Summary and Conclusion

5. SUMMARY AND CONCLUSION

The Indian Textile Industry is one of the oldest industry that has set its mark in global trade by holding a major share in manufacturing and exports. Starting from fibres, yarn, fabric and finished products, this industry has enormous manufacturing and entrepreneurial potential and systems, to face the stiff competition that rules today's economy. The knitwear industry in India has gained popularity over the past few decades as knitted fabrics are the most preferred fabrics by all age groups. Of the two types of knitting, weft knitting technology produces tubular knits, commonly known as circular knitted fabrics. The high productivity, low manufacturing cost, increased versatility of design techniques and consumer demand for wrinkle free, body fitting, stretchable solutions, has made weft knits very popular.

Cotton holds the name 'King of Fibres' because of its superior properties and versatile intrinsic properties that make it a fibre of all masses and occasions. The natural twist in cotton makes it ideal for spinning strong yarns to make a number of textile products. This fibre readily combines with all other natural as well as synthetic fibres to form blends and mixture fabrics. Various wet processing treatments are being done today to enhance the value of the cotton and its blends. One such synthetic fibre which is commonly used in combination with cotton is spandex popularly known as 'Lycra'. When combined with cotton, lycra brings about two significant changes namely greater degree of stretch and resistance to wrinkling, which are lacking in the cent per cent cotton fabrics. Cotton and Lycra Cotton occupy a major share in the production of the knitted fabrics.

The type of yarns chosen, knitting techniques adopted for fabric manufacture and the method of processing of the knitted fabric play an important role in determining the quality of the end product. Scouring and bleaching are important wet processing steps in pretreatment by which non cellulosic impurities of cotton are removed and the fibres are cleaned. Traditional scouring contributes significantly to the BOD, COD, TDS and alkalinity of the effluent. Hence alternatives to chemicals have been the aim of every textile processor to achieve the required results with less harmful substances thereby reducing environmental pollution. Product technologies or manufacturing processes that reduce pollution or waste, energy use or material use in comparison to the technologies that they replace are known as 'Clean Technologies'. One such tool that comes under the umbrella of clean technology is enzyme technology and its application in the textile industry opens new areas of research and manufacturing.

Enzymes are substrate specific, bio degradable and work in mild conditions of temperature and pH. Most of the enzymes used in the textile industry belong to class III, that is, Hydrolases. Some of the enzymes used for pretreatment are amylase, pectinase, lipase, glucose oxidase, peroxidase, catalase and cellulase.

Currently a large variety of knitted fabrics are wet processed in and around Tirupur, a textile hub for knitwear in South India and 90 per cent of the industries use chemicals for pretreatment and subsequent finishing. It has been estimated that a major share of effluent (75%) is from the pretreatment sector in wet processing. Hence there is a need to try alternatives that would control pollution in the pretreatment step in wet processing. With this background, the study, '**Effect of Bio and Chemical Pretreatments on Cotton and Lycra Cotton Weft Knits**', was undertaken to serve as a guide to all the industries that take up pretreatment of raw cotton and its blends and help to suggest an eco friendly alternative with lower and biodegradable effluent, to control environmental pollution.

The specific objectives of the present study are to:

- conduct an industrial survey to elicit information about commonly used manufacturing and processing techniques for weft knitted fabrics.
- produce ring spun carded and combed cotton yarns for making 100 per cent cotton and lycra cotton weft knitted fabrics
- optimize the enzyme add on used for bio pretreatment to achieve the essential properties for dyeing
- investigate the effect of bio and chemical pretreatments on the properties of cotton and lycra cotton weft knits after pretreatment, dyeing and wear study
- evaluate the effect of bio polishing on the bio and chemical pretreated cotton and lycra cotton weft knits and
- study the techno economics of bio and chemical pretreatments for cotton and lycra cotton weft knits.

EXPERIMENTAL PROCEDURE

The experimental procedure comprised of Industrial Survey, Experiment, Evaluation, Techno Economic Study and Statistical Analysis.

A. Industrial Survey

Two hundred processing industries were selected to gather information about commonly manufactured weft knitted fabrics, pretreatment processes used in wet processing, the effluent parameters and the dyes used for knitted fabrics.

B. Experiment

Shankar 6 cotton was selected to produce the 30 Ne carded and combed yarns by the ring spinning process. Based on the results of the survey, two knit structures, Single Jersey and Rib, were selected for 100 per cent cotton and lycra cotton fabrics. Two types of pretreatment methods were used namely bio pretreatment and chemical pretreatment. The chemical pretreatment method was the one commonly used by the industries. The bio pretreatment method was formulated with commercial enzymes from Novozymes, Denmark. Enzyme pectate lyase was used for scouring and hydrogen peroxide for bleaching, as it was eco friendly. Catalase enzyme was used to remove the hydrogen peroxide before the dyeing process. Acid cellulase enzyme was used for the bio polishing treatment.

