CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 SUMMARY

To make 100% cotton fabrics suitable for using in apparels meant for the present generation, it is expected that an optimum blend of a few of the easy-care, hygiene and protective functional properties viz., excellent crease recovery with greater strength retention, very good soil release property, reduced flexural rigidity, sufficient antimicrobial property and adequate flame retardancy should be present in the fabric. For achieving this objective, finishing chemicals which can impart multiple functional properties are chosen and applied on cotton fabric. In this study, chitosan and polycarboxylic acids viz., maleic acid, itaconic acid, tartaric acid and citric acid are selected for application on 100% cotton fabric to impart these multiple functional properties.

Effect of sole application of the above four PCAs on 100% cotton fabric has been studied. Four concentrations of each of the PCAs have been applied on cotton to study the effect of concentration of PCAs in imparting the functional properties.

Suitable combinations of PCAs have been applied on the samples to study the behavior of PCAs in combination in imparting the functional properties. Four binary combinations and one ternary combination have been chosen and applied using three concentrations in each combination and three
ratios in each concentration to study the effect of quantity of each PCA in a particular combination on influencing the functional properties.

Chitosan in three concentrations and three different curing conditions have been applied on cotton fabric to study the effect of concentration and curing conditions in imparting the functional properties.

In the final part of the study, combinations of chitosan and PCAs have been applied on cotton to achieve an optimum blend of the functional properties imparted individually by PCAs or chitosan. Different combinations using single PCAs or mixed PCAs with chitosan are applied on cotton fabric samples to study which of PCAs in single and which of the combinations of PCAs when mixed with chitosan are effective in imparting the functional properties in cotton.

7.2 CONCLUSIONS

Studies on application of single polycarboxylic acids on cotton lead to the following conclusions.

i) The polycarboxylic acids used in the study viz., itaconic acid, tartaric acid, maleic acid and citric acid form ester crosslinks between the cellulosic chain which improve the easy-care properties of the PCAs treated fabrics.

ii) Crease recovery behavior has been improved. Crease recovery angle of maleic acid and itaconic acid treated samples is better than the other two PCAs, citric acid and tartaric acid. Maximum CRA is recorded as 278° for 6% MA and 5% IA treated samples, which is more than that of the resin treated control sample.
iii) Citric acid increases CRA to a moderate level only as the crosslinking ability of CA is hindered by the hydroxyl groups present in it. Tartaric acid has two hydroxyl groups in its structure and exhibits the lowest performance among the four PCAs.

iv) Even after 20 laundry washes, CRA remains higher than that of parent sample for all PCAs treated samples. In cases of MA and IA, these values are higher than that of control sample especially at higher concentrations.

v) Tensile strength of the PCAs treated fabrics is affected by crosslinking of cellulose. At higher concentrations, MA and IA treated samples show the maximum strength loss of 31% and 33%, which is still much lower than that of the resin treated samples. In case of tearing strength testing, uniform strength loss is obtained in all PCAs treated samples.

vi) PCAs treatment reduces the stiffness. Irrespective of the PCAs used, bending length values are much lower in the range of 0.90cm-1.15cm. Therefore, an additional softener treatment is not required which is environmentally and economically advantageous.

vii) Soil release properties of the PCAs treated fabrics have been found to be excellent with a maximum soil release grade of 5 in a grade scale of 1 to 5. Unlike resin crosslinked fabric, PCAs crosslinked fabric does not require an exclusive treatment with soil release chemicals.

viii) Whiteness retention percentage of all the samples has been found to be good. More than 93% whiteness retention is obtained for all the samples.
ix) Maleic acid and itaconic acid impart the above functional properties more effectively than citric acid and tartaric acid. 4%, 5% and 6% are the effective concentrations to achieve these properties efficiently.

With respect to the studies conducted on cotton using combination of polycarboxylic acids, following conclusions are made.

i) Functionality of the PCAs increases when PCAs are combined together. It is due to the copolymerisation of the PCAs which results in better crosslinking of cellulose compared to single PCAs.

ii) Most of the combination samples show CRA values greater than the control samples due to better crosslinking.

iii) MA and IA combination treated samples at 6% concentration and 2:1 ratio recorded maximum CRA of $281^\circ$. Though CA performs only moderately when applied in single, it exhibits synergism in combination. Hence CA combination samples show better crease recovery behavior.

iv) Most of the samples show only 10% decrease in the CRA when they are subjected even up to 20 laundry washes. It clearly demonstrates that their wash durability is good.

v) Since combination of PCAs has resulted in better crosslinking, tensile and tearing strength of the combination of PCAs treated fabrics is found to decrease considerably but not to the extent of resin treated one. 18% - 35% strength loss is obtained in both tensile and tearing strength testing.
vi) Higher strength loss has occurred in samples containing either of MA or IA, which also exhibit better crease recovery behavior compared to other combinations.

vii) Though the combination of PCAs treatment reduces the stiffness of the treated samples considerably compared to that of the resin treated samples, the values in terms of bending length and flexural rigidity are slightly higher than those of single PCAs treated samples. MA & IA and MA & CA treated samples show higher stiffness compared to other binary combinations and the ternary combination.

viii) Combinations of PCAs have improved the soil release properties, with all the samples showing maximum soil release grade of 5 making the samples much easy-care.

ix) Whiteness retention percentage of all the combination samples has been found to be reduced. Combinations containing either CA or TA reduce the whiteness to about 6% - 8% from the parent sample.

x) Among all the combinations used, combination of MA and IA is the most successful one, especially at higher concentration of 5% and 6%, for imparting the above functional properties.

