Abiotic Degradation by Air Oven Treatment of Locally Available Polyethylene (PE) Plastics Branded as Lucky Bag and Anchor

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Abstract

Air oven treatment of locally available polyethylene (PE) plastics branded as Lucky bag and Anchor was conducted as abiotic degradation process in order to evaluate the extent of their thermal degradability. Air oven treated Lucky bag films indicated the decreased values in tensile strength of 2.4 MPa from the original value of 16.1 MPa and 83% loss of the original value of elongation at break while air oven treated Anchor films the tensile strength decreased to 5.7 MPa from the original value of 22.9 MPa and 99% loss of the original value of elongation at break resulted during the two month degradation course. The results of SEM and EDXRF analyses showed surface erosion, diffusion and leakage of additives incorporated in the plastic films. The results in FTIR spectra clearly indicated the progressive changes in chemical structure in the internal material of plastic films with the occurrence of small transmittance.

Key words: PE plastics, air oven treatment

Introduction

The continuous use of packaging plastic materials results in the tremendous amounts of refuse and becomes a serious litter problem in municipal solid waste (MSW) due to their persistence in the environment. According to the statistics of Pollution Control and Cleansing Department (PCCD), Yangon City Development Committee (YCDC) of 2007 revealed that plastic occupied 12% of the MSW. Due to public's perception of plastics as litter and emission of some irritant gases from burning them, the disposal of the used plastic materials is becoming a major concern.

Bond cleavage of plastic polymers can occur at the temperature above their critical temperatures that is mostly higher than 400-600°C. Vinyl polymers such as polypropylene (PP), PE, polystyrene (PS) are prone to thermal degradation, which can occur either by chain scission or nonchain scission routes. Chain scission involves the cleavage of the backbone bonds to yield free-radical segments whilst nonchain scission

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involves the elimination of a small molecule from a substituent group and double-bond formation. PE and PP degrade in the manner of random hemolytic breakage of their polymer chains, resulting in a complex mixture of low-molecular weight degradation products (Fried, 1995). PE is stable up to 103°C in inert atmosphere (Schnabel, 1981) however, whereas at elevated temperatures the rate of various chemical reactions such as oxidation increased and led to degradation of the polymer indirectly. The thermally oxidized polymers changed to ketones, alcohols, and esters when the concentration of oxygen is not limited. Hydroperoxides and peroxides are also primary products of thermal oxidation (Dilara and Briassoulis, 2000).

Abiotic degradation through air oven treatment was considered as thermal treatment to evaluate the degradability of locally available PE plastics branded as Lucky bag and Anchor by assessing mechanical properties, surface analysis by Energy Dispersive X-Ray Florescence (EDXRF), surface morphological changes by Scanning Electron Microscopy (SEM) and functional group analysis by Fourier Transform Infrared (FTIR).

Materials and Methodology

Materials

Two branded plastics, namely, Lucky bag and Anchor were purchased from the local retail market.

Methodology

Air Oven Treatment

Air oven treatment of plastic films was conducted in a hot box air oven with fan, 15 amp, 240 volt, Gallenkamp, England.

The plastic films were prepared by initially shredding them to strips to an average size of 15 ×14 cm^2 and placed in an air box oven at 70°C for 11, 22, 30, 45 and 60 days.

Evaluation of Degradability of Air Oven Treated Plastics

Changes in Mechanical Properties

Mechanical properties such as tensile strength and elongation at break were measured using tensile tester machine at the Laboratory of Rubber Research Technologies and Training Center. The testing method follows British Standard (BS 903, Part 2A) that describes the determination of tensile stress strain properties of vulcanized rubber and thermoplastic materials. The plastic films before and after being subjected to air oven treatment were analyzed for their changes in mechanical properties.

Changes in Surface Morphology

The surface morphology before and after being subjected to air oven treatment was observed using JEOL JSM-5610- Scanning Electron Microscope at the Universities' Research Center (URC).