Optimization of the enzymes used namely pectate lyase, catalase and acid cellulase were done using the response surface design, Box and Benkhen model, of three levels of the variables. A multiple linear regression analysis was used to determine the relationship between these variables. The response surface design served the basis for the optimization of the three enzymes used for the bio pretreatment and bio polishing processes for both cotton and lycra cotton.

The bio and chemical pretreated samples without bio polishing and the bio and chemical pretreated, bio polished samples were subjected to [hot brand] reactive dyeing. Combination shade, light blue colour with shade depth 0.222 per cent and dark blue colour with shade depth 3.033 per cent respectively were selected for the study. The dyed fabrics were subjected to a softening treatment called balloon padding followed by drying. The dried fabrics were compacted and the fabric was ready for conversion to apparel.

Round neck basic T shirts with short sleeves were constructed for the wear study. Thirty students of age group 15-25 years were selected for the wearer trials based on convenience sampling. The garment was worn from 8.30 am to 6.30 pm for a period of 300 hours covering 30 washes. After each wear the T shirts were collected from the subjects, cleaned, pressed and given for the next wear.

C. Evaluation

Evaluation of the processed material was done at different stages namely grey fabric, after pretreatment and bio polishing, dyeing and wear by visual assessment and laboratory tests.

- **Visual Assessment**

The pretreated and dyed samples were evaluated by a panel of thirty judges comprising of post graduate students specializing in Textiles and Clothing. A proforma, which included details regarding general appearance, colour, lustre and texture of the samples, was used to collect information. The data collected was consolidated.

- **Laboratory Tests**

The laboratory tests conducted included Geometrical Properties, Tests after Pretreatment and Bio polishing and Evaluation of Fabric Properties after Dyeing and Wear. The geometrical properties studied were Wales and Courses per Unit Length, Stitch Density, Loop Length, Thickness, Count, Mass per Unit Area and Geometrical Constants. The tests conducted after Pretreatment and Bio Polishing were pH of Fabric, Absorbency, Fabric Weight, Bursting Strength, Degree of Polymerization, Residual Alkali, Whiteness and Yellowness Index, Comfort Properties, Low Stress Mechanical Properties and Effluent Estimation. Skewness, Bursting Strength, Abrasion Resistance, Flexural Rigidity, Drape, Pilling, Air Permeability, Wicking, Dimensional Stability, Colour Fastness and Instrumental Colour Measurements were the tests carried out after dyeing and wear.

D. Techno Economic Study

The cost incurred for bio and chemical pretreatments in terms of cost for chemicals, enzymes and auxiliaries, water, energy, steam and time cycle were estimated for both cotton and lycra cotton weft knitted fabrics. The cost for bio polishing and dyeing were also included in the study.

E. Statistical Analysis

The statistical analysis included response surface design for enzyme optimization, Analysis of Variance (4 –way interactions) for tests after pretreatment and bio polishing, Analysis of Variance for tests after dyeing and wear, linear regression analysis for wicking tests and 't' test for effluent estimation.

FINDINGS OF THE STUDY

INDUSTRIAL SURVEY

- The first choice of fibre was Cotton by cent per cent of the industries surveyed and the second choice was Lycra Cotton fabrics (87%).
- Shankar 6 cotton variety was highly preferred by 51% of the industries surveyed; 77% used 30 Ne cotton yarn for weft knitting; 42% of the industries used combed 30 Ne cotton yarn while 32% preferred carded 30 Ne cotton yarn.
- Lycra denier commonly used was 40 denier by 47% of the industries surveyed.
- Weft knitting was popular among 89% of the industries and single jersey (45%)and 1x1 rib (27%) were the knitted structures commonly produced.
- All the industries (100%) used chemical pretreatment with four step after treatment. Enzymes were used for bio polishing by 100% of the industries surveyed as it was insisted by the buyer.
- Commonly used dyes were reactive hot brand (95 %) since colour fastness was good.
- Cent per cent of the industries were aware about the Pollution Control Board Norms and Zero Discharge.
- Of the industries surveyed, 45% produced 80,000 to 3,00,000 of effluent litres per day. Chemical Flocculation (50%)and Reverse Osmosis (40%) were the most regularly used methods for effluent treatment while the remaining 10% used combination methods.
- The recycled water was used for gardening (48%), boiler for steam generation (32%) and for processing (20%).
- A majority of the industries (65%) wanted no change in existing conditions, 20% were flexible enough to adopt new technologies like enzymes and 15% were interested in special machinery that could be profitable as well as environment friendly.
- Regarding the opinion on advantages of enzyme usage : 55% felt enzymes were eco friendly, 21% felt environmental degradation could be avoided by using enzymes and 13% felt that enzymes were human friendly.

