# RHEOLOGICAL AND THERMAL PROPERTIES OF PALM KERNEL SHELL FILLED LOW DENSITY POLYETHYLENE COMPOSITES

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by

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A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

**School of Materials Engineering**
**UNIVERSITI MALAYSIA PERLIS**

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## TABLE OF CONTENTS


| | | PAGE |
|---|---|---|
| **THESIS DECLARATION** | | i |
| **ACKNOWLEDGEMENT** | | ii |
| **TABLE OF CONTENTS** | | iii |
| **LIST OF FIGURES** | | ix |
| **LIST OF TABLES** | | xv |
| **LIST OF ABBREVIATIONS, SYMBOLS OR NOMENCLATURES** | | xix |
| **ABSTRAK** | | xxii |
| **ABSTRACT** | | xxiii |
| **CHAPTER 1: INTRODUCTION** | | |
| 1.1 | Research Background | 1 |
| 1.2 | Problem Statement | 6 |
| 1.3 | Objectives of Study | 7 |
| 1.4 | Scope of Study | 8 |
| 1.5 | Outline of Thesis Structure | 9 |
| **CHAPTER 2: LITERATURE REVIEW** | | |
| 2.1 | Rheology | 11 |
| | 2.1.1 Fundamental of Rheology | 11 |
| | 2.1.2 Viscosity | 13 |
| | 2.1.3 Classification of Fluids | 15 |


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2.1.3.1 Time Independent Fluids 16

2.1.3.2 Time Dependent Fluids 21

2.1.3.3 Viscoelastic Behaviour 23

2.1.4 Importance of Rheology 24

2.1.5 Rheological Devices 29

2.1.5.1 Melt Flow Indexer 30

2.1.5.2 Capillary Rheometer 33

2.1.6 Rheological Studies of Thermoplastic/Natural Filler Composites 39

2.2 Thermal Analysis 40

2.2.1 Thermal Analysis of Composite Materials 42

2.3 Composites 44

2.4 Matrix 45

2.4.1 Polymer Composites 46

2.4.2 Thermoplastic Composites 47

2.5 Polyethylene 49

2.5.1 Polyethylene Composites 51

2.5.2 Low Density Polyethylene (LDPE) 53

2.6 Filler or Reinforcement 54

2.6.1 Natural Fillers 57

2.6.2 Natural Fillers Composites 66

2.7 Palm Kernel Shell (PKS) 67

2.8 Chemical Modification 71

2.8.1 Compatibilizer 72

2.8.1.1 Poly(ethylene-co-acrylic acid) (PEAA) 75

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2.8.2 Coupling Agent 77

2.8.2.1 Acrylic Acid 78

2.8.2.2 3-Aminopropyltriethoxysilane (3-APE) 79

2.8.2.3 Coconut Oil Coupling Agent (COCA) 82

2.8.3 Eco-degradant 84

2.9 Summary of Literature Review 84

**CHAPTER 3: METHODOLOGY**

3.1 Materials 86

3.1.1 Low Density Polyethylene 86

3.1.2 Palm Kernel Shell (PKS) 86

3.1.3 Compatibilizer 87

3.1.4 Coupling Agent 88

3.1.5 Coconut Oil Coupling Agent (COCA) 89

3.1.6 Eco-degradant 90

3.2 Chemical Modification of PKS 90

3.3 Preparation of LDPE/PKS Composites Different Filler Loading and Different Chemical treatments 91

3.4 Rheological Properties of LDPE/PKS Composites 93

3.4.1 Melt Flow Index Test 93

3.4.2 Capillary Rheometry 93

3.5 Thermogravimetric Analysis (TGA) 95

3.6 Fourier Transform Infrared (FTIR) 95

3.7 Scanning Electron Microscopy (SEM) 95

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**CHAPTER 4: RESULTS AND DISCUSSIONS**


