CHAPTER 10

CONCLUSION

10.1 INTRODUCTION

Conclusion of the present investigations based on the qualitative analysis of the research work is presented in this chapter. The contributions of the present investigations highlighted in Section 10.2 and Section 10.3 present the major conclusions of the investigations. The scopes for further research have been projected in the Section 10.4.

10.2 CONTRIBUTION OF THE PRESENT WORK

Organic cotton fabric preparation is a crucial process among the various wet processing treatments, which in turn decides the absorbency and reactivity of the cotton fibres in dyeing and finishing processes. Though alkali scour and alkaline bleaching systems have been well established, in industrial practices, such processes lead to higher effluent loads. The enzyme assisted processes have been practiced industrially in desizing and scouring with pectinase enzyme alone. The pectinase enzyme which removes pectinase compounds in the cotton fibre, and during hydrolysis of pectin groups, other fatty, oil and wax compounds partially removed from the existing enzyme treatments. The study on enzyme technology is required to analyse the hydrolysis of non-cellulosic compound such as pectin, wax, fat and oil on the organic cotton fabric to enhance the better water absorbency, wetting for biopreparation process.
In the present research work, an attempt was made in the ecofriendly textile wet processing of biopreparation of organic cotton fabric with bacterial enzymes. The process optimization of enzymatic desizing and scouring of organic cotton fabric was carried out with bacterial enzymes namely alpha-amylase, pectinase, protease, lipase and cellulase enzymes. In the First stage, the grey organic cotton warp yarns were sized with polyvinyl alcohol (PVA) based thin boiled starch and then fabricated into plain woven organic cotton fabric using power loom. The grey organic cotton fabric was processed with alpha amylase enzymes for biodesizing process and their process conditions such as enzyme concentration, reaction time, pH and temperature were optimized using Box-Behnken optimization techniques. In the second stage, the enzymatic desized organic cotton fabric was processed with pectinase, protease, lipase and cellulase enzymes for enzymatic scouring treatments. The individual enzyme and binary enzyme combinations on the effect of non-cellulosic substance hydrolysis on the organic cotton fabric were analysed and the performance of bioscouring process was optimized and scouring performance such as wax removal %, pectin removal %, fabric whiteness index, yellowness index and brightness index were investigated at various enzymatic process conditions. The pectinolytic and proteinolytic activity on the organic cotton fabric was optimized with pectinase, and protease & lipase enzymes respectively. Then bioscouring of organic cotton fabric was optimized with mixed enzymatic systems using four enzymes namely pectinase, protease, lipase and cellulase and process conditions and their fabric characteristics such as water absorbency, wax removal, pectin removal and whiteness index, yellowness index, brightness index were analyzed using Artificial Neural Networks (ANN). Third stage, the bioscouring performance of organic cotton fabric were analysed with mixed enzymatic process conditions using Ultra sonic treatments (sonication method) and aerodynamic system (air pressure) for enhancing the enzymatic process and their performance levels have been investigated. Fourth stage, the
single stage enzymatic processing of desizing, scouring and bleaching performance were analysed with and without sonication and aerodynamic system and their performance in terms of biopreparation of organic cotton fabric through bacterial enzymes were analysed. This scientific research study will be helpful to the organic cotton processors for the eco-friendly and sustainable textile wet processing using bacterial enzymes in desizing of PVA starch based desizing operations and bioscouring of organic cotton fabric through mixed enzymatic system using pectinase, protease, lipase and cellulase enzymes.

10.3 MAJOR CONCLUSIONS

From the analysis of the bioprocessing of organic cotton with various bacterial enzymes namely alpha amylase, pectinase, protease, lipase and cellulase, the following conclusions are arrived at:

The process optimization of desizing of PVA starch sized organic cotton fabric have been studied and the process variables such as alpha amylase enzyme concentration, temperature and reaction time was optimized to achieve the required desizing efficiency in terms of weight loss % of fabric and degradation of PVA starch during desizing process on the organic cotton fabrics.

- The alpha-amylase enzymes are better active and catalyze the degradation of PVA starch at temperature range of 50-55° C and 60 min time to achieve required level of 8% size removal efficiency. The pH of the desizing bath is major influence for better reaction of enzyme to catalyze the hydrolysis of starch groups.

- The higher enzyme concentration at 4% level and higher temperature of 60°C were noticed lesser time to achieve
required desizing efficiency. Process variables are optimized using design-expert software 8.0 and it will pave the way to predict the enzyme kinetics at various concentrations, temperature and reaction time to achieve required desizing efficiency with minimum error %.

- This study will be helpful to the organic cotton processors for the eco-friendly and sustainable textile wet processing using alpha amylase enzyme in desizing of PVA starch based desizing operations.

The process optimization of bioscouring of 100% organic cotton fabric through enzyme technology has been studied with selective specific mixed enzymatic system using four enzymes namely alkaline pectinase, protease, lipase and cellulase. From the bioscouring process with bacterial enzymes, pectinase enzyme plays important role in removal of pectin groups and protease & lipase plays esterification of oil, wax and fatty substances in the organic cotton during bioscouring process. The cellulase enzyme enhances the pectinolytic reaction of pectinase enzyme to fasten the enzyme reaction. The pectinase and protease binary enzyme combination was observed higher rate of pectinolytic and proteinolytic activity on organic cotton fabric when compared with pectinase and lipase enzyme combinations. Because protease enzyme can be removal of high and medium volatile fatty substances and lipase enzyme responsible for low volatile fatty substance hydrolysis.