Surface Analysis

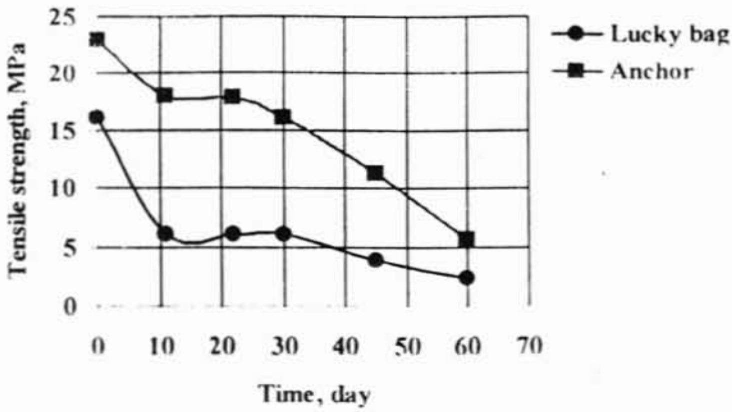
The surface analysis of plastic films before and after being subjected to air oven treatment was observed using EDX-700 spectrophotometer at the Universities' Research Center (URC).

Results and Discussion

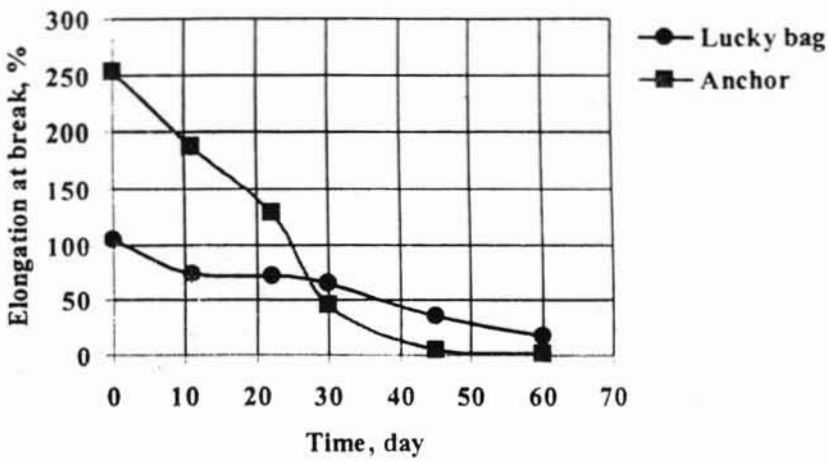
Air oven treatment of plastic films was conducted as abiotic oxidative degradation process. The rate of abiotic degradation process depends on the control of oxidation of the carbon chain polymers by the incorporated antioxidants and stabilizers. As shown in Figure 1, both the values of tensile strength and elongation at break decreased with longer treatment time. The tensile strength abruptly decreased to 6.1 MPa on the 11^{th} day, and then gradually decreased to 2.4 MPa from the original value of 16.1 MPa on the 60^{th} day for Lucky bag brand film while Anchor brand films showed decrease in tensile strength value of 5.7 MPa from the original value of 22.9 MPa on day 60. Especially, the value of elongation at break showed 83% decrease from the original value of elongation at break (decreased to 17.8% from 106%) as for Lucky bag. However, 99% decrease of the original value of elongation at break (decreased to 2.3% from 253%)

on day 60 was occurred for Anchor brand film. Also all air oven treated films became discolored and a little bit hardened after 60 days. Overall, decrease in the values of tensile strength and elongation at break resulted for both plastic films. According to the statement of Orhan and Büyükgüngör (2000), the value of elongation at break is most sensitive to degradation of the plastic materials, whilst the tensile strength is a far less sensitive indication due to the increased value resulting from initial cross-linking processes caused by free-radical chemistry in operation.