| | | |
|---|---|---|
| 4.1 | Effect of Filler Loading on Properties of LDPE/PKS Composites | 96 |
| | 4.1.1 Melt Flow Index Test | 96 |
| | 4.1.2 Capillary Rheometer Test | 100 |
| | 4.1.3 Thermogravimetric Analysis (TGA) | 110 |
| 4.2 | Effect of Poly(ethylene-co-acrylic acid) (PEAA) on Properties of LDPE/PKS Composites | 116 |
| | 4.2.1 Melt Flow Index Test | 116 |
| | 4.2.2 Capillary Rheometer Test | 120 |
| | 4.2.3 Thermogravimetric Analysis (TGA) | 124 |
| | 4.2.4 Fourier Transform Infrared (FTIR) | 128 |
| 4.3 | Effect of Acrylic Acid (AA) on Properties of LDPE/PKS Composites | 130 |
| | 4.3.1 Melt Flow Index Test | 130 |
| | 4.3.2 Capillary Rheometer Test | 133 |
| | 4.3.3 Thermogravimetric Analysis (TGA) | 137 |
| | 4.3.4 Fourier Transform Infrared (FTIR) | 140 |
| 4.4 | Effect of 3-Aminopropyltriethoxysilane (3-APE) on Properties of LDPE/PKS Composites | 142 |
| | 4.4.1 Melt Flow Index Test | 142 |
| | 4.4.2 Capillary Rheometer Test | 145 |
| | 4.4.3 Thermogravimetric Analysis (TGA) | 149 |
| | 4.4.4 Fourier Transform Infrared (FTIR) | 153 |


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4.5 Effect of Coconut Oil Coupling Agent (COCA) on Properties of LDPE/PKS Composites 156

4.5.1 Melt Flow Index Test 156

4.5.2 Capillary Rheometer Test 159

4.5.3 Thermogravimetric Analysis (TGA) 162

4.5.4 Fourier Transform Infrared (FTIR) 165

4.6 Effect of Eco-degradant PD 04 (Eco-degradant) on Properties of LDPE/PKS Composites 167

4.6.1 Melt Flow Index Test 167

4.6.2 Capillary Rheometer Test 170

4.6.3 Thermogravimetric Analysis (TGA) 174

4.6.4 Fourier Transform Infrared (FTIR) 177

4.7 Summary of Results 179

4.7.1 Rheological Properties 179

4.7.2 Thermal Properties 183

**CHAPTER 5: CONCLUSION AND SUGGESTION**

5.1 Conclusion 185

5.2 Suggestion 187

**REFERENCES** 189

**APPENDIX A** 204

**APPENDIX B** 205

**APPENDIX C** 206

**APPENDIX D** 207

**APPENDIX E** 208

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**APPENDIX F** 209

**APPENDIX G** 210

**APPENDIX H** 211

**APPENDIX I** 212

**APPENDIX J** 213

**APPENDIX K** 214

**APPENDIX L** 215

**APPENDIX M** 216

**APPENDIX N** 217

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## LIST OF FIGURES


| FIGURE | | PAGE |
|---|---|---|
| 2.1 | Shear strain (the top plate is moved to the right by distance X) | 12 |
| 2.2 | Simple steady shear of a fluid between two infinite plates | 13 |
| 2.3 | Polymer molecule disentangling from its neighbours under the influence of shear | 15 |
| 2.4 | Types of time-independent flow behaviour | 17 |
| 2.5 | Types of flow illustrating shear rate dependence | 19 |
| 2.6 | Qualitative shear stress-shear rate behaviour for thixotropic and rheopectic materials | 23 |
| 2.7 | Typical viscosity curve of a PP-homopolymer, MFR (230 °C/2.16kg) of 8 g/10 min, at 230 °C with indication of the shear rate regions of different conversion techniques | 26 |
| 2.8 | Rheological parameters acting as a link between molecular structure and final properties of a polymer | 28 |
| 2.9 | Rheometers for filled polymer systems | 30 |
| 2.10 | Schematic of melt flow indexer | 31 |
| 2.11 | Primary correlation between viscosity of a polymer melt and recommended processing method | 32 |
| 2.12 | Schematic of capillary rheometer | 34 |
| 2.13 | Chemical structure of polyethylene | 49 |
| 2.14 | Schematic representations of the different classes of polyethylene. (a) high density polyethylene; (b) low density polyethylene; (c) linear low density polyethylene; (d) very low density polyethylene | 50 |


