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Physical-Mechanical Properties of Polyethylene Reinforced by Polypropylene Under the Influence of Citric Acid

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Abstract: Blends specimes consist of polyethylene reinforced with different ratio of polypropylene (5, 10 and 15%) is prepared in this study. The effect of different concentration of citric acid on mechanical and physical properties of these polymeric blends specimens such as maximum tensile strength, maximum deformation, impact energy, hardness and electical conductivity is investigated in current study. The blends specimens are tested after immersed for 30 days in citric acid with concentration of 5, 10 or 20%. The obtained results showed that the reinforcement by polypropylene improve the maximum tensile strength and hardness properties while reducing to some extent the maximum deformation, impact energy and electrical cnductivity properties. Citric acid played the role of plasticizer and led to a relative increase in maximum tensile strength, maximum deformation, impact energy and electrical conductivity while led to a slight decrease in hardness of blends specimens.

Key words: Polyethylene, citric acid, mechanical properties, electrical conductivity, blends specimens, impact energy

INTRODUCTION

Polymeric materials is very important and widely used materials in our daily and industrial lives in the recent years. There are several reasons for this great importance of polymeric materials in various industrial applications that can be mentioned of which the huge range of properties exhibited by polymeric materials and their easy to manufacturing and forming. To obtain appropriate combination of mechanical, physical, chemical and thermal properties for a specific application requirements a new approach has been executed recently in science and technology of polymeric materials by mixed two or more materials under a specific conditions (Altan and Yildirim, 2010; Salih *et al*., 2013).

Blending of polymeric materials which different chemically is an important factor in industrial production with suitable or intermediate material properties. Polymers blend performance relies on mechanical, physical and other properties of polymeric components as well as its arrangement in space where the polymeric materials are exist either as a single phase or two phases or more depending on their molecular weight (Kukaleva *et al*., 2000).

Polyethylene (PE) and Polypropylene (PP) blends have attracted considerable attention from many researchers because of their economic importance and to obtain appropriate and intermediate properties from both blend components such as high stiffness, acceptable ductility, high softening temperature, high hardness, good impact strength, good chemical connection and easy to processing (Li *et al*., 2003; Rose *et al*., 2008; Su *et al*., 2017).

One of the most important applications in which polymers (such as polyethylene and polypropylene) are used is the preservation of nutrients and acid solutions that result from them. Food, like all other materials has several effects on properties of polymeric containers during the storge period. Citric acid is a material that has received considerable attention from many researchers to study its positive and negative effects on the properties of polymeric materials such as barrier, structural, mechanical, chemical and physical properties (Shi *et al*., 2008; Kahar *et al*., 2014; Mariano-Torres *et al*., 2015). The aims of the present study are preparation specimens consist of polyethylene reinforced by different concentration of polypropylene and studying its mechanical and physical properties

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before and after immersed it for 30 days in citric acid with different concentration (5, 10 and 20%).

MATERIALS AND METHODS

The used polymeric materials in present study were commercial products from a chinese origin which are High Density Polyethylene (HDPE) and Polypropylene (PP) (Huajin T30 S). Polyethylene has density of 0.96 g/cm^3, melt flow index of 5.6 g/10 min and molecular weight of 76000-80000. Polypropylene has density 0.899 g/cm^3, melt flow index of 8.3 g/10 min and molecular weight of 81000-90000. The specimens of polymeric materials were immersed in anhydrous citric acid produced in a form transparent crystals, odorless, white crystalline powder with a strong taste of acidity and it is very soluble in water and alcohol.

Polyethylene and polypropylene blend specimens preparation: The polyethylene and polypropylene pellets have been mixed according to the required concentratin of polypropylene (5, 10 and 15%) in the base material which is polyethylene and the pellets mixture is melted using heating chamber (180-190°C and 3 kW heat power) in a co-turning twin screw extruder instrument with rotational speed of 25 rpm to homogenize polymers blended and forming it as long strips in mold zone. The blends specimens is prepared using compression moulding technique which include placing the blended polymer strips in a steel mold preheated to a temperature of 160°C for 1 h to produce the suitable strips thickness. The compression technique was done under pressure of 300 kg/cm^2 for 5-15 min depending on the type of the required blend.