This deterioration in mechanical strength may be due to the destruction of the amorphous phase of plastic films, causing reduction in impact strength that leads to more rapid physical disintegration. This embrittlement should be as short as possible, most importantly, should lead to fragmentation of all kinds of plastics. Fried (1995) stated that at embrittlement, a relatively high concentration of carbonyl compounds and particularly carboxylic acids and esters may have taken place which may be identified by FTIR analysis. As shown in Figures 2 (a) and (b), both Lucky bag and Anchor plastic films showed clearly as PE plastic films by the presence of significant bands at the wavelength of 2,850 cm^{-1} and 2,920 cm^{-1} that indicates the stretching (C–H) in methylene group. That was evident again by the appearance of significant band at 1,460 cm^{-1} that indicates scissoring motion of (H–C–H) in methylene group and four or more methylene groups were presented by the indication of a significant band at the wavelength 720 cm^{-1}. Scott (1995) stated that polyolefins like PE contain few double bonds and are much more resistant to oxidation. If molecular fragmentation occurs in films, the significant band of carbonyl formation (=C=O) should have appeared at the wavelength 1,650-1,750 cm^{-1}. From the results of Figures 2 (a) and (b), there was no distinct indication of carbonyl group formation in the said wavelength, however, the results significantly indicated the chemical changes in both plastic films for the same length of treatment time. Air oven treated both plastic films showed the same results when comparison was made as regards percent transmittance in Y-ordinate in FTIR spectra. A small percent of transmittance occurred by the oxidized both plastic films. This means that both plastic films became more transparent after air oven treatment due to the fact that there was lower transmittance, as shown by greater absorbance as judged by the formulation of absorbance is equal to 2 - log (% transmittance).



(a)



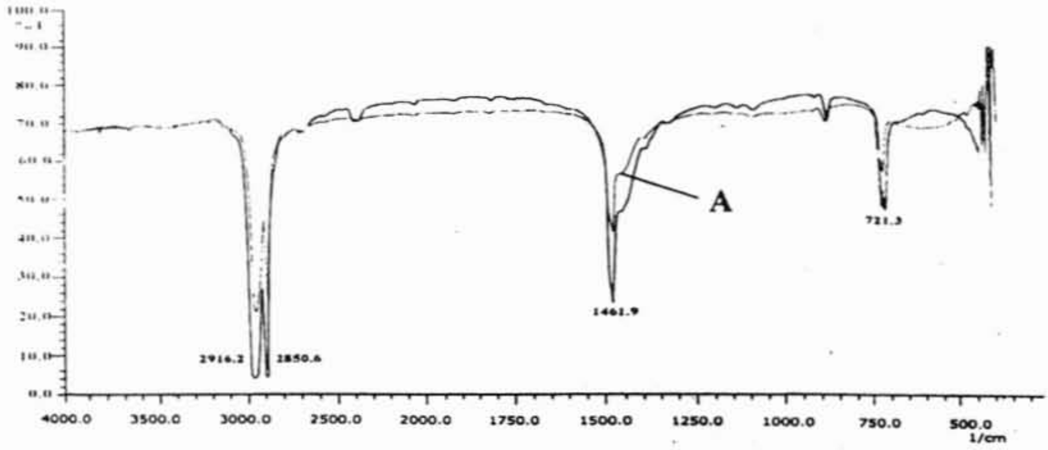
(b)

Figure 1 Changes in Mechanical Properties of 60-Day Air Oven Treated PE Plastic Films (a) Tensile Strength and (b) Elongation at Break

Table 1 represents the results of surface analysis by EDXRF. The elements such as Titanium (Ti), Calcium (Ca), Sulphur (S), Iron (Fe), Zinc (Zn), Potassium (K), Mercury (Hg) and Nickel (Ni) were incorporated in both Lucky bag and Anchor brands films. After getting stresses by air oven treatment, some elements present in films leaked on the surface especially the appearance of Hg, S and K as tabulated in Table 1. The additives and degradation products were diffused and leaked from the polymer matrix, resulting in the decrease of mechanical properties and the polymer matrix became more brittle.

