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The ICAC Recorder

Innovative Interventions for Value Creation in Cotton Lint & Waste to Wealth Part-1: Value Addition to Comber Noil

1. Introduction

"Cotton is grown to be spun" is an old dictum among cotton processors. Spinning is considered to be a mechanical process by which a few fibres are brought and drawn together in such a manner that a cohesive twisted structure is formed. The number of fibres brought together is dependent upon the count or yarn diameter envisaged. In the process of dismantling a high density compressed bale to produce a yarn, the fibres undergo a series of processes such as opening and cleaning, individualization and parallelization, drawing, thinning down with all fibres brought together and made parallel to an imaginary yarn axis, before being inserted with a twist to form a yarn. In these mechanized operations the compressed fibres are decompressed, opened and individualized devoid of organic trash that was entangled with them. The individual fibres as a result are subjected to mechanical forces in all directions longitudinal and lateral with a preferential longitudinal pull. While preparing a homogenized drawn sliver prior to twisting, the now opened and separated fibres undergo a predominantly longitudinal drag and in both the above major operations wastes are generated that comprise in the initial stages more organic trash and less of good fibres. In the later stages of processing on a larger measure, good fibres are discarded as waste.

(a) Waste Generated in Processing

The composition of the waste generated depends on the type of operation viz. cleaning, parallelizing drawing, combing (a process to remove short fibres), and in the final stage of twisting and forming a yarn (fibre fly) {1,2}. The amenability to cleaning of cotton fibres dictated by the initial trash content, fibre length and maturity, also decides the type and quantity of waste released in each mechanical operation. As far as fibre wastes are concerned, Card waste and comber waste are the two major fractions that contain good fibres which could be put to further use. Flat-strip waste although contains less amount of fibres longer in nature, Comber waste or noils as they are referred to, are a source of good fibres large enough in quantity capable of being put to use separately.

(b) Comber Noils

Comber noil is regarded more as a by-product of yarn manufacture during combing, an operation designed to remove short floating fibres in a sliver. It is a relatively trash-free waste generated

Table-1. Parameters of Virgin Cotton and Comber Noil Extracted from the Virgin Cotton.

Parameters	Cotton	Comber Noil
2.5% span length (mm)	28-32.5	15-21
Micronaire Value	3.8-4.2	2.5-3.5
Tenacity(g/tex)*	24-28	17-19
Short fibre Content	10	8-10
Immature Fibre Content (%)	Less than 10	18-21
Neps and Seed coat fragments	150 &10	Significantly higher than virgin cotton

*Tenacity in ICC mode

in large quantity. The operation of combing is carried out to produce combed yarns unlike carded yarns (where this operation is avoided) of high quality devoid of shorter fibres for special down- stream processing. To make the parallelized sliver further aligned, bereft of short and floating fibres, the comber removes about 15 -18% of the fibres from the sliver. This is the place in mechanical processing of cotton, wherein, bulk of waste of shorter fibres is produced. For a cotton to be used to prepare combed yarn, the virgin material has to be of certain characteristics. Table-1 enumerates the characteristics of both the virgin material as well as comber waste generated.

Since combing is done both in the forward and backward directions to achieve better cohesiveness and longitudinal alignment without floats, the penetration of combs and number of passages decide the fibre parameters and extent of noils removed {3}. A study on the distribution of the length of fibres prevalent in Comber noil led to an interesting inference that, about 2/3 of the comber waste contained fibres less than 15 mm length while 1/3 of the fraction was above that category {4}. As already noted, being trash free, and essentially consisting of short opened fibres, these are either alone or in blends with virgin cotton used to prepare rotor/OE yarns and further converted into fabrics in handloom as well as in power loom.

(c) Bleached Comber Noil

In order to make comber noil as a marketable commodity, the material has to be cleaned, got rid of the wax content and colour. Therefore, scouring and bleaching are the two processes carried out to improve its grade. While scouring is a process to remove natural impurities including wax and pectin, traditionally it is carried out by treating with low concentration of NaOH at high temperature. To comply with eco regulations, nowadays enzymatic treatment either with a single enzyme or a cocktail of enzymes is carried out to get the desired impact.

Bleaching is a process to get rid of the residual colour and to make the noil white. Again, conventionally, the bleach used to contain chlorine. However, the modern practice is to bleach using peroxide solution due to environmental considerations of effluent. More recently, a single bath enzymatic scouring and peroxide bleaching has been developed {5} to achieve the output with less water and chemical, keeping the impact of the treatment to the environment to the minimum. The chemical composition of bleached comber noil is given in Table-2.

