Antistatic packaging of carbon black on plastizers biodegradable polylactic acid nanocomposites

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Abstract: Poly(lactic acid) (PLA) is a biodegradable aliphatic polymer obtained from renewable sources; its main application is in the packaging sector. Electronic components require the use of antistatic packaging that prevents damage and electric shock. As PLA has no conductive characteristics, it requires the addition of conductive carbon black to make the polymer less resistive as the dissipative material and making it suitable for the manufacture of antistatic packaging. In this study plasticizer PLA was prepared by solution casting method with plasticizer thymol at (95/5) and carbon black at 0.5, 1, 3, 5, and 10 wt %. Samples were characterized by FTIR, Tensile Strength, Tear Resistance, Hardness, electrical conductivity, color and brightness, contact angle, and thermal gravimetric analysis. The addition of carbon black in the plasticizer PLA increases the electrical conductivity of PLA and less resistive that suitable for use as antistatic packaging for the transportation and storage of electronic components. Mechanical tests show reduced the tensile strength and tensile modulus but increased in elongation, Tear Resistance but decreased in hardness because used thymol as plasticizers at PLA/thymol (95/5) and films composites change from brittle to ductile . The results of contact angle of pure PLA is 83° that mean hydrophobic materials and decreased to 45° at PLA/thymol/carbon black to obtain hydrophilic materials that able to dissipate or promote the decay of static electricity and improve process ability of electronic device. Optical such as Color and Brightness show that Transparency decreased but suitable for antistatic packaging and became opacity at 10% carbon black. The addition of carbon black in the PLA increases the thermal stability of nanocomposites.

1 Introduction

PLA is linear aliphatic thermoplastic polyester derived from lactic acid, which is obtained from the fermentation of 100% renewable and biodegradable plant sources, such as corn or rice starches and sugar feed stocks [1]. PLA is produced by direct condensation polymerization of lactic acid or by ring-opening polymerization of lactide. PLA is degradation products are non-pollutant and non-toxic. Thus, PLA is a green alternative to petrochemical commodity plastics, used in packaging, agricultural, disposable materials, textiles, and in application is in the packaging sector [2]. Electronic components require the use of antistatic packaging that prevents damage and electric shock. As PLA has no conductive characteristics, it requires the addition of allotrophic carbon forms such as bio carbon to make the polymer less resistive as the dissipative material and making it suitable for the manufacture of antistatic packaging and electronic industry [3]. Thymol is one of the efficient plasticizers used for polylactic acid because of non-toxic, biology miscibility and biodegradability; thymol can effectively increase the chain mobility of PLA, and improve its ductility and draw ability, thus broadening the range of potential applications such as electrical and antistatic packaging to keep the film and not tearing [4].
Carbon black is produced by the reaction of a hydrocarbon fuel such as oil or gas with a limited supply of combustion air at temperatures of 1320 to 1540°C. The unburned carbon is collected as an extremely fine black fluffy particle (10^-500) nm [5]. Carbon black is widely used as filler in elastomers plastics and paints to modify the mechanical and electrical and the optical properties of the materials in which they are dispersed and consequently determine their application in given market segment, carbon black when compounded with plastics imparts unique properties, such as UV protection, electrical conductance range of dark opacity and reinforcement. The primary carbon black characteristics that influence the properties of carbon black compounds with elastomers are the particle size, aggregate size, the morphology of the carbon black aggregates and its microstructure. [6].

Carbon black is a semiconductor and has hidden energies separating the filled valence band with the empty conduction band. If the minimum energy required to transfer an electron from the valence band to the conduction band is below the energy for the longest wavelength of the incident light (700 nm infrared), then all visible wavelengths are absorbed and the material appears black [7].

