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Properties characterization of plasticized polylactic acid /Biochar (bio carbon) nano-composites for antistatic packaging

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Abstract

A new type of light-weight nanocarbon prepared by the spray-drying method to obtain particle size of 21.7 nm based on the polylactic acid biodegradable film in antistatic packaging. Biocarbon (biochar) is the carbon derived from plants, and soils to naturally absorb and store carbon dioxide from the atmosphere because it is renewability. Therefore it has been used to reinforce biodegradable polylactic acid (PLA) to obtain 100 % recyclable material.

Plasticizer thymol of polylactic acid and biochar (biocarbon) were used as composites were prepared by a solution casting method with (0.5-10) wt% biochar. The films were characterized using FTIR, electrical conductivity, mechanical properties, contact angle and color and brightness were studied. Results showed that electrical conductivity of increased with increased biochar making the composite less resistive and suitable for use as antistatic packaging for the transportation and storage of electronic components. Mechanical tests showed reduced tensile strength and tensile modulus but increased in elongation. Also Tear Resistance and Hardness decreased because used thymol as plasticizers at PLA/thymol (95/5) and films composites change from brittle to ductile. The results of the contact angle of pure PLA is 83° means hydrophobic materials and decreased to 54° at PLA/thymol/biochar 10% to obtain hydrophilic materials which is able to dissipate or promote the decay of static electricity and improve the processability of the electronic device. Optical properties such as color and brightness showed decreased but suitable for antistatic packaging and became opacity at 10% biochar.

Key words
Polylactic acid, biochar (biocarbon), antistatic packaging, contact angle.

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تشخيص مواصفات المتراكب لملدن البولي لاكتك اسد مع الكاربون الحيوي في الاغلفه ضد الكهربائيه الساكنه

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الخلاصة

تم تحضير نوع جديد من الكاربون النانوي بطريقه التجفيف – الرش وتم الحصول على الجسيمات بحجم حبيبي 21.7 نانو متر استخدم مع البوليمر الحيوي المتحلل البولي لاكتك اسد في تطبيق الاغلفه ضد الكهرباء الساكنه. الكاربون الحيوي المستخدم تم الحصول عليه من النبات والاشجار الذي يمتص غاز ثاني اوكسيد الكاربون القابل للتجديد. تم استخدامه كمواد تقويه في البولي لاكتك اسد الحيوي للحصول على متراكب متحلل بنسبه 100%.

تم استخدام الملدن الثايمول مع المتراكب بولي لاكتك اسد والكاربون الحيوي لتحضير المتراكب بطريقه الصب بنسب مئويه وزنيه تراوحت بين wt% (0.5-10)، تم التشخيص باستخدام تحويلات فورير للاشعه تحت الحمراء والتوصيليه الكهربائيه والخواص الميكانيكيه وزاويه التماس واللون وشده السطوع. اظهرت النتائج بان التوصيليه الكهربايه تزداد مع زياده نسبه الكاربون الحيوي والتي تجعل المتراكب ذات فائدة ومناسب لاستخدامه في التغليف المضاد للكهرباء. اما الفحوصات الميكانيكيه اظهرت انخفاض في معدل الشد ومعامل الشد مع زياده في معدل الاستطاله ومقاومه التمزق والصلادة بسبب استخدام الثايمول كملدن بنسبه 5% وبذلك تتغير الماده من السلوم الهش الى اللدن. نتائج زاويه التماس للبوليمر بولي لاكتك اسد هي 83° والتي تبين بان الماده كاره للماء وانخفضت في المتراكب لتصل الى 54° لتتحول الى السلوم المحب للماء الذي يعمل على تقليل من الكهرباء والشحنات المتولده على السطح وتحسين قابليه الغلاف. نتائج فحص اللون والسطوع انخفضت بشكل قليل ولكنها مناسبه للتغليف ضد الكهربائية الساكنه وازدات عتوميه عند النسبه 10 % من الكاربون الحيوي.

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 allotropic 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].

Biochar (bio-carbon) remaining solid product obtained from the pyrolysis of biomass product, is porous a carbonaceous material occurs when lignocellulosic biomass is pyrolysis at temperatures (~>350–400 °C) in limited or neutral oxygen environment, which means the cost of biochar is much lower compared with other carbon products and degradability[5]. Highly carbonized biochar (>90 wt.% of carbon) is chemically stable under ambient conditions. Biochar (bio-carbon) low cost and economical aspect are critical, that is finding applications in composite/polymer sector and able to increase mechanical, electrical and thermal properties and eco-friendly carbon-based material are in different fields and biochar could become me a leader among carbon materials in composites [6]. In general, the application of biocarbh-based, high hardness/stiffness, inert towards fire) to develop novel polymer composites [7].

