CONTENTS

LIST OF ABBREVIATIONS, vii

CHAPTER

1 GENERAL INTRODUCTION, 1

- 1.1 Availability of Raw Material to Pulp and Paper Industry, 1
- 1.2 Non-wood Fibers, 2
- 1.3 Non-wood Fibers as Pulp and Papermaking Raw Material, 2
- 1.4 Challenges in the Use of Non-woods, 4
- 1.5 Kenaf for Papermaking, 4
- 1.6 Problem Statement and Rationale, 5
- 1.7 Research Objectives, 5
- 1.8 Organization of Research, 6

2 LITERATURE REVIEW, 8

- 2.1 Kenaf, 8
 - 2.1.1 History of Kenaf as a Source of Papermaking Fiber, 8
 - 2.1.2 Characteristics of Kenaf Plant, 8
 - 2.1.3 Chemical Composition of Kenaf, 10
 - 2.1.3.1 Lignin, 11
 - 2.1.3.2 Cellulose, 13
 - 2.1.3.3 Hemicelluloses, 14
 - 2.1.3.4 Extractives, 14
 - 2.1.4 Chemical Pulping of Kenaf Fibers, 15 2.1.4.1 Kraft Pulping, 15
- 2.2 Pulp Bleaching, 16
 - 2.2.1 Bleaching Processes, 17
 - 2.2.2 Use of Oxygen and Peroxide in ECF Bleaching, 18
 - 2.2.3 Hydrogen Peroxide Bleaching, 20
 - 2.2.4 Conditions of Hydrogen Peroxide Bleaching, 20
 - 2.2.4.1 Mechanisms of Peroxide Decomposition in Alkaline Solution, 21
 - 2.2.4.2 Effect of Magnesium on Stability of Alkaline Peroxide Solutions, 22
 - 2.2.5 Pressurized Peroxide Bleaching, 23
 - 2.2.5.1 Process Variables of PO Stage, 23
 - 2.2.6 Oxygen Bleaching, 25
 - 2.2.6.1 Condition of Oxygen Bleaching, 25
 - 2.2.7 Ozone Bleaching, 26
 - 2.2.7.1 Conditions of Ozone Bleaching, 26
- 2.3 Ways to Increasing the Strength and Surface Properties of Paper, 27
 - 2.3.1 Beating of Fibers, 27
 - 2.3.2 Dry-strength Additives, 28
 - 2.3.3 Sizing, 29
 - 2.3.3.1 Polyvinyl Alcohol, 31
 - 2.3.3.2 Starch, 31
 - 2.3.3.3 Chitosan, 33
 - 2.3.2.4 Mechanism of Chitosan as a Surface Additive, 34
- 2.4 Topography of Surface, 36

2.5 Printing Paper, 37

MATERIALS AND METHODS, 39

- 3.1 Chemical Characteristics, 39
 - 3.1.1 Raw Material Preparation, 39
 - 3.1.2 Organic Compositions, 40
 - 3.1.3 Inorganic Compositions, 40
- 3.2 Fiber Morphology Determination, 41
- 3.3 Kraft Pulping, 41
- 3.4 Determination of Pulp Reject, Yield and Kappa Number, 42
- 3.5 Handsheets Formation and Testing, 42
- 3.6 Pulp Bleaching Procedures, 44
 - 3.6.1 Oxygen Bleaching, 44
 - 3.6.2 Ozone Bleaching, 44
 - 3.6.3 Hydrogen Peroxide Bleaching, 45
 - 3.6.4 Oxygen Pressurized Hydrogen Peroxide Bleaching, 46
 - 3.6.5 Chelation, 46
 - 3.6.6 ECF Bleaching, 47
- 3.7 Determination of Bleached Pulp Properties, 47
 - 3.7.1 Kappa Number, 47
 - 3.7.2 Viscosity, 48
 - 3.7.3 Selectivity, 48 3.7.4 Pulp Brightness, 48
- 3.8 Beating of Pulps, 49
- 3.9 Handsheet Making and Paper Evaluation, 49
- 3.10 Determination of Basis Weight, Thickness and Bulk, 50
- 3.11 Characteristics of Polymers Used for the Experiment, 50
- 3.12 Application of Polymers, 52
- 3.13 Determination of Properties of Treated Papers, 53
 - 3.13.1 Retention of Polymer on Paper, 54
 - 3.13.2 Film Forming Characteristics, 56
- 3.14 Printability and Print Quality Tests, 56
 - 3.14.1 Surface Topography, 56
 - 3.14.2 Dynamic Absorption Test (DAT), 59
 - 3.14.3 Oil Absorption, 60
 - 3.14.4 Ink Transfer, 60
 - 3.14.5 Ink Set-off and Ink Density, 62
 - 3.14.6 Ink Penetration Depth, 62