In plastics materials are inherently isolative (typical surface resistivity’s in the range of (10^{12}–10^{14} ohm.cm^2) and cannot dissipate a static charge. This inherent insulation causes the plastic tend to hold electrostatic charges and allow electromagnetic=radio frequency interference (EMI=RFI) to pass thorough [8]. An antistatic packaging is used to prevent the buildup of static electrical charge from the transfer of electrons to the surface of plastic. Nowadays, plastic has replaced metals and become the materials for internal in electronic components because of they have greater in flexibility, lighter weight, color ability and cost effectiveness. Therefore, the challenge is to convert inherent insulating thermoplastic material to become products which provide antistatic or electrostatic dissipative or EMI=RFI shielding figure 1 [9]

![Figure 1: Surface resistivity of materials](image)

The new field of application for PLA composites is antistatic packaging that protects the product not only against physical and environmental damage but also against electrostatic discharge. An electrostatic discharge (ESD) occurs when there is a transfer of electric charges between bodies that have different electrostatic potentials. The use of antistatic packages with a certain degree of electrical conductivity for electronic devices is necessary because the charges on the surface of these materials can cause some problems, such as dust contamination and short circuit, which can influence both the appearance and the performance of the final products and even cause a fire or an explosion in cause a fire or an explosion in hard drive, sound card, or video card [10].

Surface wettability has an important role in antistatic packaging that wetting is commonly characterized by the contact angle, which Wettability is usually quantified in terms of observed contact angles, so from a practical point of view, a simple methodology is needed to account for the heterogeneous rough surface influence on wetting and contact angle measurements. Hydrophilic Surface characterized by Young contact angle for water that is smaller than 90°. Hydrophobic Surface contact angle for any liquid that is larger than or equal to 90°. In contrast to the case of hydrophilic surfaces, the hydrophilic materials are plasticizer thymol improved flexibility and durability that used in films and cables. It was commonly thought that plasticizers work by (increasing the "free volume") or swelling them and thus significantly lowering the glass transition temperature for the plastic and making it softer [11].

Wang et al.(2008) [12] prepared PLA/carbon black and PLA/carbon black/plasticizers composites used acetyl tributyl citrate and as plasticizers prepared by melt blending for antistatic packaging. The effect of different contents of carbon black (5,10,15)% was investigated by FTIR, thermal, mechanical, morphological, and electrical resistivity. Fourier transform infrared spectroscopy revealed that there is a little interaction between PLA and black carbon and interaction is enhanced with the addition of carbon black, and with increasing carbon black the storage modulus, and glass transition temperature increased.
Thaís Ferreira da Silva et al. (2018) [13] show that Poly (lactic acid) (PLA) used in the packaging sector use in antistatic packaging that prevents damage and electric shock. PLA was melt blended with 5, 10, and 15 wt % of carbon black to make the polymer less resistive as the dissipative material and making it suitable for the manufacture of antistatic packaging, carbon black is a great option to increase the electrical conductivity of PLA.

The purpose of this work is using carbon black and provides a very homogeneous mixture between the composites. The effect of different contents of carbon black was also investigated. mechanical, electrical, color, and contact of antistatic packaging based on biodegradable polymers to replace alternative polymers such as Polyethylene terephthalate (PET) used in antistatic packaging.

2 Experimental work

2.1 Materials: Pure grade PLA AI - 1001 with density 1.25 g/ cm$^3$ supplied by (Shenzhen Esun Industrial Co.,Ltd. Chain). Chloroform Solution was purchased from Applied Chem (Germany).

2.2 Carbon black: Nano carbon black filler with particle size (60 nm) is shown in figure (2) measured by (SPM) supplied from Sigma-Aldrich company.

![Granularity normal distribution chart for carbon black particle](image)

2.3 Preparation method: Film of PLA/thymol blend was prepared with weight of 95/5 (w/w) dissolving in chloroform for (60°C) for 2 hours under magnetic stirring continuously until the solution was cleared; then cast into petri dish with 20cm in diameter at room temperature for 24 hours to ensure complete solvent removal. PLA/thymol /carbon black composite films were prepared by swollen carbon black (CB) in chloroform by mixing for one hours, and add PLA/thymol solution until homogenous and even black and evaporated at room temperature (25°C and a relative humidity 50%) until films were formed and cut into test figure (3).

