Recycled and Blended Cotton Yarn Test Result