VISUAL ASSESSMENT

From the visual assessment ratings it can be concluded that similar effects were noticed in the treated 100 per cent cotton and lycra cotton weft knits. They are as follows:

- Bio pretreated and dyed knits, irrespective of fabric structure and colour, exhibited better ratings than the chemical pretreated and dyed knits in terms of all the criteria analysed.

The maximum ratings in bio pretreated and dyed cotton 78% and lycra cotton 81% were good in general appearance.

- The combed yarns showed better results than the carded yarns in all cases.
- The samples dyed with lighter tone of blue were brighter than those dyed with the darker shade of blue.
- Bio polishing treatment improved the colour depth, evenness, texture and lustre of all the samples whether it was chemical or bio pretreated. The percentage ratings were higher in the bio pretreated samples (98-100%) than chemical pretreated samples (73-81%). The bio pretreated, bio polished and dyed cotton and lycra cotton samples were rated as good in general appearance by cent per cent of the judges.

LABORATORY TESTS

Geometrical Properties

- The wales per centimetre increased while the courses per centimetre decreased in a majority of the treated samples, when compared to their controls, after pretreatment and bio polishing irrespective of yarn type(carded/combed), fabric structure (single jersey/rib) and fibre content (100% cotton/ lycra cotton).
- Stitch density increased in all the samples when compared to their controls in both cotton and lycra cotton samples.
- A mixed trend was noticed in loop length but the readings were close to the originals in both cotton and lycra cotton fabrics.
- The mass and thickness of all the samples decreased after pretreatment and subsequent bio polishing.
- A reduction in loop shape factor was noticed in all the cotton and lycra cotton samples after pretreatment and bio polishing when compared to their controls.

Tests after Pretreatment and Bio polishing

- All the bio pretreated samples, with and without bio polishing, exhibited values closer to neutral pH when compared to the chemical pretreated samples in both cotton and lycra cotton weft knits.
- In both cotton and lycra cotton weft knits, all the bio pretreated samples, with and without bio polishing, the absorbency time in seconds were lower indicating better absorbency than the chemical pretreated and bio polished counterparts.

- All the chemical pretreated samples, with and without bio polishing, showed higher percentage of weight loss when compared to the bio pretreated samples in both cotton and lycra cotton weft knits.
- The bursting strength of all the bio pretreated samples, with and without bio polishing, exhibited higher values than the chemical pretreated and bio polished samples in both cotton and lycra cotton weft knits.
- In both cotton and lycra cotton weft knits, higher degree of polymerization values were noticed in all the bio pretreated samples, with and without bio polishing, when compared to the chemical pretreated samples, indicating lesser damage to the cotton fibre.
- The residual alkali in all the bio pretreated samples, with and without bio polishing, was comparatively less than the chemical counterparts in cotton and lycra cotton weft knits, as the quantity of alkali used in chemical pretreatment was high.
- In both cotton and lycra cotton weft knits, a majority of the chemical pretreated samples, with and without bio polishing, showed a higher whiteness index when compared to the bio pretreated and bio polished counterparts
- The yellowness index of all the bio pretreated samples, with and without bio polishing, exhibited higher values than the chemical pretreated and bio polished samples, in both cotton and lycra cotton weft knits.
- **Comfort properties**

A majority of the chemical pretreated samples showed better air permeability values when compared with the bio pretreated and bio polished samples in both cotton and lycra cotton weft knits which may be due to the variation of thickness between the samples.

Higher values in both q_{max} and thermal conductivity were obtained in all the chemical pretreated samples in both cotton and lycra cotton weft knits when compared to the bio pretreated and bio polished samples.

In both cotton and lycra cotton weft knits, a majority of the bio pretreated samples, with and without bio polishing, exhibited higher slope values, in the linear regression analysis, than the chemical pretreated and bio polished counterparts indicating better wicking ability in the bio pre treated samples.