![Samples of test of pure PLA and PLA/thymol /CB composites](image)

2.4 Characterizations:
2.4.1 Thickness: Determination of thickness of pure PLA and PLA composites calculated by electronic digital micrometer type (293-821, Mitutoyo) sensitivity was used to measure the thickness of composites films and find that is 0.110 mm.

2.4.2 Fourier Transform Infrared (FTIR) Analysis: The infrared spectra were recorded with the help of Shimadzu type FTIR -7600 in range 400 to 4000 cm\(^{-1}\).

2.5 Electrical properties: The electrical resistance has been measured as a function of temperature in the range (303-393K) by using the resistivity (\(\rho\)) of the films is calculated by using the following equation:

\[
\rho = \frac{R \cdot A \cdot L}{1}\tag{1}
\]

Where: \(R\) is the sample resistance, \(A\) is the cross section area of the film and \(L\) is the thickness of the samples. The conductivity of the films was determined from the relation:

\[
\sigma = \frac{1}{\rho} \tag{2}
\]

The activation energies could be calculated from the plot of \(\ln \sigma\) versus \(1000/T\) from Arrhenius equation to obtain the Activation Energy (\(E_a\)) by the following formula:

\[
\sigma = A \exp \left(-\frac{E_a}{k_B T}\right) \tag{3}
\]

\(k_B\) is the Boltzmann's constant which is \(1.3806 \times 10^{-23} \text{ J/K}\), \(T\) is the temperature in Kelvin. The \(E_a\) is in practice taken to be the slope of an Arrhenius plot of \(\ln (\sigma)\) versus \(1/T\) in Kelvin \([15]\).

2.6 Mechanical Properties

2.6.1 Tensile Strength: According to ASTM D-882\([14]\) standard modulus of elasticity, tensile strength, and elongation equipped with a 5 kg load cell in tensile mode. Tested films were cut into 10 mm width and 150 mm in length and the initial gauge length and the speed were fixed at 10 mm/min. Tensile strength (\(\sigma_s\)), Young’s modulus (\(E\)) were determined according to the following equation:

\[
\sigma_s = \frac{F}{A} \tag{4}
\]

\[
E = \frac{F \cdot L_0}{A \cdot \Delta L} \tag{5}
\]

Where: \(F\): force exerted on an object under tension, \(L_0\): original length, \(A\): cross section area, \(\Delta L\): length of the object changes

2.6.2 Tear Strength: Tear strength of films was determined on the same Universal Electronic Dynamometer according to ASTM D-1922\([15]\] by the trouser tear method. The sample size was 100 mm long and 63 mm wide having a cut of 50 mm at the center of one end. A pendulum impact tester is used to measure the force required to propagate slit a fixed distance to the edge of the test sample.

2.6.3 Hardness: The experiment was conducted at room temperature (25\(\degree\)C) with 50% humidity. The surface hardness of the samples was measured by using a (Shore A durometer) according to ASTM D 2240\([16]\). All the hardness values reported are obtained from at least three test results.

2.7 Optical Properties

2.7.1 Color test and Brightness: Color properties were evaluated measuring color coordinates in the CIELAB color space \(L^*\) (lightness), \(a^*\) (redness - greenness) and \(b^*\) (yellowness - blueness) were analyzed using a Konica CM-3600d color. Average values for samples were calculated by the color difference (\(\Delta E\)) was evaluated by Eq. (6) \([17]\)

\[
\Delta E = \sqrt{\Delta a^2 + \Delta b^2 + \Delta L^2} \tag{6}
\]

Where: \(\Delta L = L_{\text{stander}} - L_{\text{sample}}\), \(\Delta a = a_{\text{stander}} - a_{\text{sample}}\), \(\Delta b = b_{\text{stander}} - b_{\text{sample}}\) , Standear values for white plate were \(L = 96.86, a = -0.02\) and, \(b = 1.99\) respectively for pure polylactic acid.