4.1.1 Organic Compositions, 64

RESULTS AND DISCUSSIONS, 64

- 4.1 Chemical Components of Kenaf Fractions, 64
 - - 4.1.1.1 Holocellulose Content, 64
 - 4.1.1.2 Alpha-cellulose Content, 64 4.1.1.3 Hemicellulose Content, 65
 - 4.1.1.4 Pentosan Content, 66

 - 4.1.1.5 Lignin Content, 66
 - 4.1.1.6 Extractives Content, 67
 - 4.1.2 Inorganic Compositions, 67

- 4.1.2.1 Ash Content. 67
- 4.1.2.2 Trace Element, 68
- 4.2 The Morphology of Kenaf Fibers, 69
- 4.3 Laboratory-scale Pulping of Kenaf, 71
- 4.4 Handsheets Evaluations, 73
 - 4.4.1 Canadian Standard Freeness, 73
 - 4.4.2 Sheet Density, 74
 - 4.4.3 Tear Index, 75
 - 4.4.4 Burst Index, 76
 - 4.4.5 Tensile Index, 76
 - 4.4.6 Tensile Energy Absorption, 77
 - 4.4.7 Stretch, 77
- 4.4.8 Zero-span Breaking Length, 77
- 4.5 Whole Stem, 78
- 4.6 Bleaching of the Pulp with ECF and TCF Sequences, 78
- 4.7 Evaluation of Bleaching Processes, 82
 - 4.7.1 Pulp Brightness, 82
 - 4.7.2 Viscosity and Selectivity, 83
 - 4.7.3 Pulp Yield, 84
 - 4.7.4 Strength Properties of Bleached Pulp, 84
 - 4.7.5 Preliminary Screening, 85
- 4.8 Properties of TCF and ECF Bleached Kenaf Pulps after Beating, 85
- 4.9 Effect of Polymers on Paper Properties, 92
 - 4.9.1 Chitosan, 93
 - 4.9.2 Cationic Starch and PVA, 96
 - 4.9.3 Retention of Polymers on the Fibers, 97
 - 4.9.4 Effect of Chitosan Addition on Surface Properties of Paper, 101
 - 4.9.5 Effect of Cationic Starch Addition on Surface Properties of Paper, 103
 - 4.9.6 Effect of PVA Addition on Surface Properties of Paper, 105
 - 4.9.7 Effect of Chitosan as an Additive in Surface Sizing, 106
- 4.10 Surface Topography and Printability, 107
 - 4.10.1 Characterization of Surface Topography (Profilometry), 107
 - 4.10.2 Dynamic Absorption Test, 113
 - 4.10.3 Oil Absorption, 114
 - 4.10.4 Ink Transfer, 115
 - 4.10.5 Print Density and Ink Penetration, 116
 - 4.10.6 Ink Set-off, 117
 - 4.10.7 Gloss Contrast, 117

5 CONCLUSIONS AND RECOMMENDATIONS, 119

- 5.1 Morphology and Chemical Analysis, 119
- 5.2 Kraft Pulping, 119
- 5.3 Bleaching, 119
- 5.4 Enhancing the Strength and Surface Properties, 120
- 5.5 Printability and Print Quality, 120
- 5.6 Recommendations for Future Research, 121

REFERENCES, 123 APPENDICES, 136