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| | | |
|---|---|---|
| 2.15 | Classification of PE grades | 51 |
| 2.16 | Classification of composite materials | 56 |
| 2.17 | Classification of natural fibres | 58 |
| 2.18 | Chemical structure of cellulose | 60 |
| 2.19 | Chemical structure of hemicelluloses | 61 |
| 2.20 | Chemical structure of lignin | 61 |
| 2.21 | Cross section of oil palm fruits | 68 |
| 2.22 | Schematic model of fibre modifications | 72 |
| 2.23 | The function of the compatibilizing agent in the lignocellulosic filler-polyolefin composite system | 74 |
| 2.24 | Chemical structure of poly(ethylene-co-acrylic acid) | 76 |
| 2.25 | Chemical structure of acrylic acid | 78 |
| 2.26 | Chemical structure of 3-aminopropyltriethoxysilane | 80 |
| 3.1 | The cleaned palm kernel shell | 87 |
| 3.2 | The schematic reaction of coconut oil and ethylene diamine | 89 |
| 4.1 | MFI values of LDPE/PKS composites at different filler loading | 97 |
| 4.2 | Apparent viscosity versus temperature of LDPE/PKS composites at different filler loading | 99 |
| 4.3 | Apparent shear stress versus apparent shear rate of LDPE/PKS composites with different filler loading at 180 °C | 102 |
| 4.4 | Scanning electron micrograph of PKS | 104 |
| 4.5 | Apparent viscosity versus apparent shear rate of LDPE/PKS composites with different filler loading at 180 °C | 105 |
| 4.6 | Apparent shear stress versus apparent shear rate of LDPE/PKS composites with 20 php PKS loading at different temperature | 106 |


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| | | |
|---|---|---|
| 4.7 | Apparent shear viscosity versus apparent shear rate of LDPE/PKS composites with 20 php PKS loading at different temperature | 108 |
| 4.8 | Apparent viscosity versus temperature of LDPE/PKS composites with different loading under fixed shear rate | 109 |
| 4.9 | Thermogravimetric analysis curves of PKS, LDPE, and LDPE/PKS composites at different filler loading | 111 |
| 4.10 | Derivative thermogravimetry curves of PKS, LDPE, and LDPE/PKS composites with different filler loading | 114 |
| 4.11 | Effect of filler loading on MFI values of uncompatibilized and compatibilized LDPE/PKS composites | 117 |
| 4.12 | Apparent viscosity versus temperature of uncompatibilized and compatibilized LDPE/PKS composites | 119 |
| 4.13 | Apparent shear stress versus apparent shear rate of uncompatibilized and compatibilized LDPE/PKS composites at 180 ºC | 121 |
| 4.14 | Apparent viscosity versus temperature of uncompatibilized and compatibilized LDPE/PKS composites at fixed shear rate | 123 |
| 4.15 | Thermogravimetric analysis curves of uncompatibilized and compatibilized LDPE/PKS composites | 125 |
| 4.16 | Derivative thermogravimetry curves of uncompatibilized and compatibilized LDPE/PKS composites | 127 |
| 4.17 | FTIR spectra of uncompatibilized and compatibilized LDPE/PKS composites | 129 |
| 4.18 | Schematic reaction between PKS and PEAA | 129 |