- The alkaline pectinase enzymes are better active and catalyze the degradation of pectin at temperature range of 55-60 deg C and time of 45min to achieve required level of 75-80% pectin degradation. The pH of the process bath is also a major influence for better reaction of enzyme to catalyze the hydrolysis of pectin groups.
- The higher enzyme concentration at 6% level and higher temperature of 60 deg C took lesser time to achieve required pectin hydrolysis.

- The wax and oil substances using protease and lipase responsible for proteinolytic activity and pectinase enzyme responsible for pectinolytic activity on the organic cotton fabric were analyzed with individual and binary mixed enzyme combination.

- Another interesting observation was noticed that while higher rate of pectin removed by pectinase which removes wax groups also, it may be due the binding groups of pectin and wax together in the cellobiose and cementing nature. It was observed that the water absorbency of fabric was noticed in the range of 2-10 sec.

- The better water absorbency was noticed at (a) 8% of pectinase and 3% of protease; (b) 8% pectinase and 0.8% of lipase; (c) 8% of pectinase and 0.8 of cellulase binary enzyme combinations. The lower the water absorbency time better scouring can be done.

- Protease enzyme plays important role in degradation or breakdown of wax and oil substances present in the organic cotton fabrics. The combination of protease and lipase enzyme was carried out to optimize the better removal of wax and oil substances at various combinations treated at 60 deg C, 60 min reaction time.

- From the test results, it was observed interesting that wax removal rate was achieved 52.8% at 6% protease and 0.8%
lipase binary mixed enzyme treatment on the organic cotton fabric.

- The highest fabric brightness in bioscouring organic cotton fabric was achieved while treating the fabric with 8%pectinase, 3%protease, 0.8%lipase and 0.8% cellulase at 60 minute time, 55 deg C, and pH 8.5. It may be due to higher whiteness of 52.413 and lower yellowness index of 13.14 and fabric treated higher pectinase and cellulase concentrations.

- It was also noticed that higher concentration of cellulase enzyme treated fabric observed higher brightness index due to surface smoothness of the organic cotton fabric.

- The lowest brightness index of organic cotton fabric was noticed when treated with absence of pectinase and cellulase, 2%protease and 0.8% lipase enzyme conditions. It was noticed that pectinase and cellulase enzymes plays important role in brightness index of the bioscouring organic cotton fabrics, and also cellulase enzyme supports the exo and endo partial surface reaction of the organic cotton fabrics.

The bioscouring performance of 100% organic cotton fabric using mixed enzymatic system was studied through ultrasonic (sonication) and aerodynamic (air pressure) treatments at various process variables using artificial neural network. From the research study the following conclusions were derived:

- The output result to achieve the desired bioscouring of organic cotton fabric on their physical properties such as fabric weight loss, water absorbency, wetting area, whiteness index, yellowness index, and brightness index in the specific enzymatic system, the software opted best process conditions
at 8% alkaline pectinase, 3% protease, 0.8% lipase and 0.8% cellulase process condition at temperature of 55 deg C and reaction time 60 minutes at pH 8.5 with 1.0% desirability.

- From the best opted test results, the actual pectin and weight loss of the bioscoured organic cotton fabric was achieved 68.40% and 4.80% respectively with error of 1.218% in case of with ultrasonic treatment, the fabric weight loss was observed 5.46% and pectin removal up to 76.46%.

- The sonicator efficiency was achieved 8-12% higher bioscouring performance on organic cotton fabric through mixed enzymatic system when compared to without sonication.

- In case of aerodynamic method, (a) the actual pectin and weight loss of the bioscoured organic cotton fabric was achieved 78.40% and 4.92% respectively with error of 1.018%, (b) the fabric weight loss was observed 6.38% and pectin removal up to 81.42%.

- The overall aerodynamic efficiency was achieved 9.72%, 24.08% and 37.20% treated at 8 kPa, 12 kPa and 16 kPa air pressure levels respectively on organic cotton fabric through mixed enzymatic system when compared to without aerodynamic.

The present research work also deals with single stage (a) enzymatic desizing and scouring process and (b) enzymatic scouring and bleaching process with various approaches for improvement of the organic cotton fabrics characteristics.

- The organic cotton fabric treated with ultrasonic and aerodynamic system in the single stage enzymatic scouring
and bleaching treatments were noticed higher degradation of pectin (above 75%) and wax components (above 80%) in the bioscouring process and also noticed better water absorbency < 1 sec and fabric whiteness (above 80%) and brightness index (above 73%). These fabric properties are comparable with chemical alkaline scouring and bleaching followed in the industrial practices.

- Sonication method which improves enzyme cavitation in the catalysis of enzymes for break down of pectin and wax/oil substances faster than normal method of treatments.

- Aerodynamic method improves catalysis of enzymes by boosting / energizing air pressure of living organisms.

This study will be helpful to the organic cotton processors for the eco-friendly and sustainable textile wet processing using specific mixed enzymatic system in bioscouring processes.

10.4 **SCOPE FOR FUTURE WORK**

This area of research work has wider scope for future research and could result in innovative products with improved functional properties which will be useful for mankind. Further the work could be extended in the following areas:

a. The present research work has concentrated on the development of biopreparation of organic cotton fabric for ecofriendly process. This research could also be extended for single stage enzymatic desizing, scouring, bleaching and natural dyeing, to study the enhancement of organic cotton quality.
b. Low water and energy conservation between sonication and aerodynamic method can be carried out to establish the synergism in the organic cotton processing.

c. Kinetics of the combined preparation can be analysed using Michaelis-Menten, Line weaver and Burk plot to understand contribution of individual enzymes in the biopreparation process.

d. Effluent level of the chemical and enzymatic process can be extended for further work in the ecofriendly processing of organic cotton process.