CHAPTER VI
CONCLUSIONS AND RECOMMENDATIONS

PP/organoclay nanocomposites with various clay contents were prepared via a master batch by melt blending in a twin screw extruder using Surlyn® as a reactive compatibilizer. The properties of PP/organoclay nanocomposites, crystal structure, thermal behavior, mechanical properties and oxygen gas permeability, were studied and compared to pure PP. According to XRD patterns, the addition of the organoclay does not affect the crystal structure of PP matrix. However, the incorporation of the organoclays can enhance the thermal stability of PP/organoclay nanocomposites. The melting and crystallization temperatures of the nanocomposites are higher than those of pure PP but less sensitive to the clay content. It can be concluded that the addition of clay has minimal effect on the melting and crystallization temperatures of the nanocomposites. The crystallinities of the nanocomposites are slightly higher than that of pure PP. This could be attributed to the organo-modified clays acting as a nucleating agent for the crystallization of the PP matrix. Young's modulus of the nanocomposites was greater than those of pure PP and gradually decreased when the organoclay content increases to 5 wt%. In case of tensile strength, it was lower than that of virgin PP and decreased with increasing the clay content. Moreover, the elongation at break of the nanocomposites was reduced with increasing the clay contents. The decrease in mechanical properties of the nanocomposites may involve with the aggregations of clay or the remaining of some impurities in bentonite. The oxygen gas permeability of the nanocomposite films was lower than that of pure PP and reduced slightly with increasing the clay content.

The evaluation of PP/organoclay nanocomposite intelligent packaging based on PEDOT:PSS and Cu^{2+} sensors was demonstrated. The response to chicken meat at room temperature for sensors with various thicknesses, sensor concentrations, clay contents in the nanocomposite film, the amount of meat samples, and type of sensor (PEDOT, Cu^{2+}) were studied. The color changes of the intelligent films were measured by using a Chroma Meter and reported in Hunter system (L^*, a^*, and b^*) values and total color difference (TCD). It was found that sensors with the greatest thickness (1000 rpm) showed higher response than those coated at 2000 or 3000 rpm. This is due to the greater amount of material on the film sensors, compared to the thinner film. The sensors with the highest concentration showed the greatest response among those sensors. The reason of this result is similar to that of sensor with various thicknesses. The sensor response at 1%wt clay in nanocomposite films gives the faster response than 3%wt clay and 5%wt clay, respectively. This is explained by the improvement of gas barrier properties with high clay contents in nanocomposite films. The sensor responses of 150 g of meat samples showed the higher value than 100 g, 50 g, and 25 g, respectively due to higher volatile base concentration in the package-headspace. From the comparison of both sensors, it was clear that the Cu^{2+} sensor showed higher sensitivity than PEDOT:PSS sensor and easy to observe the color change at the point of spoilage (12 h) with the naked eyes. However, if the amount of meat samples is more than 200 g, the PEDOT:PSS sensor will be effective. A delay between the increase in microbial population and the sensor response was observed. This delay is inherent as volatile base generation follows the rise in microbial population. The receiving electron of PEDOT:PSS and Cu^{2+} sensors from total volatile basic nitrogen (TVB-N) was confirmed by the result of electrical conductivity.

The results presented in this study indicated that PP/organoclay nanocomposite film coated with Cu^{2+} sensor could be employed as an effective chromic intelligent packaging for evaluating meat freshness due to absolutely visible to the naked eyes at the onset of meat spoilage, 12 h, thus enabling the "real-time" monitoring of spoilage. Moreover, the leakage of Cu^{2+} is below the limitation of residual Cu of the U.S. Food and Drug Administration (FDA). However, nanocomposite film coated with PEDOT:PSS sensor cannot be used as an effective chromic intelligent packaging since it cannot be easily observed by human eyes. In addition, both sensors could be used as electrical-intelligent packaging.

Recommendations

(1) Because microbial population and microbial activity are temperature dependants, ongoing research is assessing the sensor response at refrigerated temperature (0-4°C).

(2) The use of intelligent film for the other types of meat such as fish should be investigated for further study.

(3) Gas permeable membrane may be added with sensor in order to protect the sensor from excess humidity while allowing gaseous compounds to pass through and to prevent the sensor to come in direct contact with the food product within the packaging.

(4) The other techniques such as incorporating Cu^{2+} into clay minerals to form an ion pair between Cu^{2+} and layer silicate may be applied.

(5) The other types of sensors should be studied.