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| | | |
|---|---|---|
| 4.19 | Effect of filler loading on MFI values of untreated and treated LDPE/PKS composites with AA | 131 |
| 4.20 | The apparent viscosity versus temperature of untreated and treated LDPE/PKS composites with AA | 132 |
| 4.21 | Apparent shear stress versus apparent shear rate of untreated and treated LDPE/PKS composites with AA at 180 ºC. | 134 |
| 4.22 | Apparent viscosity versus temperature of untreated and treated LDPE/PKS composites with AA at fixed shear rate | 136 |
| 4.23 | Thermogravimetric analysis curves of untreated and treated LDPE/PKS composites with AA | 138 |
| 4.24 | Derivative thermogravimetry curves of untreated and treated LDPE/PKS composites with AA | 139 |
| 4.25 | FTIR spectra of untreated and treated LDPE/PKS composites with AA | 141 |
| 4.26 | Schematic reaction of PKS and AA | 141 |
| 4.27 | Effect of filler loading on MFI values of untreated and treated LDPE/PKS composites with 3-APE | 143 |
| 4.28 | Apparent viscosity versus temperature of untreated and treated LDPE/PKS composites with 3-APE | 144 |
| 4.29 | Apparent shear stress versus apparent shear rate of untreated and treated LDPE/PKS composites with 3-APE at 180 ºC | 146 |
| 4.30 | Apparent viscosity versus temperature of untreated and treated LDPE/PKS composites with 3-APE at fixed shear rate | 148 |
| 4.31 | Thermogravimetric analysis curves of untreated and treated LDPE/PKS composites with 3-APE | 150 |


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| | | |
|---|---|---|
| 4.32 | Derivative thermogravimetry curves of untreated and treated LDPE/PKS composites with 3-APE | 152 |
| 4.33 | FTIR spectra of untreated and treated PKS with 3-APE | 154 |
| 4.34 | Schematic reaction of PKS and 3-APE | 155 |
| 4.35 | Effect of filler loading on MFI values of LDPE/PKS composites with and without COCA | 157 |
| 4.36 | Apparent viscosity versus temperature of LDPE/PKS composites with and without COCA | 158 |
| 4.37 | Apparent shear stress versus apparent shear rate of LDPE/PKS composites with and without COCA at 180 °C | 160 |
| 4.38 | Apparent viscosity versus temperature of LDPE/PKS composites with and without COCA at fixed shear rate | 161 |
| 4.39 | Thermogravimetric analysis of LDPE/PKS composites with and without COCA | 163 |
| 4.40 | Derivative thermogravimetry curves of LDPE/PKS composites with and without COCA | 164 |
| 4.41 | FTIR spectra of LDPE/PKS composite with and without COCA | 166 |
| 4.42 | Schematic reaction between PKS and COCA | 166 |
| 4.43 | Effect of filler loading on MFI values of LDPE/PKS composites with and without eco-degradant | 168 |
| 4.44 | Apparent viscosity versus temperature of LDPE/PKS composites with and without eco-degradant | 169 |
| 4.45 | Apparent shear stress versus apparent shear rate of LDPE/PKS composites with and without eco-degradant at 180 °C | 171 |


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| | | |
|---|---|---|
| 4.46 | Apparent viscosity versus temperature of LDPE/PKS composites with and without eco-degradant at fixed shear rate | 173 |
| 4.47 | Thermogravimetric analysis curves of LDPE/PKS composites with and without eco-degradant | 175 |
| 4.48 | Derivative thermogravimetry curves of LDPE/PKS composites with and without eco-degradant | 176 |
| 4.49 | FTIR spectrum of LDPE/PKS composites with and without eco-degradant | 178 |
| 4.50 | Schematic reaction between PKS and eco-degradant | 178 |


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## LIST OF TABLES


| TABLE | | PAGE |
|---|---|---|
| 2.1 | Approximate ranges of melt indices used in commercial conversion process | 25 |
| 2.2 | Chemical composition, moisture content and microfibrillar angle of plant fibres | 59 |
| 2.3 | Comparative properties of natural fibres with conventional reinforcing fibres | 63 |
| 2.4 | Advantages and disadvantages of natural filler | 65 |
| 2.5 | The amount of biomass available from palm oil industry as of 2010 | 68 |
| 2.6 | The composition of PKS | 69 |
| 2.7 | Fatty acids composition of virgin coconut oil | 83 |
| 3.1 | Properties of low density polyethylene Titanlene LDF265YZ | 86 |
| 3.2 | Properties of poly(ethylene-co-acrylic acid). | 88 |
| 3.3 | Properties of acrylic acid | 88 |
| 3.4 | Properties of 3-aminopropyltriethoxysilane | 89 |
| 3.5 | Properties of eco-degradant PD 04 | 90 |
| 3.6 | Formulation of LDPE/PKS composites at different filler loading | 92 |
| 3.7 | Formulation of uncompatibilized and compatibilized LDPE/PKS composites | 92 |
| 3.8 | Formulation of untreated and treated LDPE/PKS composites with AA and 3-APE | 92 |