Tensile strength measurement: The pure polyethylene and blends specimens have been prepared according to the procedure ASTM D638-87 adopted by standard test methods for tensile properties of plastics. The maximum tensile stress and maximum deformatiom to the breaking point for all specimens conditioned with or without citric acid are determined from drawing a stress-strain diagram using computer controlled electronic universal testing machine Model WDW-5E of chinese origin. The gauge length or initial distance between mechanical instrument grips is 50 mm and separation speed is 30 mm/min at temperture of 21°C. The stress was applying until the failure is occur and in this instant the maximum tensile strength is measured and can be determined from the following equation (Shubhra *et al*., 2013; Su *et al*., 2017):

$$\text{Max. tensile stress}\,(\sigma)(\text{MPa}) = \frac{F_{max}}{A} = \frac{F_{max}}{w.t} \quad (1)$$

Where:

w and t = The width and thickness of the specimen, respectively

F_{max} = The maximum tensile load which applied to the specimen at the failure instant

Maximum deformation: The maximum deformation or elongation at the breaking piont is measured by the mechanical instrument or calculated from Eq. 2 when the maximum tensile stress is reached for all specimens which were immersed for 30 days in citric acid or without citric acid (Shubhra *et al*., 2013):

$$\delta_{max} = L_f - L_o \quad (2)$$

where, L_f and L_o are final and gauge length of specimen, respectively.

Impact energy: The required absorbed energy to produce fracture in the blend specimen is measured using charpy impact test machine, XJU-22 time group Inc., according to the procedure ASTM ISO 179 at temperature of 21°C. The specimens which consist of pure polyethylene or polyethylene with polypropylene is prepared and cut in the dimensions of 15×3×90 mm which was immersed in citric acid or without citric acid. The required impact energy is calculated from the following equation (Shubhra *et al*., 2013):

$$\text{Impact energy}\,(\text{kJ/m}^2) = \frac{\text{Required engery for fracture (kJ)}}{\text{Cross section area of specimen}\,(\text{m}^2)} \quad (3)$$

Hardness: Hardness can be defined as a resistance measuring of localize plastic deformation or penetration produced by drilling, impact, abrasion, wear and scratching (Salih *et al*., 2013;Mariano-Torres *et al*., 2015). The hardness test was preformed using a durometer shore D according to the procedure adopted by ASTM D570 on the blends specimens with dimensions of 15×3×90 mm. Five readings were recorded and the average value is adopted in the obtained results.

Electrical conductivity: The electrical conductivity is measured by measuring the resistance of each sample then by using the following equation (Linares *et al*., 2008; Eluchie, 2016):

$$\rho = R\frac{A}{l} \quad (4)$$

Where:

ρ = The resistivity of the specimen

R = Electrical Resistance of the specimen

A and L = The cross-sectional Area and Length of each specimen, respectively

And the electrical conductivity can be calculated using the following equation (Linares *et al*., 2008; Eluchie, 2016):

$$\sigma = \frac{1}{\rho} \quad (5)$$

where, σ is electrical conductivity.

RESULTS AND DISCUSSION

Mechanical properties of polyethylene and polypropylene blends: The mechanical properties of polyethulene and polypropylene blends is presented as a function of polypropylene percentage in Fig. 1-4 which explain that the increasing of polypropylene concentration in blends causes to increase the maximum tensile strength and hardness and in the same time the blends specimens behavior is changed from soft and tough to hard and less tough with the increment of polypropylene concentration which lead to decrease impact energy and maximum deformation to the breaking point. This due to the truth that polypropylene is strong and have a rigid methyl groups connected with carbon atoms of the polymer main chain (Dhoble *et al*., 2005; Salih *et al*., 2013).