A = after air oven treatment

(a)



(b)

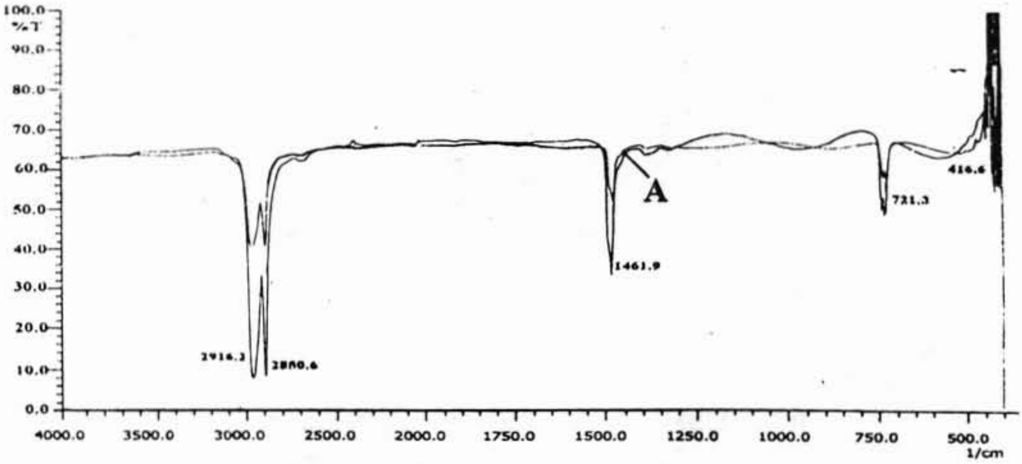


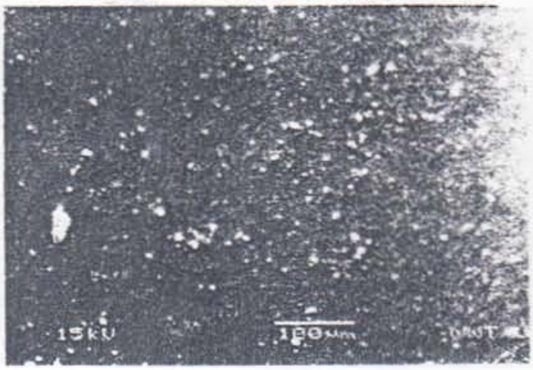
Figure 2 FTIR Results of Changes in Chemical Structure of 60-Day Air Oven Treatment (a) Lucky Bag and (b) Anchor

From the images of SEM analysis, it was found that there was surface erosion and leakage of white matters from the surface due to the stress of air oven treatment as indicated in Figures 3.

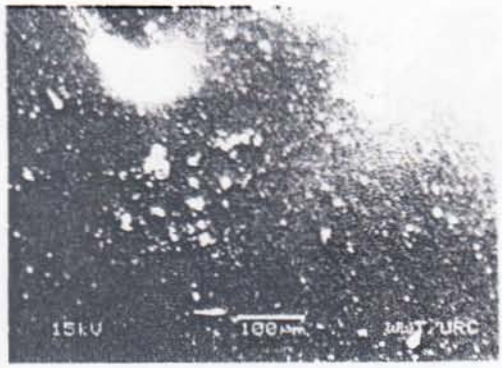
Table 1 Results of Surface Analysis by EDXRF of Oxidized PE Film

Element	Plastic Film			
	Lucky Bag		Anchor	
	Untreated	Air oven treated	Untreated	Air oven treated
Ti	51.94	51.21	69.01	54.52
Ca	43.26	42.40	14.87	18.65
S	3.79	3.96	ND	7.01
Fe	1.01	0.69	13.07	6.02
Zn	ND	0.40	1.68	1.03
K	ND	ND	ND	11.01
Hg	ND	ND	ND	1.76
Ni	ND	ND	-	-
Cu	-	-	1.38	ND

ND = Non Detectable



Untreated film, Lucky bag



Air oven treated film, Lucky bag

Untreated film, Anchor

Air oven treated film, Anchor

Figure 3 SEM Images of Lucky Bag and Anchor PE Films