Biocarbon (biochar) is contains of amorphous carbon structures and turbostratically stacked graphene sheets, that make the conductive phase of the composites and antistatic application, that depending on the processing temperature and preparation biocarbon that obtain a good conductor of electricity, and the high specific area of these materials allows for low loadings to be sufficient to fundamental properties concerning mechanical, thermal, electrical, and contact angle of plastic materials [8].

In plastics materials are inherently isolative average 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 to tends to hold electrostatic charges and allow electromagnetic radio frequency interference (EMI=RFI) to pass thorogh [9]. An antistatic packaging is used to prevent the buildup of static electrical charge from the transfer of electrons to the surface of the plastic. Nowadays, plastic has replaced metals and become the materials for internal in electronic components because they have greater in flexibility, lighter weight, colorability 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 (Fig.1) [10].

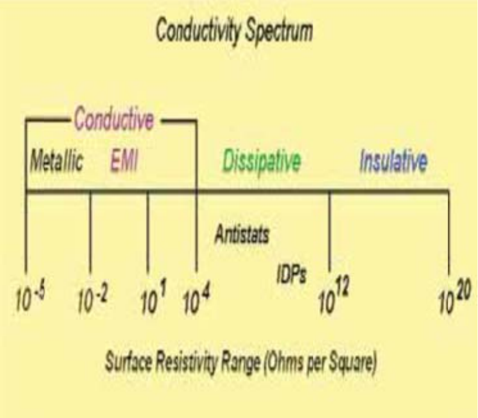

Fig.1: Surface resistivity of materials.

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 hard drive, sound card, or video card [11].

Nan et al. [12] showed and synthesis of polyvinyl alcohol and biocarbon (biochar) by casting method in (2-10 wt%) to characterized the electrical conductivity, mechanical and thermal properties finally shows the mechanical reduced the tensile strength of the PVA/biochar composites but improved in electrical, thermal gravimetric analysis that means biochar holds great potential to replace the carbon nanotubes (CNT) and graphene as a filler of polymers in electrical applications.

Surface wettability has an important role in antistatic packaging that wetting is commonly characterized by the contact angle, which is defined as the angle between the tangent to the liquid–vapor interface and the solid surface at the three-phase contact line that a low contact angle is obtained when the liquid phase spreads on the surface, while a large contact angle is observed when the liquid phase beads on the surface [13]. Hydrophobic polymers such as polylactic acid generate static electricity during processing, causing dangerous explosions and attract dust, that causes a problem in PLA films is usually solved by adding hydrophilic additives in polymer carrier such as with additives having molecules with one hydrophilic end that migrates to the surface of the film [14]. Once on the film surface, the hydrophilic materials is 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 [15].

The purpose of this work is using spray–drying method to prepare nano bio carbon and provide a very homogeneous mixture between the composites. The effect of different contents of biocarbon was also investigated. mechanical, electrical, color and contact of antistatic packaging based on biodegradable polymers to replace alternative polymers such as Polyethylene terephalate (PET) used in antistatic packaging.

Experimental work

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

Biochar (biocarbon): Biochar material were prepared by spray – drying method to produced nano biochar. Biochar pellets were swelling in water (5gm to 100ml) and used a spray-drying method of producing a dry powder from a liquid or slurry by rapidly drying with hot gas, depending on the process needs, drop sizes from 5 to 500 μm can be achieved with the appropriate choices. The dry powder is often free-flowing, and biocarbon filler with a particle size (21.7 nm) is shown in Fig.2 measured by SPM of nano biocarbon.

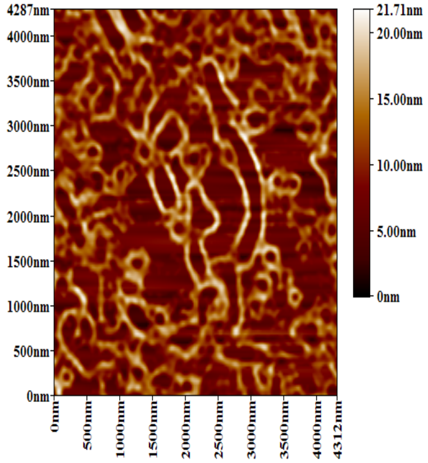

Fig.2: Granularity normal distribution chart for nano biocarbon.

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 20 cm in diameter at room temperature for 24 hours to ensure complete solvent removal.

PLA/thymol/nano biocarbon composite films were prepared by swollen biochar (biocarbon) in chloroform by mixed for one hour, and add PLA/thymol solution until homogenous and even black and evaporate in room temperature (25 °C and a relative humidity with 50 %) until films were formed and cut into test (Fig.3).