Electrical conductivity of polyethylene and polypropylene blends: The use of polymers in the field of engineering as insulators is gaining increasing importance day after day. The choice of insulator polymer for each case depends on the severity of its isolation and its various physical properties on a wide range of thermal grades and frequency of electric fields (Linares *et al*., 2008). The obtained results from Fig. 5 showed that the reinforcement of polyethylene with different concentrations of polypropylene (5, 10 and 20%) led to decrease the electrical conductivity of the plymeric blends specimens and increase their electrical resistivity which makes it more electrically isolated.

Effect of citric acid on the mechanical properties and electrical conductivity of polyethylene and polypropylene blends

Maximum tensile strength: Figure 6 indicated the effect of citric acid concentration on maximum tensile strength of different polyethylene and polypropylene blends specimens. The obtained results indicate that citric acid improves somewhat the maximum tensile strength and the rate of increase varies by acid concentration. The values of maximum tensile strength increase with increment citric acid concentration except for blend specimen of polyethylene and 15% polypropylene (PE with 15% PP) immersed in citric acid at a concentration of 20%. This increasing in values of maximum tensile strength is due to the effect of the remaining acid molecules in the fine spaces on the composition blends specimens (Kahar *et al*., 2014).

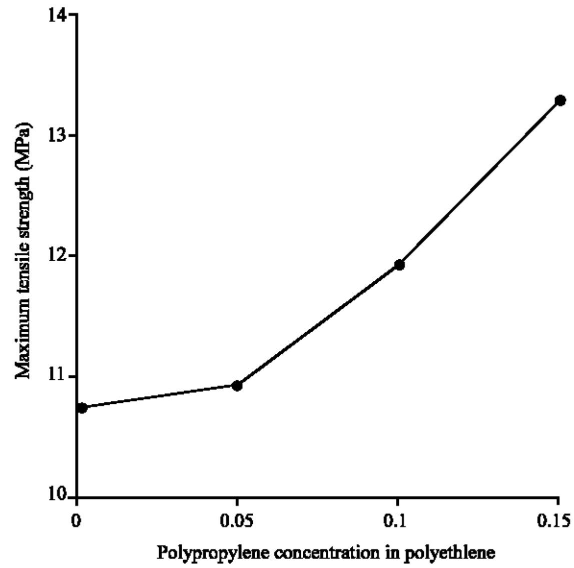

Fig. 1: Maximum tensile strength of blends specimens with respect to PP concentration in PE

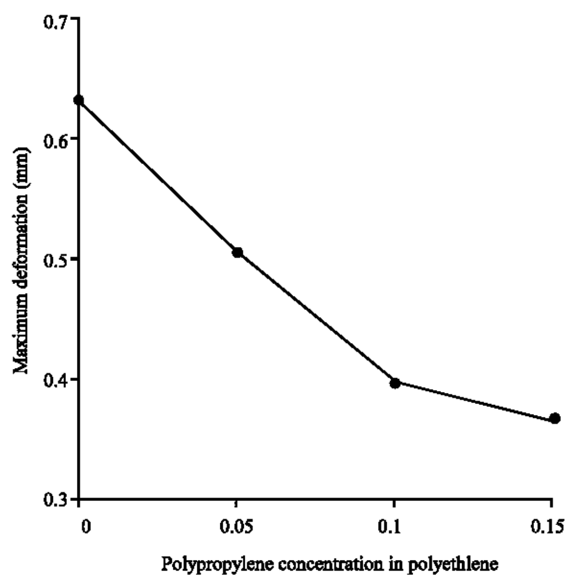

Fig. 2: Maximum deformation of blends specimens with respect to PP concentration in PE

Maximum deformation: The maximum deformation to the breaking point of the different blends specimens with respect to the citric acid concentration is shown in the Fig. 7 which indicates that the increasing in the