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| | | |
|---|---|---|
| 3.9 | Formulation of LDPE/PKS composites with and without COCA and eco-degradant | 93 |
| 4.1 | Values of *A*, *E* and $R_0$ of LDPE/PKS composites at different filler loading | 99 |
| 4.2 | Values of *K* and *n* of LDPE/PKS composites at different filler loading | 102 |
| 4.3 | Values of *A*, *E* and $R_0$ of LDPE/PKS composites with different filler loading at fixed shear rate | 110 |
| 4.4 | Percentage of weight loss of PKS, LDPE, and LDPE/PKS composites at different filler loading | 112 |
| 4.5 | DTG data of PKS, LDPE, and LDPE/PKS composites at different filler loading | 116 |
| 4.6 | Values of *A*, *E* and $R_0$ of uncompatibilized and compatibilized LDPE/PKS composites | 119 |
| 4.7 | Values of *K* and *n* of uncompatibilized and compatibilized LDPE/PKS composites | 121 |
| 4.8 | Values of *A*, *E* and $R_0$ of uncompatibilized and compatibilized LDPE/PKS composites at fixed shear rate | 123 |
| 4.9 | Percentage of weight loss of uncompatibilized and compatibilized LDPE/PKS composites | 126 |
| 4.10 | DTG data of uncompatibilized and compatibilized LDPE/PKS composites | 128 |
| 4.11 | Values of *A*, *E* and $R_0$ of untreated and treated LDPE/PKS composites with AA | 132 |


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| | | |
|---|---|---|
| 4.12 | Values of *K* and *n* of untreated and treated LDPE/PKS composites with AA | 134 |
| 4.13 | Values of *A*, *E* and $R_0$ of untreated and treated LDPE/PKS composites with AA at fixed shear rate | 136 |
| 4.14 | Percentage of weight loss of untreated and treated LDPE/PKS composites with AA | 138 |
| 4.15 | DTG data of untreated and treated LDPE/PKS composites with AA | 140 |
| 4.16 | Values of *A*, *E* and $R_0$ of untreated and treated LDPE/PKS composites with 3-APE | 145 |
| 4.17 | Values of *K* and *n* of untreated and treated LDPE/PKS composites with 3-APE | 146 |
| 4.18 | Values of *A*, *E* and $R_0$ of untreated and treated LDPE/PKS composites with 3-APE at fixed shear rate | 148 |
| 4.19 | Percentage of weight loss of untreated and treated LDPE/PKS composites with 3-APE | 150 |
| 4.20 | DTG data of untreated and treated LDPE/PKS composites with 3-APE | 152 |
| 4.21 | Values of *A*, *E* and $R_0$ of LDPE/PKS composites with and without COCA | 158 |
| 4.22 | Values of *K* and *n* of LDPE/PKS composites with and without COCA | 160 |
| 4.23 | Values of *A*, *E* and $R_0$ of LDPE/PKS composites with and without COCA at fixed shear rate | 162 |


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| | | |
|---|---|---|
| 4.24 | Percentage of weight loss of LDPE/PKS composites with and without COCA | 163 |
| 4.25 | DTG data of LDPE/PKS composites with and without COCA | 165 |
| 4.26 | Values of *A*, *E* and $R_0$ of LDPE/PKS composites with and without eco-degradant | 169 |
| 4.27 | Values of *K* and *n* of LDPE/PKS composites with and without eco-degradant | 171 |
| 4.28 | Values of *A*, *E* and $R_0$ of LDPE/PKS composites with and without eco-degradant at fixed shear rate | 173 |
| 4.29 | Percentage of weight loss of LDPE/PKS composites with and without eco-degradant | 175 |
| 4.30 | DTG data of LDPE/PKS composites with and without eco-degradant | 177 |
| 4.31 | Summary of rheological behaviour of LDPE/PKS composites with different chemical modifications | 180 |
| 4.32 | Summary of activation energy of LDPE/PKS composites with different chemical modifications | 182 |
| 4.33 | Summary of thermal properties of LDPE/PKS composites with different chemical modifications | 184 |