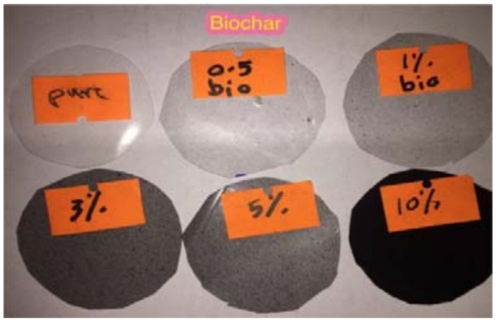

Fig.3: Samples of pure PLA and PLA/thymol /biochar composites.

Characterizations

Thickness: Determination of thickness of pure PLA and PLA composites calculated by electronic digital micrometer used to measure the thickness of composites films and find that is 0.110 mm.

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

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

$$\rho = R.Al \quad (1)$$

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:

$$\sigma dc. = 1/\rho \quad (2)$$

The activation energies could be calculated from the plot of Ln σ versus l000/T from Arrhenius equation to obtain the Activation Energy (Ea) by the following formula:

$$\sigma = A \exp(-Ea / K_B T) \quad (3)$$

K_B is the Boltzmann's constant which is 1.3806×10^{-23} J/K, T is the temperature in Kelvin. The Ea is in practice taken to be the slope of an Arrhenius plot of ln (σ) versus $1/T$ in Kelvin [16].

Mechanical properties

Tensile strength: According to ASTM D-882 [17] 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 (σ_S), Young's modulus (E) were determined according to the following equation:

$$\sigma_s = F / A \quad (4)$$

$$E = F L_0 / A \Delta L \quad (5)$$

where: F: force exerted on an object under tension, L_0: original length, A: cross section area, ΔL: length of the object changes.

Tear strength: Tear strength of films was determined on the same Universal Electronic Dynamometer according to ASTM D-1922[18] 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.

Hardness: The experiment was conducted at room temperature (25C) with50% humidity. The values of hardness that measured by Shore A durometer) according to ASTM D 2240 [19].

Optical properties

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 a difference (ΔE) was evaluated by Eq. (6) [20].

$$\Delta E = \sqrt{\Delta a2 + \Delta b2 + \Delta L2} \quad (6)$$

where: ΔL = L stander*-L sample, Δa = a stander*– a sample, Δb = b stander*-b sample, Stander values for white plate were L = 96.86, a = - 0.02 and, b = 1.99 respectively for pure polylactic acid.

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 sec, for a period of 20 min. Swelling tests were carried out according to ASTM D7334 [21]. The value of the contact angle indicates how hydrophobic the surface is mean large contact angle whereas a small contact angle indicates to a hydrophilic surface.

Results and discussion

FTIR of a chemical substance shows marked selective absorption in the infrared (IR) region. Fig. 4 shows the peaks of pure PLA appear peaks at 1418, 2994 and 3600 cm^{-1} was assigned to the C–O, C–H(double) and O–H stretching of the –CH(CH$_3$)–OH end group of PLA, respectively. PLA the peak at 3000-2850cm^{-1} were assigned to the –C–H asymmetric and symmetric vibration of CH$_3$ groups in the side chains, peak at 3424 cm^{-1} of -OH. The peak at 2921cm^{-1} asymmetric stretching –CH$_2$, 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 appear at peal at 1414 cm^{-1} of–CH$_3$ 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.

Fig.4 represents PLA/thymol/ biochar composites, the band at –C–O bond stretching (955 cm^{-1}) in –CH–O– groups, bands at 730 and 805 cm^{-1} owing to ring vibrations of aromatic groups. Presence of thymol evidenced by the presence of phenolic groups bands from 3650 to 3200 cm^{-1}, and at 1000-970 cm^{-1} corresponding to C-O bending.

The bands of biochar is appear at 734 cm^{-1} 875 cm^{-1}, 1436 cm^{-1}, 1517 cm^{-1}, 1681 cm^{-1} and a very bands in the range of (2920 – 3400) cm^{-1}. These peaks correspond to the vibrational deformation of aromatic C-H and C-O from carbonates, C-O vibrations from leftover carbohydrates present in the parent feedstock, C-O vibrations from esters, aromatic vibrations of C-H or C-O vibrations from carbonates, carbonyl vibrations C-C and vibrations, carbonyl vibrations within carboxyl groups, carboxylic anhydrides and ketones, aliphatic C-H vibrations, aromatic C-H vibrations and hydroxyl vibrations respectively. The peak at around (2920– 3400) cm^{-1} of O-H groups present in the biochar, there was greater absorbance from 1700 to 1740 cm^{-1} about the stretching of the carboxyl group (C=O) and the C=C molecular bonds of the aromatic compounds. Polar functional groups that can form and enhance bond ability include carbonyl (C=O), carboxyl (HOOC), hydroperoxide (HOO-), and hydroxyl (HO-) groups. Even small amounts of reactive functional groups incorporated into polymers can be highly beneficial to improving surface characteristics and wettability.