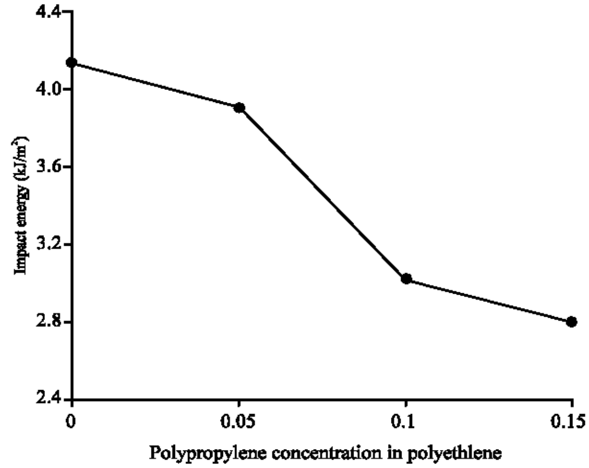

Fig. 3: Impact energy of blends specimens with respect to PP concentration in PE

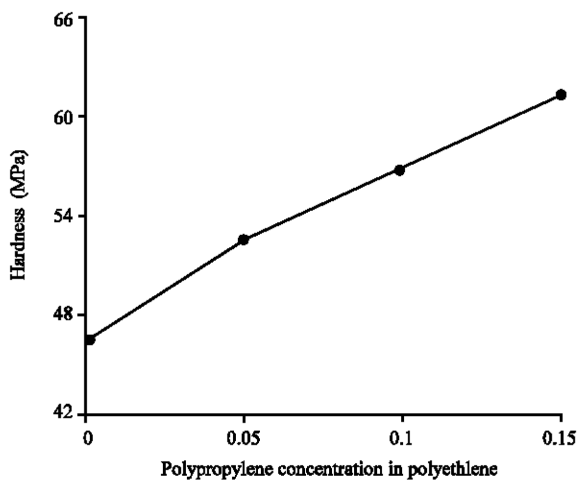

Fig. 4: Hardness of blends specimens with respect to PP concentration in PE

citric acid concentration leads to increase the maximum deformation of the polyethylene and polypropylene blends speciments except of PE with 15% PP blend specimen immersed in citric acid at a concentration of 20%. The residual amount of the citric acid in blend specimens worked as plasticizer that leads to interactions between blend molecules leading to increased the maximum deformation (Shi *et al*., 2008). Hence, the addition of the citric acid to the blends is a helpful method to improve the specimens flexibility.

Impact energy: The required impact energy or toughness is an important factor in selection of the materials because it determines the polymer ability to resistance a resulting

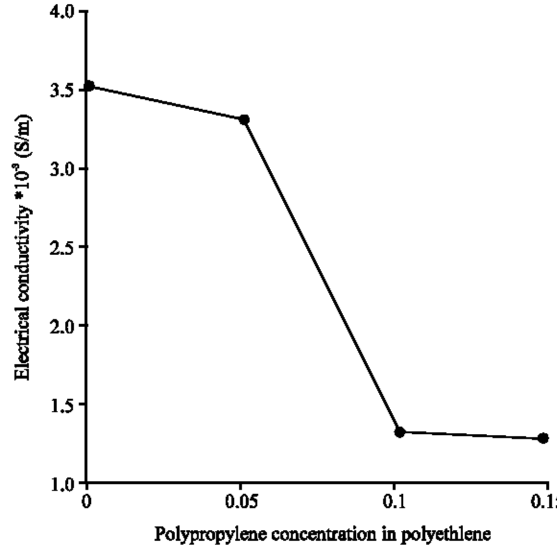

Fig. 5: Electrical conductivity of blends specimens with respect to PP concentration in PE