2.7.2 Contact angles: The contact angles (CA) were measured by the sessile drop technique using a contact angle system (OCA20, Data physics, Germany) at room temperature. The testing liquids were waters measured in a Goniometer (KSV instruments, Finland, Model: CAM101, software: Attention Theta) through drop shape analysis. The contact angles of water was measured (mean of right and left contact angles) on a flat sample surface at an interval of 60 s for a period of 20min. Swelling tests were carried out according to ASTM D7334\([18]\). The value of the contact angle indicates how hydrophobic the surface is mean large contact angle whereas a small contact angle indicates to hydrophilic surface.

2.8 Thermal gravimetric Analysis(TGA): Thermal-induced weight loss of the sample was measured in dynamic heating by thermogravimetric analysis used (STA PT-1000 linseis, Germany) in an nitrogen atmosphere in the temperature range of 100–500\(\degree\)C and heating rate 10 c/min .

3 Results and Discussion

FTIR analysis of a chemical substance shows marked selective absorption in the infrared (IR) region. Figure 4 Shows the peaks of pure PLA appear peaks at 1418, 2994 and 3600 cm\(^{-1}\) were assigned to the C–O, C–
H(double) and O–H stretching of the –CH(CH3)–OH end group of PLA, respectively. PLA the peak at 3000-2850 cm⁻¹ were assigned to the –C–H asymmetric and symmetric vibration of CH₃ groups in the side chains, peak at 3424 cm⁻¹ of –OH. The peak at 2921 cm⁻¹ asymmetric stretching –CH₂-, peak at 1730 cm⁻¹ corresponding to the stretching vibration carbonyl group (C=O) from the repeated ester units (is due to the carbonyl group in the lactic acid), peaks at (1300-1500) cm⁻¹ of the deformational vibrations of methyl group of PLA are appeared at peak at 1414 cm⁻¹ of –CH₃ bending vibration and peak at 1150 cm⁻¹ of –C–O– stretching vibration from the ester units, and peak at 934 – 851 cm⁻¹ of C–C single.

At figure (4b) represented by PLA/thymol/C.B showing the band at –C=O bond stretching (955 cm⁻¹) in –CH–O– groups, bands at 754 and 869 cm⁻¹ owing to ring vibrations of aromatic groups. Presence of thymol evidenced by the presence of phenolic groups bands from 3500 to 3229 cm⁻¹, and at 1416 cm⁻¹ corresponding to C=O bending. Absorbance peaks of the CB particles at 969 attributed to the carbonyl C=O stretching mode, and the peak at 701-688 cm⁻¹ is associated with the C=C stretching in the cyclic ring. Peak at 1610 cm⁻¹ is associated with conjugate C=C bending mode and Peak at 2879 cm⁻¹ are ascribed to C≡C stretching mode in the carbon skeleton. There were many functional polar groups like carboxylic, phenolic, lactonic on the surface of C.B, which could form the interaction with C-O, CH-O, and O-C-O groups of PLA.

3.1 Mechanical properties
The stress-strain behavior of the various samples is shown in Fig(5) shows the values of pure PLA that tensile strength 36 MPa, Elongation (8.5 %) and Young Modulus 2.83 GPa because that PLA based materials are rigid and brittle polymer at room temperature (RT) due to its Tg ~ 55 °C [6]. Fig(5) showed the effect of thymol as plasticizer contents(95/5)w% on the mechanical properties of PLA films that intended for antistatic packaging applications required sufficient flexibility to avoid breaking during the packaging procedure that mean need have high flexibility and reduce brittleness of PLA and increase ductility of...
PLA because able thymol increases the ability of PLA to plastic deformation which is reflected in the decrease of yield stress and an increase of % elongation that appear in Fig (5) that decrease in TS from (36.43 to 24.12) MPa, Young modulus from (2.83 to 2.02) GPa but improved and increased in Elongation between (8.5-72) % at break of PLA film upon blending with thymol. This behavior might be because some plasticizing effect caused by the addition of thymol to the polymer matrix resulting in the increase in ductile properties, which would also resulting changes in the crystallinity of polymer that changes might be due to the increase in the chain mobility of polymer matrix.