Following conclusions are drawn based on the outcome of the studies using chitosan of three different concentrations cured using three different curing conditions.

i) Chitosan treatment imparts antimicrobial property in cotton. 0.5% chitosan treated samples show a marginal improvement in microbial protection. 1% chitosan treated samples show maximum antimicrobial activity. Increase in concentration
from 1% to 1.5% doesn’t increase the microbial protection further, in any significant manner.

ii) Curing conditions chosen for this study have insignificant influence on antimicrobial activity among single concentration samples.

iii) Zone of inhibition ranges from 23mm – 27 mm for E.coli and 25mm - 31 mm for S. aureus bacterial strains for 1% chitosan treated samples.

iv) Chitosan finished samples show class I flammability as compared to class III flammability for untreated parent sample. Flame propagation time increases as the concentration of chitosan increases with a maximum of up to 16.31 seconds for 1.5% chitosan treated sample which is comparable to 17.89 seconds for THPC treated control fabric.

v) All the samples show enhanced soil release property with a soil release grade of 4 which is only 3 for untreated fabric. This has improved the easy-care property.

vi) In addition to the above functionalities, crease recovery properties are also marginally improved. CRA of 230° is recorded for 1% and 1.5% chitosan samples cured at 170°C.

vii) In both tensile and tearing strength testing, decrease in strength values is found to be very low. 0.5% and 1% samples show strength loss values lower than 6% and 1.5% chitosan treated samples show up to 11% strength loss values.

viii) 1% chitosan treatment cured at 170°C for 3min is the successful concentration and curing condition to achieve maximum functionalities cotton.
Studies on combination of chitosan and PCAs lead to the following conclusions.

i) Chitosan can be crosslinked with cellulose using PCAs and therefore better bonding has resulted between chitosan and cotton fabric.

ii) Because of the better bonding of chitosan and the crosslinking of cellulose by PCAs, an optimum blend of functional properties viz., good antimicrobial protection, improved crease recovery with greater strength retention, excellent soil release properties, reduced stiffness and low flammability characteristics can be achieved in cotton.

iii) Antimicrobial property exhibited by the fabric treated with all combination samples is good with zone of inhibition ranging from 21mm to 25mm for \textit{E.coli} and 24mm to 27mm for \textit{S. aureus}.

iv) Chitosan in combination with MA or IA samples have slightly higher inhibition values than the CA combination.

v) Antimicrobial activity is mainly contributed by chitosan and not influenced by the presence of PCAs in combination. PCAs increase the durability of antimicrobial activity.

vi) All the chitosan and PCAs combination samples show class I flammability which means that these samples are suitable for applications that require lower flammability.

vii) MA has increased the flame propagation time. 5% MA and chitosan sample show a flame propagation time of 16.84s, which is the highest among all the samples and is comparable to that of THPC treated control fabric.
viii) Combination of PCAs with chitosan has imparted excellent soil release characteristics in the finished fabric with a maximum soil release grade of 5. This enhances the easy-care nature of the fabric.

ix) Another vital characteristic imparted by combination of PCAs and chitosan finishing is the crease recovery behavior. CRA of the finished sample has increased up to 261° which is very much closer to the value of 265° for the resin treated control sample. PCAs crosslinking contributes to the improved crease recovery behavior mainly and the presence of chitosan does not interfere in it.

x) Strength loss values are very low compared to the control samples. 18.7% of tensile strength loss has been obtained for 5% MA and chitosan combination. In case of tearing strength, almost all samples exhibited strength loss values in the range of 13% - 15%.

xi) Combination of PCAs and chitosan treatment has reduced the stiffness of the samples. Therefore, there is no need of a softener treatment as required in case of resin finishing.

xii) Among the finishing combinations, in single PCAs combination, 1% chitosan + 5% maleic acid and in mixed PCAs combinations, 1% chitosan + 5% of maleic acid & itaconic acid (total concentration is 5%) are found the optimum combinations for achieving the multifunctional properties in an efficient manner on cotton textiles.
Summary of the study suggests that if the end use requirement demands only crease recovery properties, then it would be preferable to go for treatment with MA or IA at 5% concentration or treatment with their combination at 6% concentration and 1:1 ratio considering the reduced strength loss values obtained among the samples of this concentration.

If the requirement demands improved crease recovery and reduced stiffness, then MA or IA treatment at 5% concentration or their combination at 6% concentration and 2:1 ratio would be preferable.

If the end use requirement demands only antimicrobial properties, it would be preferable to go for a treatment with 1% chitosan cured at 170° C for 3min duration.

If the customer demands a blend of antimicrobial and crease recovery, then the choice would be a combination of 1% chitosan and 5% MA or the combination of 1% chitosan and 5% mixed PCAs of MA & IA. Combination of 1% chitosan and mixed PCAs of MA & CA would form an economical recipe for a comparable performance with MA & IA combination with chitosan. Presence of MA would be desirable as it enhances the flame resistant characteristics of the treated fabric, which is considered as an added advantage.
7.3 SUGGESTIONS FOR FUTURE WORK

Study can be extended by applying other range of chemicals like glyoxal and DMeDHEU on cotton individually and in combination with PCAs to optimize the process benefits and cost.

Fabrics of different constructions can be selected and used for crosslinking with PCAs to study the influence of these constructional parameters in imparting the functional properties.

Different types of catalyst system other than sodium hypophosphite can be tried for PCAs application. Combinations of different catalyst systems can also be tried to assess the efficiency of them in imparting functional properties.

Derivatives of chitosan which were not used in the earlier researches can be used to study their effects in imparting functional properties. Combinations of derivatives of chitosan and new PCAs can be tried to study the functional behavior of the finished cotton fabric.