- **Low Stress Mechanical Properties:**

Tensile: A reduction in values was noticed in Linearity of Load (LT) in all the treated 100% cotton and lycra cotton samples, when compared to their controls. A majority of the bio

pretreated samples exhibited lower values when compared to the chemical pretreated samples, with and without bio polishing. Higher values in Tensile Energy (WT), Tensile Resilience(RT) and Extensibility (EMT) were noticed in a majority of the bio pretreated samples, when compared to the chemical pretreated samples in both 100% cotton and lycra cotton samples.

Shear: A majority of the bio pretreated samples, with and without bio polishing, showed higher loss in values with regard to Shear Stiffness (G), Hysteresis of Shear Force (2HG) and (2HG5) when compared to the chemical pretreated and bio polished counterparts, in both 100% cotton and lycra cotton samples.

Bending : The Bending Rigidity (B) and the Hysteresis of Bending Movement (2HB) of 100% cotton and lycra cotton samples, showed higher reduction values among a majority of bio pretreated samples, with and without bio polishing, when compared to the chemical pretreated counterparts, indicating more flexibility.

Compression: A majority of the chemical pretreated samples, with and without bio polishing, exhibited lower values in Linearity of Compression (LC) and Compressional Energy (WC), and higher values in Compressional Resilience (RC) and Percentage Compression, when compared to the bio pretreated and bio polished counterparts, in both 100% cotton and lycra cotton samples.

Fabric Thickness and Weight: In both 100% cotton and lycra cotton samples, a lesser reduction in Fabric Thickness (To) and (Tm) and the Fabric Weight was noticed in the bio pretreated samples after pretreatment and bio polishing, when compared to the chemical pretreated counterparts.

Surface : In 100% cotton weft knits, the course direction showed greater loss of values in Coefficient of Friction (MIU) and Mean Deviation of MIU (MMD) in all the treated samples when compared to their controls. The bio pretreated samples, with and without bio polishing, showed higher loss values when compared to their respective chemical pretreated samples. In the case of lycra cotton weft knits, the same trend was noticed in both the wale and course directions. With regard to Geometrical Roughness (SMD), a higher percentage reduction was seen in a majority of the bio pretreated samples, with and without bio polishing, in both 100% cotton and lycra cotton weft knits, when compared to their respective chemical pretreated samples.

- **Effluent Estimation :** The deviation from the Pollution Control Board Norms showed a substantial reduction in effluent load after bio pretreatment in terms of pH of Effluent, Colour, TDS, TSS, COD and BOD, when compared to the effluent load after chemical pretreatment, in both 100% cotton and lycra cotton weft knits. After bio polishing, the same trend was noticed in 100% cotton and lycra cotton weft knits, indicating that enzyme treatments are eco friendly.

Tests after Dyeing and Wear

- Positive skewness in the wale direction and negative skewness in the course direction was observed in all the bio pretreated samples with and without bio polishing. The bio pretreated and dyed samples, showed differences closer to zero values when compared to the chemical counter parts. The same trend was observed in the lycra cotton dyed samples before and after wear. In the case of bio pretreated 100% cotton and lycra cotton weft knits, zero values were noticed in four and seven samples respectively, indicating good skewness values.

- The bursting strength of all the treated samples exhibited reduction in values when compared to their controls. All the bio pretreated and dyed samples as well as the bio pretreated, bio polished and dyed samples before and after wear, showed higher values than the chemical pretreated counterparts irrespective of the type of yarns, knit structures and the colours dyed. The same trend was seen in the lycra cotton weft knits.

- With regard to abrasion resistance, the lowest values were observed in all the bio pretreated and dyed samples as well as the bio pretreated, bio polished and dyed samples before wear, when compared to the chemical pretreated and bio polished counterparts. After wear, the resistance to abrasion was better in the bio pretreated dyed samples, with and without bio polishing, when compared to their respective chemical pretreated samples. The same trend was noticed in the lycra cotton dyed samples, before and after wear.

- A majority of the chemical pretreated and dyed samples, with and without bio polishing, showed reduced values in flexural rigidity when compared to their bio pretreated counterparts. After wear, all the chemical pretreated and dyed samples, with and without bio polishing, showed the same trend. In the case of lycra cotton, all the chemical pretreated and dyed samples, with and without bio polishing, showed lower flexural rigidity values when compared to the respective bio pretreated and dyed samples, before and after wear.

- Lower values of drape coefficient was noticed in the chemical pretreated, dyed samples but after bio polishing a majority of the bio pretreated, bio polished and dyed samples exhibited lower values. After wear, a majority of the bio pretreated and dyed samples, with and without bio polishing, exhibited lower values than their respective chemical pretreated and dyed samples. The latter trend was observed in all the lycra cotton dyed samples before and after wear.