At PLA/thymol/C.B composites, PLA lost its excellent tensile strength but it was found that the tensile strengths decreased between (25.5-14) MPa respectively because increased the carbon black concentration the composites became more fragile. The elongation at break for PLA/thymol/C.B composites are increased between (90-320) %respectively because used thymol as plasticizer.
Figure 5: Mechanical properties of pure PLA and PLA/thymol /carbon black composites

In Table (1) shows the values of tear propagation test simulates a pre-existing tear in the film and determines the amount of energy that each material is able to absorb before it fails (catastrophic tear growth). Tear resistance is the force it takes to rip a plastic film. Generally plastic sheet with a property of brittleness will have very low tear resistance and well known that brittle materials absorb lesser energy to fracture than the ductile materials, this is clearly proved from the Table (1), pure PLA is a brittle material it shows tear resistance is 12.5 mN/mm only and decreased when add plasticize thymol because was softer and its intermolecular attraction was reduced because of the penetration of the plasticize molecules into the PLA matrix. This was attributed to a decrease in the tear strength when adding the plasticizer. It is obvious that addition of thymol and carbon black improvement in tear resistance between (15.18--29.8 mN/mm) dramatically by the incorporation of the carbon black provides reinforcement and improves resilience, tear-strength, conductivity and other physical properties. The specific surface area (m²/g) of Carbon Black is a function of primary particle size. Looking at geometric proportions, we can determine that smaller Carbon Black primary particles have a higher specific surface area that are able to inhibit or at least to slow down crack propagation by deviating their tear path.

Table (1) shows that increased in values of hardness that calculated by Shore A is a measure of the resistance of a material to penetration of a spring loaded needle-like indenter, pure PLA is 97.66 and decrease to 95.16 when used plasticizers thymol because appear more flexible plastic but causes a loss of strength and hardness (that direct proportion to tensile strength) and increased between (97.65- 99.16) the because increased the contain of carbon in carbon black.

Table (1): Mechanical properties of pure PLA, PLA/thymol and PLA/thymol /carbon black

| Samples          | Young Modulus GPa | Tear Resistance mN/mm | Hardness Shore A |
|------------------|-------------------|-----------------------|------------------|
| Pure PLA         | 2.83              | 12.5                  | 97.66            |
| PLA/Thymol 95/5 % | 2.02              | 11.4                  | 97.60            |
| PLA/Thymol/0.5%C.B | 1.24              | 15.18                 | 97.56            |
| PLA/Thymol/1%C.B | 1.13              | 16.7                  | 98.30            |
| PLA/Thymol/3%C.B | 1.01              | 19.3                  | 98.50            |
| PLA/Thymol/5%C.B | 0.98              | 27.4                  | 99.13            |
| PLA/Thymol/10%C.B | 0.76              | 29.8                  | 99.16            |

3.2 Electrical Properties
The natural electrical properties of PLA can be used to create materials with stable electrostatic charges such as the electrets used in biodegradable filtration materials. The surface resistivity is within the range \(10^{10} - 10^{12} \, \Omega /\text{cm}\) for an antistatic film[11].