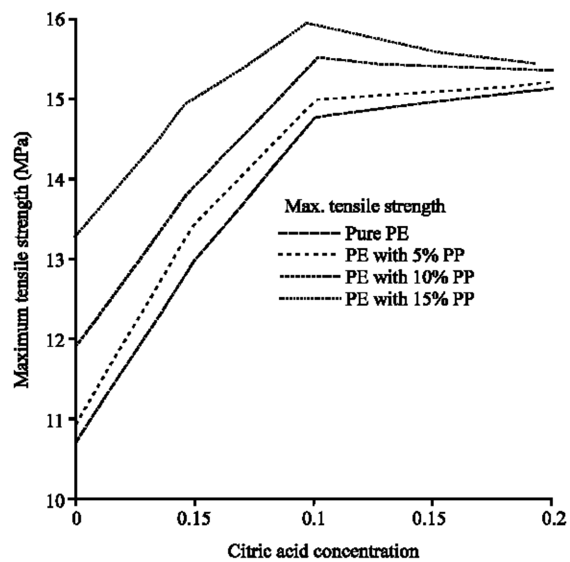

Fig. 6: Effect of citric acid concentration on maximum tensile strength of different blends specimens

load from moving body at high speed, so, it is the required energy to spread a crack cross the specimen. The influence of citric acid concentration on the impact energy of different polyethylene and polypropylene blends is shown in Fig. 8. The obtained results showed that impact energy for pure polyethylene specimens, polyethylene with 5% polypropylene specimens and polyethylene with 10% polypropylene specimens increase with citric acid concentration increment from 0-20%. This can be

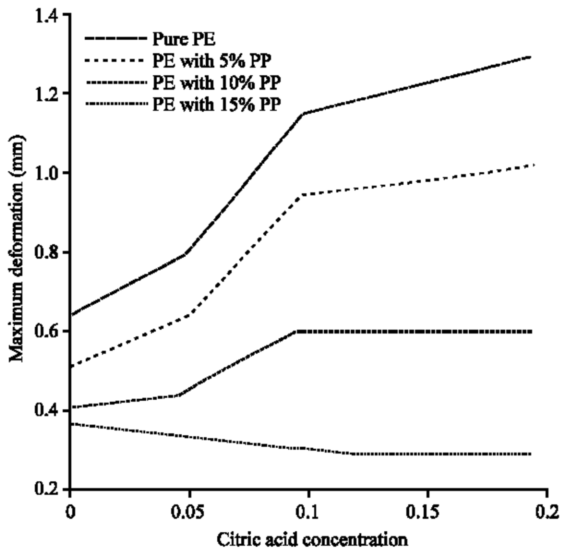

Fig. 7: Effect of citric acid concentration on maximum deformation of different blends specimens

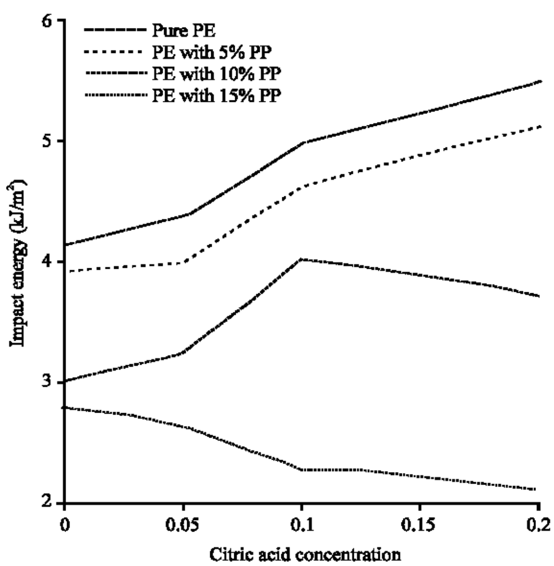

Fig. 8: Effect of citric acid concentration on impact energy of different blends specimens

attributed to the fact that citric acid works to plasticize these blends specimens and improve their flexibility as well as increase their ability to shock absorption (Shi *et al*., 2008; Kahar *et al*., 2014). In case of blends specimens consist of polyethylene with 15% polypropylene, the increasing in citric acid concentration cause to decrease their impact energy due to the effect of citric acid on the specimens structure.