Table-2. Chemical Composition of cCmber Noil

Parameters	Content
Cellulose (%)	98-99
Solubles (water, Ether etc.) (%)	1.0
Ash (%)	0.40
Degree of Polymerisation	1500

2. Comber Noil as a Marketable Commodity

Comber noil is sold as a compressed bale of weight 100 Kg (for internal consumption) and 170 Kg (for export) in India. The open-end yarn industry, in India, predominantly uses this as raw material for spinning rotor yarns of lower counts; while the combed yarns are consumed by the ring spinning industry for producing high value finer count yarns. As the comber noils have found their applications in other value-added products such as sanitary napkins and other personal care items and also in the manufacture of regenerated cellulose, the raw material got diverted into these sectors. As a result, the primary user viz. the OE yarn industry has found it to be increasingly difficult to source good quality noil both due to non-availability as well as a spurt in the raw material cost. This has put the OE yarn industry in quandary which was encouraged to add more and more rotors in the country due to easy access to raw material. The bleached noil, due to its increased accessibility to chemical reagents (low DP combined with no wax), purity and high cellulose content (see Table 2), is being favourably exploited by the Cellulose industry for manufacture of regenerated cellulose. Particularly, the small-scale manufacturers and the handloom industry find it hard to source noil at affordable prices since 2005. The export of noil to other countries has also added to this misery in good measure.

There are no authentic reports about how much noil is being produced worldwide nor what is the quantity transacted by different processing countries. In India annually about 0.25 million metric tonnes of comber noil is produced {6}. An indirect guestimate of comber noil production/ availability globally could be around 5 million bales worth US$ 1500 mn.

Figure-1. Bale of Cotton and Processing Wastes Generated

1. Raw cotton

2. Cotton Dropping Waste & Flat Waste.

3. Unbleached Comber Noil

4. Comber as Bales

5. Bleached Comber Noil

3. Application of Comber Noil for Diversified Value Addition

As noted already, unbleached ,cleaned comber noil is used to manufacture OE yarns which could further be value added by producing knits. Cleaned and bleached comber noil with its major constituent being pure cellulose, is used as raw material for cellulose manufacture and more recently in cotton nonwovens and bio-degradable cotton nonwoven based composites. In this section, a brief account is being provided on the application of comber noil for the manufacture of diversified products from low value –high volume (OE yarns) to high value - low volume cellulose and modified celluloses and nonwovens.

(a) Open-end Yarns

Cleaned comber noil either alone or in mix with virgin cotton of a desired proportion as desired by the final quality of the product, is used in a OE spinning process to produce rotor yarns {7}. Blends of comber noil and virgin cotton in different proportions were processed and OE yarns produced. From the quality of the yarns, it could be judged that addition of noil in the blend up to 25-35% did not significantly alter the mechanical behavior, although presence of virgin fibres in higher proportion enhanced the tenacity of the yarn which otherwise was found to be weaker.

If comber noil is alone used to produce OE yarns, then the counts were found to be medium-coarse. Since the majority of fibres were less than 15mm, this explains the coarser count, and that the yarn strength was marginally lower although the speed of production did not get affected. Knitted garments could be produced successfully by using those OE yarns.

(b) Absorbent cotton: Cotton balls

Apart from textiles and garments, one of the most sought-after value-added-product prepared after minimal processing is absorbent cotton or referred to as surgical cotton in medical parlance. Comber noil is cleaned, bleached, and carded to make it completely hydrophilic, free from other external agents including organic trash. The treated material is softened and sterilized (if need be) and carded (depending on the application) and compressed and baled (for easy transportation). Another form of the treated material is made into a ball, essentially for wiping. For the material produced from Comber noil, the average length of the staple is about 15mm. The salient features of this product are its inertness, lack of irritation and softer to skin {8}, highly absorbing and retaining fluid within its body without the skin/body feeling the damp, a characteristic of cotton. For medical applications, the product should satisfy the parameters prescribed in Indian/British Pharmocopia standards.

