CHAPTER IX
CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

Regarding to the active films, the bentonite was successfully modified by γ-MPS prior to mixing with PP, confirmed by FTIR spectra. XRD patterns indicated the organosilane partly intercalated to the interlamellar space of clay. After preparation of PP nanocomposites with 5 wt.% of modified clay, in the case of PP-clay nanocomposites, the FE-SEM/EDS mapping revealed that the performance of plasma provided the good distribution and dispersion of clay in the PP matrix rather than the chemical initiator. Meanwhile, the XRD pattern showed the partially intercalated PP chain into the interlamellar space of bentonite. Simultaneously, it was clearly seen that the decomposition temperature of the plasma treated nanocomposite increased most. The solvent extraction by boiling xylene was revealed that the residue of PPC-PLASMA rendered the highest of weight percentage of residue, shift of T_g to higher temperature, thermal stability, and char residue at 900 °C, which indicated the strong interaction between polymer chains and silicate layers. Silver nanoparticles was synthesized into the interlayer of nanoclay through a green approach by varying the weight percentages of silver nanoparticles (5, 10, 15, and 20 wt%). TEM images revealed the size of nanoparticles around 15 – 50 nm. XRD patterns showed the intercalation of silver nanoparticles in the intergalleries of bentonite. Silver nanoparticle-loaded bentonites (SBEN) were then modified with γ-methacryloxypropyltrimethoxysilane (γ-MPS), so called modified silver nanoparticle-loaded bentonites (MSBEN) prior to mixing with polypropylene. To begin with the preparation of PP nanocomposite masterbatch, the masterbatch was firstly fabricated via the reactive extrusion process by using a plasma generator. Afterward, the masterbatch was further mixed with PP to access PP nanocomposites with 1 wt% of clay. Finally, the nanocomposites were blown to a clear film for packaging application. PP-clay nanocomposites with 1 wt% nanoclay exhibited its intercalated and exfoliated structures observed by XRD. For mechanical properties according to ASTM D882, the nanocomposite films showed the improved Young's modulus indicating the higher stiffness of active films but the tensile strength and % elongation at break decreased compared to neat PP resulting from certain degrees of inhomogeneous aggregates and some voids around dispersed phase. For DSC analysis, it was found that crystallization temperature (T_c), melting temperature (T_m), and % crystallinity (χ_c) increased because of nucleating effect from modified bentonite. At 2 wt% loss from TGA analysis, it was evidently noticed that 20 wt% of silver nanoparticle exhibited the highest thermal stability than that of neat PP, by approximately 20 °C. The water vapor permeability rate (WVPR) and oxygen transmission rate (OTR) of nanocomposite films were investigated in accordance to ASTM E398 and ASTM D3985, respectively. This work agrees with the use of given clay (MBEN, MS5BEN, MS10BEN, MS15BEN, MS20BEN) increased the mobility distance of the gas molecules, bringing about the water and oxygen permeability being reduced by 77 % and 33 % in the case of the PPBEN film compared to neat PP films. Furthermore, in the presence of silver nanoparticles, both water and oxygen permeability rate decreased by approximately 70% and roughly 20% in all the PPSBEN films in comparison to neat PP films. From the antifungal activity test based on ASTM G 21, all of the S5BEN, S10BEN, S15BEN, and S20BEN can inhibit a growth of fungi, *Colletotrichum gloeosporioides*, after 1 day of antifungal screening test.

AS for the sensor film, a colorimetric indicator for detecting fish freshness was developed based on ethylene vinyl acetate/sappan-dyed carboxymethyl cellulose (EVA-SAP-CMC) composite films by varying the amount of dye powder (1, 3, and 5 wt% of SAP-CMC). With respect to the amount of dye added to the composite, the film become darker as evidenced in lower lightness (L*). The redness (+a*) and yellowness (+b*) were higher. The color of the pH indicator film to various concentrations of standard ammonia was recorded. After exposure to ammonia, the color gradually changed from orangish-red to orangish-pink at 0.1 mg/mL of ammonia (pH 9.25) and turned dark orangish-brown at 35 mg/mL (pH 11.31). The indicator responsiveness was found to correlate with higher ammonia concentration, thereby enabling the real-time monitoring of spoilage. Finally, the fish spoilage test was conducted via the total volatile basic nitrogen (TVBN) approach. The TVBN level increased during the storage time at room temperature. The TVBN level of 35 mg/100 g of fish sample was reached over 7 hours of storage time at room temperature implying that the fish was rarely acceptable for human consumption. The fish freshness was indicated by the relationship between TVBN values and the ΔE with greater than 2, from orangish-red to orange, during the fish starting lacking of freshness. The sensor film was able to detect the fish freshness. In conclusion, the assembly of two potential films is promising to achieve the effectiveness of a smart packaging for agricultural products.

9.2 Recommendations

Based on what we have been discovered in this study, the following recommendations are suggested in following scopes.

(1) Study on the use other types of clay, such as organoclay, or other kinds of organosilane in order to investigate the effect of reactive extrusion on delamination and dispersion of clay in polymer matrix

(2) Study on other processing techniques with plasma-assisted process, such as Brabender mixer.

(3) Study on the use of other types of natural dye so as to develop an effective sensor film