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## LIST OF ABBREVIATIONS, SYMBOLS OR NOMENCLATURES

| | |
|---|---|
| 3-APE | 3-aminopropyltriethoxysilane |
| AA | Acrylic acid |
| ABS | Acrylonitrile–butadiene–styrene |
| ASTM | American Society for Testing and Materials |
| ATR | Attenuated total reflectance |
| CMCs | Ceramic matrix composites |
| COCA | Coconut oil coupling agent |
| DP | Degree of polymerization |
| DTG | Derivative thermogravimetry |
| FTIR | Fourier transform infrared |
| GPa | Giga Pascal |
| HDPE | High density polyethylene |
| HDPE-g-MAH | Maleic anhydride grafted HDPE |
| HEMA | 2-hydroxyl ethyl methacrylate |
| L/D | Length to diameter |
| LaCOLX | Glucuronoxylan laurate |
| LDPE | Low density polyethylene |
| LLDPE | Linear low density polyethylene |
| LMDPE | Low medium density polyethylene |
| LX | Glucuronoxylan |
| MAPE | Maleic anhydride grafted polyethylene |
| MAPP | Maleic anhydride grafted polypropylene |
| MFA | Multifunctional additive |

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| | |
|---|---|
| MFI | Melt flow index |
| MFR | Melt flow rate |
| MI | Melt index |
| MMCs | Metal matrix composites |
| MPa | Mega Pascal |
| N-H | Amide II |
| NMR | Nuclear magnetic resonance |
| PA6 | Polyamide 6 |
| PBS | Polybutylene succinate |
| PC | Polycarbonate |
| PCL | Polycaprolactone |
| PEAA | Poly(ethylene-co-acrylic acid) |
| PLLA | Poly(L-lactide) |
| PMCs | Polymer matrix composites |
| PVC | Polyvinyl chloride |
| php | Part per hundred of polymer |
| PP | Polypropylene |
| PKS | Palm kernel shell |
| PS | Polystyrene |
| SANMA | Styrene–acrylonitrile–maleic anhydride copolymer |
| TGA | Thermogravimetric analysis |
| ULDPE | Ultra low density polyethylene |
| VLDPE | Very low density polyethylene |
| *A* | Coefficient related to melt viscosity |
| $CO_2$ | Carbon dioxide |

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| | |
|---|---|
| °C | Degree Celsius |
| $E$ | Activation energy |
| $F$ | Force |
| $H_2O$ | Water |
| $K$ | Melt consistency index |
| kJ/mol | Kilo joule per mole |
| $n$ | Power law index |
| η | Viscosity |
| -OH | Hydroxyl group |
| τ | Shear stress |
| $\dot{\gamma}$ | Shear rate |
| $Q$ | Volumetric flow rate |
| $R_0$ | Linear correlation coefficient |
| $T_{end\ deg}$ | End degradation temperature |
| $T_{onset}$ | Onset temperature |
| v/v | Volume/volume |
| $V$ | Velocity |
| wt% | Weight percent |

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**Sifat-sifat Reologi dan Terma Komposit Tempurung Kelapa Sawit Terisi Polietilena Berketumpatan Rendah**