The electrical conductivity of the pure PLA is showed in figure (6) and the conductivity is 1.39E-12(S/cm) because PLA is characterized by a high resistivity and insulator materials, a tendency toward static electricity. The conductivity of PLA/thymol/CB composites increased with increasing concentration of carbon black due to the reduced insulated space between carbon black particles and polylactic acid. The possibility of electrical conductivity in polymers contained in carbon blacks is due to the free charge and transported through the atoms and groups of carbon black. Carbon black has properties to give the static charge and the conductivity properties of the thermodynamic polymer systems, one of the most important factors that have an important and important role in influencing the electrical properties of the materials of carbon blacks is the size of the added particle and the degree of porosity particle, considering all these advantages of black carbon is one of the best fillings of
polymers to increase the electrical conductivity. The surface area of CB allows for stable matrices to develop at the polymer-filler interface to positive effects in terms of electrical conductivity and increased a polymer or binding agent (i.e.) Conductivity of a filled polymer increases with the specific surface area and the structure of the incorporated Carbon Black[19] that increased between (2.57E-11 S/cm to 7.88E-12 S/cm) at room temperature appear in Table (2).

Fig (6): Electrical conductivity of pure PLA and PLA/thymol/CB composites.

Table (2): Electrical conductivity values of pure PLA and PLA/thymol/CB composites.

| Samples                        | Electrical conductivity at (R.T) (S/cm) |
|--------------------------------|----------------------------------------|
| Pure PLA                       | 1.39E-12                               |
| PLA/Thymol 95/5 %              | 1.46 E-12                              |
| PLA/Thymol/0.5% CB             | 2.37E-11                               |
| PLA/Thymol/1% CB               | 2.52E-11                               |
| PLA/Thymol/3% CB               | 3.15E-11                               |
| PLA/Thymol/5% CB               | 7.88E-11                               |
| PLA/Thymol/10% CB              | 7.98E-11                               |

3.3 Contact Angle
In antistatic packaging need to prevent the build-up of static electrical charge due to the transfer of electrons to the material surface. Electrostatic charging of composites can lead dust deposition, electric shocks and damages in electronic equipment therefore antistatic packaging able to dissipate or promote the decay of static electricity and could improve process ability, mold release, and give better internal and external lubrication that by ‘soap like’ molecules with a hydrophobic and a hydrophilic part. Poly lactic acid a biomaterial that have combination of biocompatible, biodegradable and have relative hydrophobic surfaces with approximate 83° from figure 7. Hydrophilic part is plasticizer thymol caused reduce intermolecular forces and increases free volume between polymer chains, which not only increases flexibility, but also water transmission to packaging containing to be higher compare to PLA because thymol is hydrophilic in nature and functional groups ends contain hydroxyl groups that increases mass transfer through the film, due to the higher mobility of the polymer chain and higher free volume that mean thymol and rearranged the polymer chains and increased the free volume in the polymer matrix that important in antistatic packaging to reduce static in surface[20].

The water contact angle of pure PLA and PLA/thymol/carbon black composites with different is shown in figure (7) and Table (3) decreased from 83°-45° with the addition of thymol and carbon black up to 10%; this was due to the hydrophilicity of carbon black and high porosity on its surface and high-structure Carbon Blacks, and in particular oxidative post-treated Carbon Blacks, are more likely to have elevated moisture content levels that increased contact angle with water.
Figure 7: Contact angle of pure PLA and PLA/thymol/carbon black composites

Table 3: Contact angle of pure PLA and PLA/thymol/carbon black composites.

| Sample                  | Contact angle |
|-------------------------|---------------|
| Pure PLA                | 83.9°         |
| PLA/thymol (95/5)       | 77°           |
| PLA/thymol/CB 0.5%     | 76°           |
| PLA/thymol/CB 1%       | 74°           |
| PLA/thymol/CB 3%       | 66°           |
| PLA/thymol/CB 5%       | 51°           |
| PLA/thymol/CB 10%      | 45°           |

