CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In the present effort to characterize the physical, morphological, thermal, mechanical and biodegradability of the synthesized PVA/starch and PVA/starch/fibers biocomposites, results from different experimental techniques were analyzed and several properties were noted to enhance the characteristic of the biocomposites.

The PVA/starch composites are the polymer PVA blended with different kinds of tropical starches such as tapioca, rice or sago starch whilst PVA/starch/fiber composites are composites which consist of the polymer matrix, PVA, blended with different kinds of starches such as tapioca, rice and sago and mixed with different kinds of treated tropical fibers. The tropical fibers used in this study are bamboo, kenaf, roselle and napier grass fibers that has been bleached and mercerized to enhance their capability to improve the adhesion between the fibers and the PVA/starch matrix. From the results obtained from the different experimental techniques used to analyze the biocomposites, it can be deduced that compositions of the different components that make up the biocomposites and the processing conditions were the main factors that influenced their chemical structure, thermal stability, mechanical properties and biodegradability.

The analysis on the structure and morphological properties revealed, as a whole, that the different components that make up the biocomposites were compatible with each other as shown in the SEM images the PVA/starch composites where smooth external surfaces were observed. The SEM images of the composites of PVA/starch/fibers also revealed that the treated fibers that were incorporated into the PVA/starch matrix were well dispersed and well-coated by the matrix. The compatibility between the fibers, starches and PVA were also supported by the SEM images of the fractured biocomposites specimens where fibers pull-out revealed traces of polymer matrix adhering to the fibers and this indicates better wetting and closer contact between fibers and matrix. The FTIR and XRD analysis revealed that the crystallinity of the PVA/starch and PVA/starch/fibers biocomposites decreases with increasing concentrations of starches or fibers. These findings are also supported by the decreased crystallite width of the biocomposites. The decreased crystallinity of the biocomposites may be caused by the destruction of the different component's crystallinity when they were blended together to form the biocomposites.

The study of the thermal properties showed that from the TGA analysis, the PVA/starch/fibers biocomposites formed were more thermally stable than the PVA/starch biocomposites. This can be observed from the amount of the charred residues where the content of PVA/starch/fibers composites residues was higher than the amount of PVA/starch composites residues. The greater thermal stability of the PVA/starch/fibers composites may be contributed by the presence of the treated cellulosic fibers. It can also be observed from the thermograms that with increasing content of fibers, the composites showed increasing thermal stability. From the DMTA and DSC analysis, PVA/starch and PVA/starch/fibers composites showed increasing glass transition temperature, T_g and decreasing melting temperature, T_m for composites with increasing concentrations of starches or fibers. The increasing glass transition temperature, T_g and decreasing melting temperature, T_m suggests that the composites showed increasing thermal stability as the content of starches or fibers increases and the ordered association of PVA decreases with the presence of starches or fibers in the matrix. The increasing value of the storage modulus, E' as the concentration of starches and fibers increases indicates that strong interfacial interaction exists between the different components of the PVA/starch and PVA/starch/fibers blends. Indication of strong interactions between the different components in the blends is also supported by the decrease in the magnitude of loss factor, tan δ as the concentration of starches or fibers in the composite increases. It can also be concluded that between all of the different compositions of composites that were analyzed, PVA/sago/different fibers composites showed slightly higher storage modulus values than PVA/rice/different fibers and PVA/tapioca/different fibers composites in the glass transition temperature region and this confirms that PVA/sago/different fiber composite are slightly superior in strength.

From the analysis of the mechanical properties of the biocomposites, the tensile tests showed that for the PVA/starch blends, the addition of different starches in the biocomposites did not improve the composites mechanical strength and this may be contributed by poor compatibility between the PVA matrix and the starches. With increasing concentration of starches, the composites showed decreasing tensile strength and elongation at break values. As the concentration of starches in the blends increases, the blends also become more rigid and this may be conform by the increasing value of the Young modulus. The tensile strength of the PVA/starch/fibers composites obtained were lower than tensile strength values of PVA/starch composites and this may be due to the incorporation of treated fibers of non-uniform sizes and shapes that leads to phase separation. The increasing Young modulus and decreasing elongation at break values were attributed to the rigid nature of the treated fibers that reduces the ductile behaviour of the PVA/starch matrix phase. From all of the composites analyzed, the

PVA/sago/different fibers and PVA/different starches/kenaf fiber composites showed slightly higher tensile strength values than other composites. The high strength values of the two sets of composites may be due to the high amylose content of sago starch and high cellulose content of kenaf fibers.

The soil burial test methods revealed that the PVA/starch composites are more susceptible to microorganisms attack than the PVA/starch/fiber composites. This can be observed from the SEM images of the degraded specimens after 2 weeks of burial in compost soil. Addition of fiber into the biocomposites slightly decreases the degradation rate and this indicates that the fibers were either resistant to microbial attack or it restricts the availability of hydrolytic enzymes to the PVA/starch matrix. From visual observation done on the composites it can also be seen that the growth rate of microorganisms on the surface of the blends was found to be increasing with increasing concentration of starch in the PVA/starch biocomposites.

5.2 Recommendations

For further research, it can be recommended that for the blends of PVA with different starches, the starches incorporated into the blend can be modified chemically to further enhance its interfacial adhesion with the polymer matrix. This method might improve the overall strength of the composites caused by the strong interfacial adhesion between the modified starch and polymer matrix. It can also be suggested that effects from varying the concentration of starches and fibers in the composite be investigated. More composites with different proportions of starches and fibers incorporated into the PVA matrix may produce superior composites when compared with the composites analyzed in this study. Other characterization techniques such as Atomic Force Microscopy

(AFM) can also be carried out to support the results from the FTIR and XRD analysis to further study the surface morphology of the prepared biocomposites.