- With regard to pilling, the bio pretreated bio polished and dyed samples, before and after wear, were rated as 5 (no pilling) while the samples without bio polishing exhibited lower values in the pilling scale irrespective of the type of pretreatment and finish given. The fabrics knitted with combed yarn showed better values than the carded yarns in all the samples. Similar trend was noticed in the case of lycra cotton pretreated and dyed weft knits before and after wear.

- A reduction in air permeability values were noted in all the cotton and lycra cotton treated samples. Lower reduction values were observed in bio pretreated and dyed samples, with and without bio polishing, when compared to their respective chemical counterparts. After wear, the air permeability values reduced in a majority of the cotton samples. In the case of the dyed lycra cotton weft knits, after wear, a majority of the samples showed better values than those before wear.

- In both cotton and lycra cotton weft knits, a majority of the bio pretreated dyed samples, exhibited higher slope values, in the linear regression analysis, than the chemical pretreated and bio polished counterparts indicating better wicking ability in the former samples, before and after wear.

- Negative values were observed in all the cotton and lycra cotton samples in the wale direction and positive values in the course direction, with regard to dimensional stability. Zero values were observed in bio pretreated and dyed samples, with and without bio polishing. After wear, a few chemical and bio pretreated and dyed samples showed zero values. It was also observed that the dimensional change values reduced after wear in all samples indicating better stability. The same trend was noticed in the lycra cotton dyed samples before and after wear.

- Both dyed cotton and lycra cotton samples, with and without bio polishing, before and after wear, showed similar values with regard to colour fastness to washing, light and crocking. In the case of fastness to acid perspiration the chemical pretreated and dyed

samples exhibited lower ratings when compared to their respective bio pretreated and dyed samples.

- With regard to the colour difference value **(ΔE),** all the bio pretreated and dyed samples, with and without bio polishing, before and after wear, exhibited marginal to high increase when compared to the chemical standard indicating good dye pickup in the bio pretreated samples.

The relative colour strength (WSUM) values of all the dyed cotton and lycra cotton samples, with and without bio polishing, before and after wear, exhibited higher values than the chemical standard (100).

It was observed that the K/S values of all the bio pretreated and dyed samples, with and without bio polishing, before and after wear, exhibited higher values than their respective chemical counterparts, in both the dyed cotton and lycra cotton samples.

TECHNO ECONOMIC STUDY

From the techno economic study it can be understood that the total cost, includes cost incurred for chemicals/ enzymes /auxiliaries, water, effluent treatment, electricity and steam, for bio pretreatment of 1kg of cotton and lycra cotton knitted fabric was lower by 25% when compared with the cost for chemical pretreatment of 1kg of cotton and lycra cotton knitted fabric. Savings in bio pretreatment are evident in water (23%), electricity (420%) and steam consumption when compared to the cost for chemical pretreatment. The effluent treatment was reduced in terms of quantity and quality as the effluent load was reduced by 40-50%. Process cycle time was also reduced thereby productivity could be increased. Savings in dyestuff and auxiliaries are evident in the case of bio pretreated and dyed samples.

CONCLUSION

'Green' seems to be the buzzword in the textile industry, after increased awareness and concern about the environment and pollution. In the industry sector, where cost competitiveness is global, and reduced lead times and improved service to customers are paramount, enzyme treatments not only reduces the load on the effluents by avoiding chemical usage but also improves quality apart from providing a safe working environment. Enzymes, nature's bio catalyst, can serve as best alternatives to chemicals for pretreatment of Cotton and Lycra Cotton weft knitted fabrics. Bio processing yields substantial benefits to textile wet processors in terms of improved, safer fabric pretreatment, reduction in the

number of processing steps, improved fabric appearance and performance, improved production economics, and lower effluent loads. The future years will witness evolutionary developments in the field of enzymatic textile processing.

LIMITATIONS OF THE STUDY

Lack of awareness about handling and usage of enzymes among the industry personnel could create problems in processing.

Check on enzyme activity in the industry was difficult to perform without the help of a bio technologist.

The cost of enzymes were high and should be reduced to make it available for regular usage in industries.

RECOMMENDATIONS

- Peach Finish of Tencel fabrics with enzymes
- Study on Bio Pretreated Natural Dyed Cotton Fabrics

*What we all have is one **Earth** ! What we all have is one **Earth** !*
*It is this **Earth** that is passed from one generation to another*
*With each generation, we have more of us and **less of Earth***
*Let each one of us leave behind **something** for our children to enjoy...*

- Siruthuli