3.4 Color and brightness
Color is important factors to be considered in packaging since it could influence consumer acceptance and commercial success of product. PLA is highly transparent and colorless in the visible region of the spectra (400–700 nm) that havee transparent is 90.05% and the brightness is percentage reflectance of light at wavelength 457 nm show that high brightness in pure PLA that is 80.88% that appear in Table (4). For PLA/thymol that transparent is 89.87 and brightness is 88.47% that because thymol increase of the free volume of the polymer network, as explained elsewhere, thus increasing the mobility of the polymer chains and decreasing the opacity and increased transparent and brightness by permitting a better penetration of the light. Thymol was colorless semi-transparent crystals also increased in transparent and brightness the differences among samples were not perceptible to the human eyes.
For PLA/thymol/carbon black at (0.5–10)% shows decreased in L* (Transperancy ) between in (80.55-59.69) and brightness in (81.30-50.241)% because carbon black is typically contains 96-99 % pure carbon with minimal quantities of oxygen, hydrogen and nitrogen and deep black color that carbon classified a solid in
Initially formed as an aerosol or free floating particle. The films had good transparency even at high carbon black only at 10% carbon black this composite films was suitable for antistatic packaging application.

Table 4: Color Properties of pure PLA and PLA/thymol/carbon black composite

| Sample                     | $L^*$ | Brightness% |
|---------------------------|-------|-------------|
| Pure PLA                  | 90.05 | 80.88       |
| PLA/thymol (95/5)         | 89.87 | 88.47       |
| PLA/thymol/0.5%C.B       | 80.55 | 81.30       |
| PLA/thymol /1%C.B        | 75.96 | 70.40       |
| PLA/thymol/3%C.B         | 66.30 | 61.20       |
| PLA/thymol/5%C.B         | 59.69 | 50.21       |
| PLA/thymol /10% C.B      | -69.64| -12.45      |

3.5 Thermal gravimetric Analysis (TGA)

Due to their desirable features including sustainability, eco-friendly and biodegradability, poly (lactic acid) (PLA) has been attractive in polymer industries as a new class of materials. PLA can be a suitable candidate to use in packaging, fibers, membranes, tissue engineering, automotive parts and electrical devices. The temperature corresponding to the onset of degradation $T_{\text{onset}}$ for a polymer was essential for evaluating its thermal stability. Fig (8) shows the TGA curve for pure PLA and PLA/thymol/carbon black containing 1% and 5% nanoparticles at 10 °C/min under an atmosphere of nitrogen. The $T_{\text{onset}}$ temperatures were determined regarding to their mass loss shapes appear for PLA is 387.89 °C and $T_{\text{onset}}$ increased with incorporation of the nanoparticles at the whole range of heating rates and shifted to higher temperature with (430.15- 467.58) °C and show single event of a mass loss when increased carbon black and increased the temperature of degradation of the composites. The residue mass (char residue) increased with higher carbon black content. The residual mass increases in accordance with the content of carbon black.
Conclusion:

Conventional thermoplastic polymers have extremely low degradation rates, which can cause serious problems to the maintenance of environmental equilibrium. Therefore, biodegradable polymers are widely used as an alternative to waste reduction and environmental aggression. PLA is one of the polymers that have attracted the attention of researchers due to its excellent properties, biodegradability, and thermal process ability. PLA has no conductive characteristics, it requires the addition of carbon forms, such as conductive carbon black, to render the polymer less resistive to the sinking material and making it suitable for the manufacture of antistatic packaging.

The mean conductivity of PLA/thymol/carbon black composites is increased, resulted in carbon black reinforced composites that increased the elongation, and tear resistance but reduced tensile strength, tensile modulus, and hardness. Contact angle decreased when used plasticizer and carbon black because became hydrophilic surface and high porosity surface that useful in antistatic packaging to dissipate a static charge. Color and brightness show the transparency of the pure PLA film was high that 90% whiteness (L*) and decreased but remain acceptable until 5% and became opacity at 10% carbon black. The addition of (0.5, 1, 3, 5, and 10 wt% of carbon black in the plasticizer PLA makes it possible to use this material for the production of antistatic packaging for the transportation and storage of electronic devices. However, carbon black is a great option to decrease the electrical resistivity of PLA and increased electrical conductivity that allow its use as antistatic packaging. The addition of carbon black in the PLA increases the temperature of degradation and increased thermal stability.

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