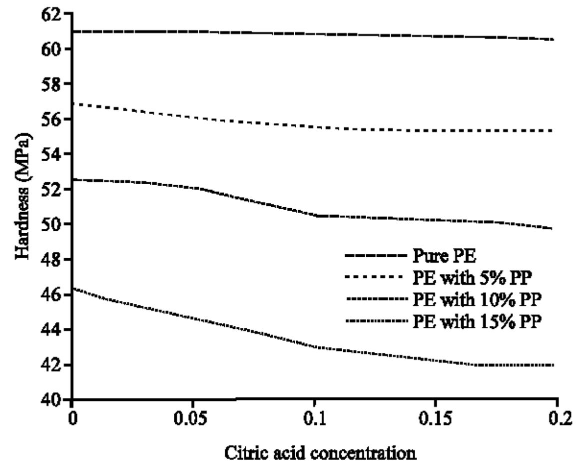

Fig. 9: Effect of citric acid concentration on hardness of different blends specimens

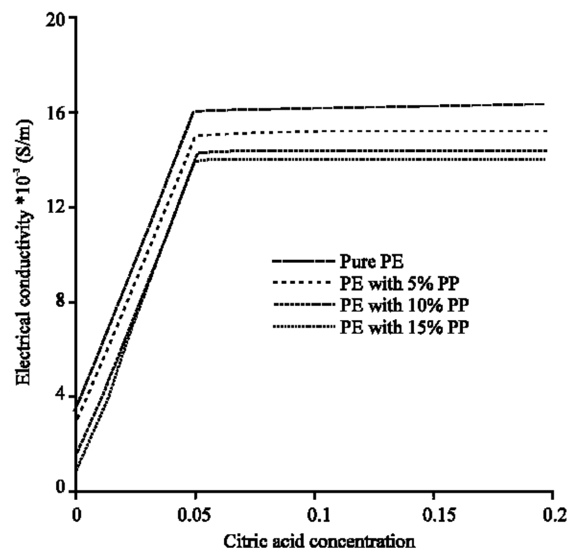

Fig. 10: Effect of citric acid concentration on electrical conductivity of different blends specimens

Hardness: Figure 9 and 10 explains the effect of citric acid on the penetration resistance or hardness of polyethylene and polypropylene blends specimens which indicated that increasing in citric acid concentration leads to reduce the hardness values of all blends specimens. This could be due to citric acid break the molecular chain of polymer and weakening the intermolecular interactions and damage molecular arragements, therefore, reduced hardness parameter (Mariano-Torres *et al*., 2015; Zhang *et al*., 2017). The figure also showed that the rate of reduction in hardness when the concentration of citric acid is changed from 0-20% is evident in case of pure polyethylene blends specimens while it is slight rate in case of polyethylene with 15% polypropylene blends specimens.

Electrical conductivity: Large molecules with special compositions of polymeric materials possess semiconductor properties. Most commercial polymers are classified as insulators. Despite the poor connectivity of polymers they can easily be converted into objects charged with stable charges (Linares *et al*., 2008). Citric acid works to raise the electrical conductivity of all polymeric blends specimens as shown in Fig. 10. The increase in electrical conductivity can be attributed to the remaining citric acid solution molecules which are a significantly intermediate conveyor for electrical charges.

CONCLUSION

From the present study which has investigated the combined effect of the polyethylene reinforcement by different concentration of polypropylene and the effect of different concentration of citric acid on the mechanical properties and electrical conductivity can be concluded the following points. The polyethylene reinforcement by polypropylene improve the maximum tensile strength, hardness and electrical resistivity while led to decreace the maximum deformation, impact energy and electrical conductivity of the polymeric blends specimens. This improvement and decreasing in mechanical properties and electrical conductivity increase with increasing the reinforcement. Citric acid played the role of plasticizer which led to increase the maximum tensile strength, maximum deformation, impact energy and electrical condutivity while caused to slight decrease in the hardness values of polymeric blends specimens.

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