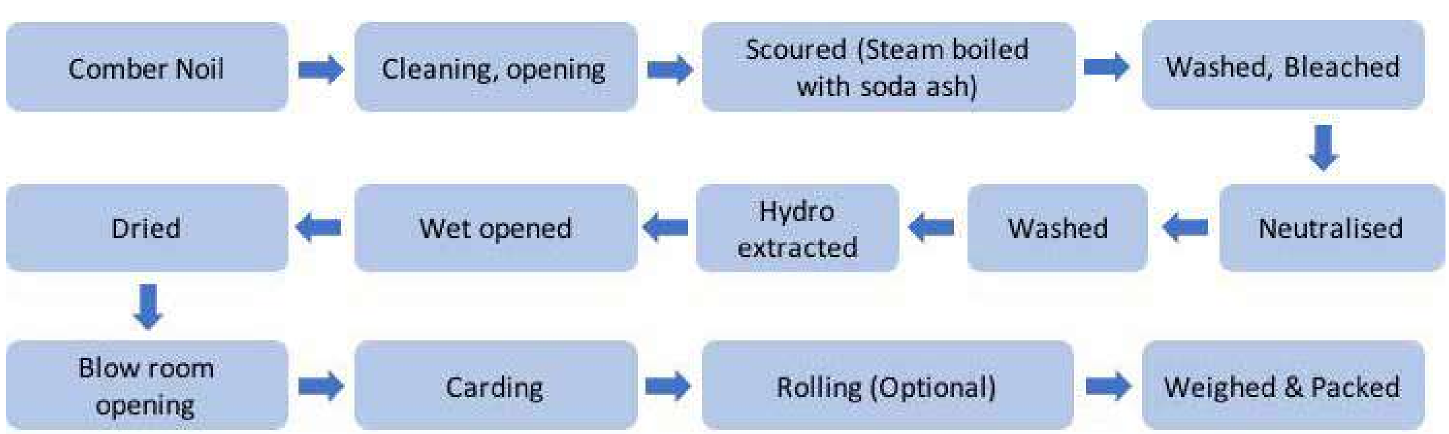
A schematic diagram (figure-2) given below illustrates the preparation of absorbent cotton from noil.

Since the production capacity could be smaller (150 mt/year), it is suitable for a small and medium enterprise establishment. Being classified as medical textiles, it is considered as a high value –low volume enterprise, with minimal processing.

(c) Cotton –based Non- woven

Cotton non-woven preparation by using comber noil has received considerable attention by researchers in the recent past {9-15}. Earlier the use of cotton in non-woven was restricted to 2%, whereas poly propylene, polyester, and other synthetic fibres used to occupy 98% of applications. The presence of foreign matter, wax, and variation in quality from batch to batch used to be referred to as hindrance in using cotton. Moreover, some of the bonding mechanisms used in the preparation of non-woven suited more to synthetic fibres. With the advent of hydro-entanglement /spun-laced/ spun-bonding technology cotton has found its application in non-woven for use in a variety of value-added-products. Non-woven, in general, possesses the advantage of high economic efficiency in production retaining the desired performance capability. Another advantage is its ability to form light weight fabrics. Cotton is preferred in special applications of skin contact as well as medical purposes due to its high absorbency, breathability, high wet strength, non-allergic, soft and its ability to hold but prevent passage of fluids. It becomes a preferred material for applications in high temperature due to its excellent resistance

Figure-2. Material Flow diagram for Absorbent Cotton



to heat, dimensional stability, and high strength at these temperatures (175^{o}c).

For preparation of hydro-entangled non-woven, comber noil is employed as raw material. A batt prepared with noil either using air laying system or needle punching, is subjected to varying water pressures to make a non-woven that could be converted to wipes, pads, gauzes and cosmetic applications. Hydro-entanglement has the added advantage that scouring could be avoided prior to bleaching as water jet is able to remove the waxy material in cotton.

(d) Pulp and paper

Comber noil after removal of organic trash and other non-cellulosic impurities could be used for pulping and converted to high value paper for use in currency, security paper etc. A dissolving grade pulp is prepared before converting the pulp to paper in conventional machines. Due to severe eco-regulations, the process of pulping and bleaching has to ensure all the norms prevalent in the region and also a fool-proof effluent management programme. Cellulose from cotton waste such as comber noil and others, were preferred to wood pulp due to their purity and fibres in pulp exhibited higher tenacity and E modulus.

(e) Regenerated Cellulose

What has been described so far concerned applications that predominantly depended on the form of the fibre, its length, short fibre content, tenacity, and maturity. Conversion of cellulose waste such as comber noil and linters to regenerated fibres relies on the quality (amount of foreign material, Degree of polymerization) and quantity of cellulose present (cellulose content) to be dissolved and regenerated.

