# Chapter 5: Conclusions and suggestions for future work

**Conclusions:**

In the present work polyvinyl alcohol – banana pseudostem fibre (PVA-BPF) composite films of different types were prepared using BPF of different sizes in native as well as acid and alkali treated forms in combination with cross-linkers and plasticizers of different types and at varying concentrations. Effects of nanofillers like nanocellulose, nanoclay and citric acid modified nanoclay on various properties of the prepared composite films were also evaluated.

The banana pseudo-stem fibres of size <50 μm at 20 wt. % were found to be the most suitable size and composition for preparing the PVA-BPF composite films. Further improvement in mechanical and water barrier properties were achieved by using sorbitol (10 wt %) as the plasticizer and, glutaraldehyde (1 wt %) as the cross-linker. Use of citric acid as the second cross-linker required a higher loading (10 wt %). Formation of multiple hydrogen bonds between hydroxyl groups of PVA chains and BPF enabled the formation of cross linked network with the cross linkers used and tensile strength, elongation at break point, water vapour permeability and contact angle values were improved by 20.8%, 41.7%, 71.6% and 5.6°, respectively. While plain PVA films were soluble in water the PVA-BPF films were insoluble but swelled to an extent of 67.4% in water after 24 hours.

The PVA-BPF composite packaging films showed promising results with respect to tensile strength, elongation at break-point, water vapor permeability and water swelling weight percent. The films were found to be fairly strong, elastic and resistant to water.

The pretreatment of BPF with acid was not beneficial at all while alkali treatment improved the mechanical and water resistance properties to a certain extent.

The nanofillers like, nano-cellulose, nano-clay, and citric acid modified nano-clay proved to be quite effective in improving the mechanical and water absorption properties of PVA-BPF composite packaging films reinforced with the said nano-fillers. Incorporation of 3 wt% nano-cellulose improved the mechanical and water barrier properties of composite films. The tensile strength, percent elongation at break point, WVP, contact angle and swelling weight improved by 14.3%, 30.5%, 29.7%, 8.8° and 75%, respectively. The improvement in these properties was due to the formation of three dimensional networks through extensive hydrogen bonding formed by nano-cellulose with PVA and BPF, all of which are rich in hydroxyl groups.

Similarly nanoclay incorporation improved the tensile strength, % elongation at break point, WVP, contact angle, and swelling weight improved by 11.5%, 26.1%, 26.7%, 4.4° and 74%, respectively at 3 wt% loading and citric acid modified nanoclay reinforcement also provided best results at 3 wt % and corresponding improvements in the properties of films were 16.4%, 27.0%, 28.6%, 7.7° and 76% for the tensile strength, % elongation at break-point, WVP , contact angle and swelling weight, respectively compared to the PVA-BPF composite films.

Citric acid modified nanoclay was able to provide better results due to widening of gallery spacing as a result of citric acid treatment. This permitted the incorporation of PVA-BPF matrix between the nanoclay platelets resulting in better exfoliation and consequently improvement in mechanical and water barrier properties.

Agglomerate formation with increasing percentage of nanocellulose as well as nanoclay, the only limitations of nano-materials, can be overcome by the combination of vigorous mixing along with ultrasonic dispersion.

**Suggestions for Future Work**

The commercial viability of the composites films developed using banana pseudo-trunk fiber requires their preparation on large scale. Thus efforts should be made to prepare these composite films through blow or compression moulding techniques. Effects of other cross-linkers and plasticizers and their appropriate combinations on the mechanical and water absorption properties also require further work. The suitability of films as packaging material with anti-microbial property requires more work. Effort should also be made to select other biological materials as additives to improve film characteristics. Incorporation of oxygen scavenging molecules in the film should be tried to prevent chemical oxidation and bacterial deterioration by aerobic organisms.

Use of chemically modified nano-fillers and their homogenization in the film casting solution also need to be studied to increase the loading and reduce agglomeration. Effects of soil characteristics (moisture content, pH, chemical composition, etc.), and aerobic and anaerobic conditions on the film biodegradability will be helpful in deciding the conditions of their use and disposal.

Other homogenisation processes should also be studied to avoid agglomeration of nanocellulose molecules thereby allowing a higher amount of nanofillers to be added which could further improve the barrier and mechanical properties of resulting composites which could be effectively used for packaging applications while being biodegradable and cost effective at the same time.