## ABSTRAK

Komposit tempurung kelapa sawit (TKS) terisi polietilena berketumpatan rendah (PEBR) telah disediakan dengan menggunakan pencampur bilah-Z pada suhu 180 °C dan kelajuan rotor 50 rpm. Kesan pembebanan TKS dan pelbagai jenis modifikasi kimia terhadap sifat reologi dan terma komposit telah dikaji. Modifikasi kimia seperti polietilena ko-akrili asid (PKAA), asid akrilik (AA), 3-aminopropiltrietoksisilana (3-APE), agen pengkupel minyak kelapa (APMK) dan eko-rosotan telah digunakan dalam kajian ini. Penambahan TKS ke dalam PEBR mengubah sifat-sifat reologi dan terma komposit. Keputusan menunjukkan bahawa peningkatan pembebanan TKS telah mengurangkan nilai-nilai indeks aliran lebur (IAL) dan indeks bukan Newtonian komposit, tetapi konsisten leburan, kelikatan dan tenaga pengaktifan komposit PEBR/TKS meningkat. Peningkatan suhu telah meningkatkan nilai nilai IAL komposit. Kelikatan komposit yang dijanakan dari reometer kapilari telah berkurang dengan peningkatan suhu. Tegasan ricih ketara komposit meningkat dengan kadar ricih ketara dan pembebanan TKS. Komposit yang ditambah dengan PKAA, AA, APMK dan eko-rosotan menunjukkan nilai-nilai IAL yang lebih tinggi tetapi komposit yang dirawat dengan 3-APE menunjukkan nilai-nilai IAL yang lebih rendah berbanding dengan komposit tanpa rawatan. Tenaga penagktifan untuk komposit dengan PKAA dan 3-APE lebih rendah, di mana tenaga pengaktifan untuk komposit dengan AA, APMK dan eko-rosotan lebih tinggi berbanding dengan komposit yang tanpa modifikasi kimia. Komposit dengan eko-rosotan memberi kelikatan yang paling rendah, dengan itu, ia menyenangkan pemprosesan komposit yang mempunyai pembebanan pengisi yang tinggi. Sifat-sifat terma komposit menunjukkan bahawa penambahan PKS telah mengurangkan suhu awal degradasi dan kehilangan berat secara keseluruhan komposit. Modifikasi-modifikasi kimia telah meningkatkan kestabilan terma komposit, di mana suhu awal degradasi yang lebih tinggi dan kehilangan berat secara keseluruhan yang lebih rendah pada suhu tinggi telah diperhatikan. Spektra FTIR menunjukkan bahawa kumpulan berfungsi untuk komposit telah berubah dengan modifikasi kimia.

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**Rheological and Thermal Properties of Palm Kernel Shell Filled Low Density Polyethylene Composites**

## ABSTRACT

The palm kernel shell (PKS) filled low density polyethylene (LDPE) composites were prepared by Z-blade mixer at temperature of 180 °C and rotor speed of 50 rpm. The effects of PKS loading and different types of chemical modifications on the rheological and thermal properties of the composites were studied. Chemical modification such as poly(ethylene-co-acrylic acid) (PEAA), acrylic acid (AA), 3-aminopropyltriethoxysilane (3-APE), coconut oil coupling agent (COCA) and eco-degradant were used in this study. The addition of PKS into LDPE matrix changed the rheological and thermal properties of the composites. The results showed that increasing PKS loading had decreased the melt flow index (MFI) values and non-Newtonian index but increased the melt consistency, viscosity and activation energy of the LDPE/PKS composites. The increasing temperature had increased the MFI values of composites. The viscosity of composites that was generated from capillary rheometer decreased with rise of temperature. The apparent shear stress of the composites increased with apparent shear rate and PKS loading. The composites with addition of PEAA, AA, COCA and eco-degradant showed higher MFI values but the composites treated with 3-APE exhibited lower MFI values than untreated composites. The activation energy for the composites with PEAA and 3-APE decreased, whereas the activation energy for the composites with AA, COCA and eco-degradant increased as compared to composites without chemical modifications. The composites with eco-degradant gave lowest viscosity, thus eased the composite processing at high filler loading. The thermal properties of composites showed that addition of PKS had decreased the onset temperature and the total weight loss of composites. The chemical modifications had increased the thermal stability of composites, whereas higher onset temperature and lower total weight loss at high temperature were observed. The FTIR spectra of composites showed that the functional groups of the composites changed with chemical modification.

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