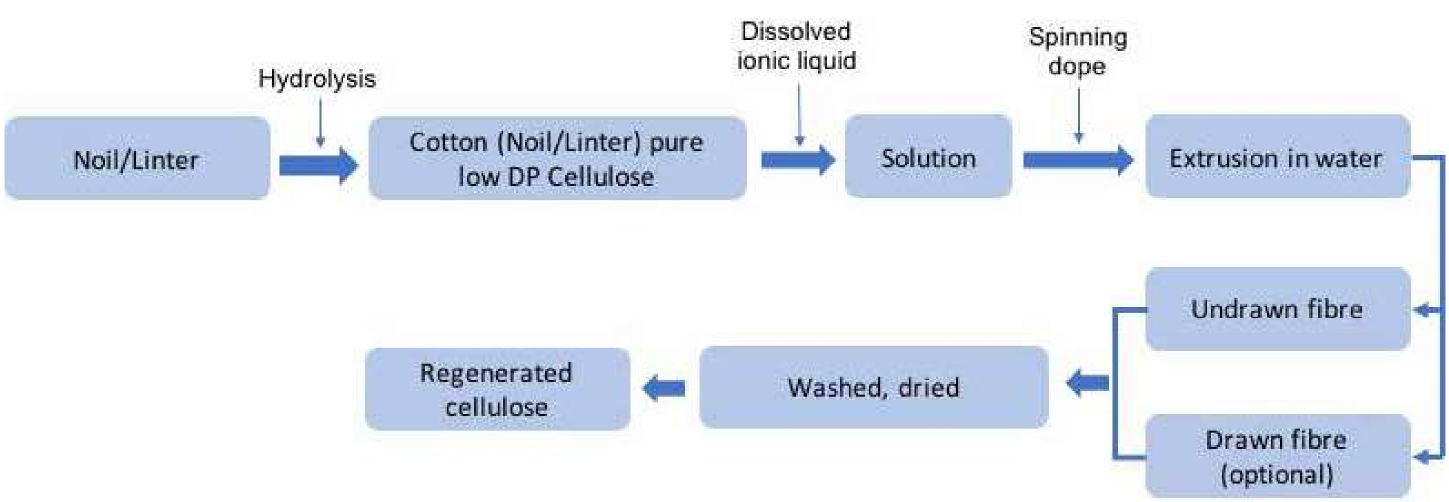
Traditionally, regenerated cellulose known as viscose rayon, is produced by dissolving cellulose in suitable solvent, carbon-di-sulphide, and extruded into filaments/staple fibres. This has environmental issues related to release of CS2, a toxic gas. Improvements in this process led to production of 'LYOCELL' fibres, which also has problems with the solvent (N. methyl morpholine oxide) and also fibrillation of cellulose. More recently use of ionic liquids to dissolve cellulose and then extrusion into fibre/filament has resulted in improved quality of regenerated cellulose fibres {16}.

Figure 3, below describes the process sequence in a schematic diagram for regenerated cellulose production by using comber noil. The choice of hydrolysis depends upon the molecular order of the starting material. The degree of polymerization of the starting material and the selection of a suitable ionic liquid are crucial factors that determine the quality of cellulose produced. These fibres produced from waste cotton lint exhibited highest thermal decomposition temperature indicating higher stability associated with high crystallinity of the material {17}. These fibres had roughly round cross sections, relatively smooth surface and rod- like longitudinal morphology. Regenerated cellulose fibres had higher tenacity and Young's modulus than conventional: 'TENCEL' fibre {18}.

(f) Micro crystalline cellulose

Microcrystalline cellulose is obtained by treating cotton with acids at desired temperature thereby hydrolyzing the chain, decreasing its degree of polymerization in a controlled manner. The final product, the purest form of cellulose produced, is used as a filler for capsules and its hardness and high binding capacity enables the active component (medical formulation) to be bound into a compact tablet. The tablet produced by using comber noil was found to disintegrate quickly in a fluid medium, enabling the release of active component at the desired source. MCC prepared from cotton (be it waste cotton, comber noils, linters, post-consumer waste) meets all the specifications of USP norms with respect to chemical identity {19} and proved to be a good additive for tablet preparation.

Figure-3. A Schematic Flow Diagram of the Material for Regenerated Cellulose Preparation by Using Comber Noil



(g) Nano Cellulose

Nano cellulose has received concerted attention by researchers due to its very specific attributes such as very large specific surface area, low weight/volume ratio. The methods of production include treatment of cotton noils/linters with acid (hydrolysis) and centrifugation to Nano-size cellulose fibres/powder {20} Alternately, fibrillation at very high speed also results in Nano fibrils after ensuring the starting material to be highly de-crystallized (treating cotton with alkali hydroxides or ethylene di amine or zinc chloride). A novel method of nano cellulose production is by producing Nano fibres by applying an electric field on a fluid jet and the process is known as electro-spinning. Cotton fibres by dissolving in suitable solvents such as trifluoro acetic acid could be converted into a fluid before subjecting to an electric field {21, 22}. The output is a mat of uniform thickness of Nano fibres which could be used in various areas such as industrial filters etc. Production of nano cellulose powder/ nano mat of fibres is a surer way of adding very high value to a material considered as low value (comber waste) by either chemical or mechanical action {23}.

(h) Bacterial Cellulose

Bacterial cellulose is a cellulose product with high purity, mechanical strength, liquid absorbing capability, biocompatibility, biodegradability with fairly high strength and crystallinity {24}. A material with high cellulose content but with low lignin content is eminently suitable for bacterial cellulose production. The dis-advantage in bacterial cellulose production is its high production cost. In order to minimize cost, efforts are being made to use novel microbial strains as well as use cotton waste as raw material {25}. The bacterial cellulose is conventionally produced by using cotton in culture media for saccharification in *Gluconacetobacter Xylinus.* The conversion rate into bacterial cellulose could be enhanced first by treating cotton waste in a suitable ionic liquid prior to introducing the culture. The water holding capacity of the product is around 99.5%, and the thickness about 2.8 mm with fairly high strength of 0.48 Newtons.

4. Entrepreneurship in Value Addition to Comber Noil

As already noted, though comber noil is extracted as a by-product during mechanical processing of cotton bale, the good amount of useful fibres that could be recovered from this so-called waste material has generated huge interest not only among researchers but also in building entrepreneurship {8 ,26, 27}. Since a lot of avenues for value addition to this cellulose fibre has been discussed in the preceding section, it is necessary to rigorously analyze the economic benefits of the process of value addition before venturing into any business activity. The non-recurring investment in land, building, & machinery, and annually recurring expenses towards water, electricity, chemicals, labour as well as in setting up a fool-proof effluent treatment mechanism has to be thoroughly examined before making a judicious choice about the plausible route for value addition.

Preparation of absorbent cotton from comber noil (referred to as cotton-wool in some circles) is considered as one of the viable value addition endeavour capable of running a successful business venture. With rising awareness about health care and increasingly available medical facilities even in every nook and corner of the country, the demand for surgical cotton is rapidly growing at the rate of 8-10% in India alone. It has been reported that a plant capacity of 100 tonnes per annum could be profitably set up with a capital investment of about US$ 75,000 and with a working capital of double the amount. The costs of land and building are not considered here as they vary from place to place. A Rate of Return (ROR) on investment of about 30-33% is also envisaged in such a plant. More improved project reports prepared recently with innovative modern processing technologies are available {28, 29} for further consultation.

Table 3. Price of Raw material and Value Added Product

Material	Price (us$/Kg)
Comber Noil	0.75-1.35
Bleached comber Noil	2-2.5
Cotton linter	1-1.5
Bleached linter	1.5-2.5
Absorbent cotton	2.25-2.75
Open End yarn	3.0-5.0 (depends on quality)
viscose	1.5-2.25
Pulp-paper Grade	1.25
Pulp-dissolving grade	1.5
Cotton linters pulp	1.5-1.75
Viscose grade pulp	1-1.2
High end paper	!.75-2.0

5. Future Outlook

Resource use-efficiency, resource conservation and waste management and containment have become the operating buzz words of any industrial activity in recent years. Textile industry is no exception to this Mantra. The comber noil generated during processing of a compressed bale has served the Open-End-Yarn industry as a veritable raw material with profitability. Many more new, exciting but unexplored business activities are waiting to be taken up and benefits reaped in coming times using this excellent cellulosic reserve. As many new ventures start springing up, the availability and price of noil would become dearer and unaffordable especially for the conventional processors as well as for small and medium enterprises. Adoption of efficient processing routes and tools and modern methods of management and a continually upgrading human resource would be the key ingredients for a successful venture using this invaluable cellulosic raw material.

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