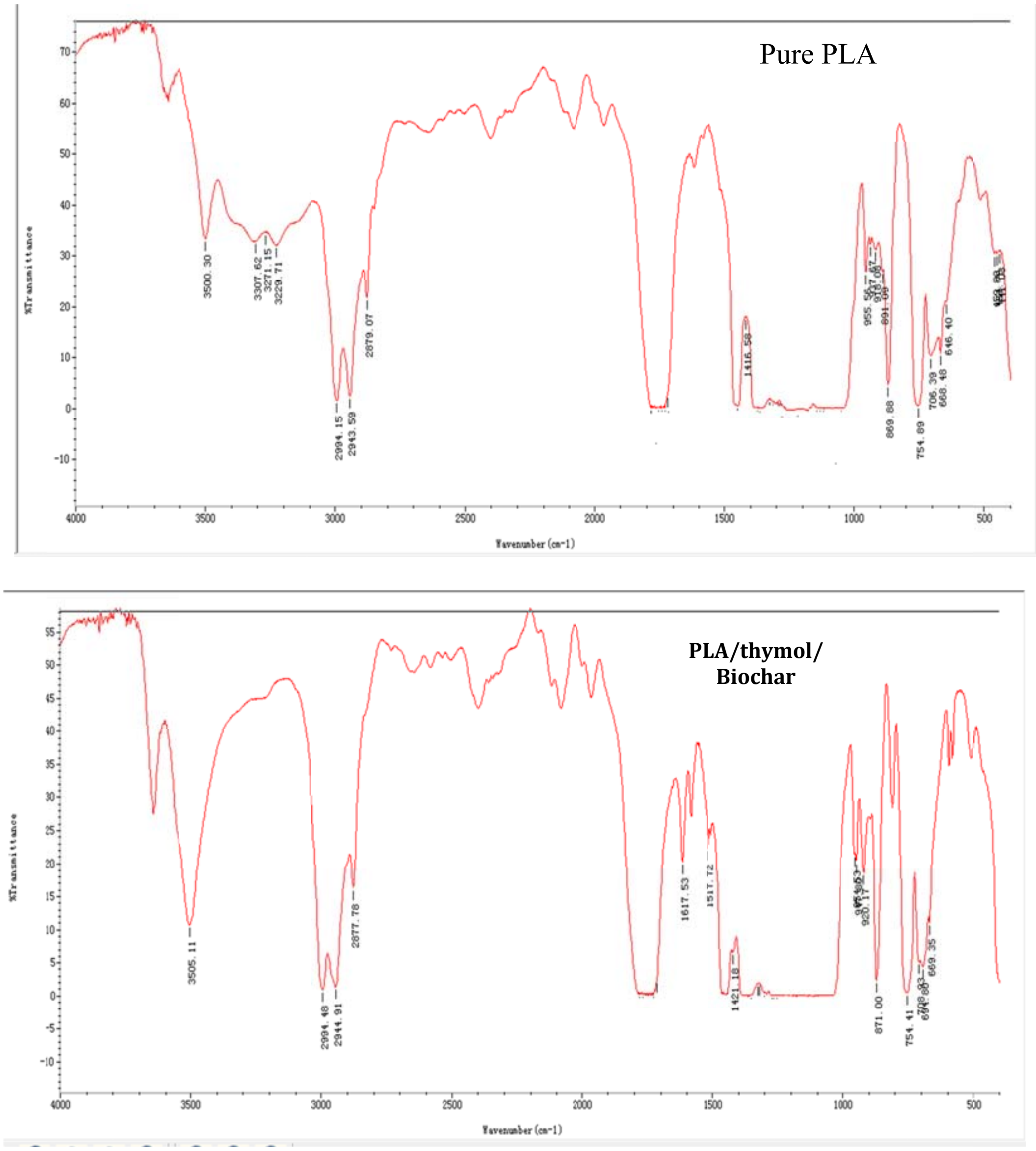

Fig.4: FTIR of pure PLA and PLA/thymol /Biochar composites.

Mechanical properties

The mechanical test of the polylactic acid matrix was modified upon the addition of biocarbon fillers. 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].

The composites intended for antistatic packaging applications required flexibility to avoid cutting during the packaging procedure that means need materials to high flexibility. The goal of blending with thymol with PLA was to enhance polymer elongation and reduce the brittleness of PLA. Plasticizer addition to PLA matrix was to decrease the rigidity of PLA and increase the ductility due to capability to 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. It could be seen that blending PLA with thymol decreases 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.

In PLA/thymol /biochar nanocomposites decreased in tensile strength, Young Modulus the combined action of thymol and biochar on the PLA mechanical behavior was resulting in more flexible and stretchable materials because the presence of the thymol ability to increase the PLA chain mobility, which also promoted a more effective dispersion of nanoparticles. These combined effects could be related to the presence of Van der Waals interactions between the hydroxyl groups of thymol appear in FTIR.

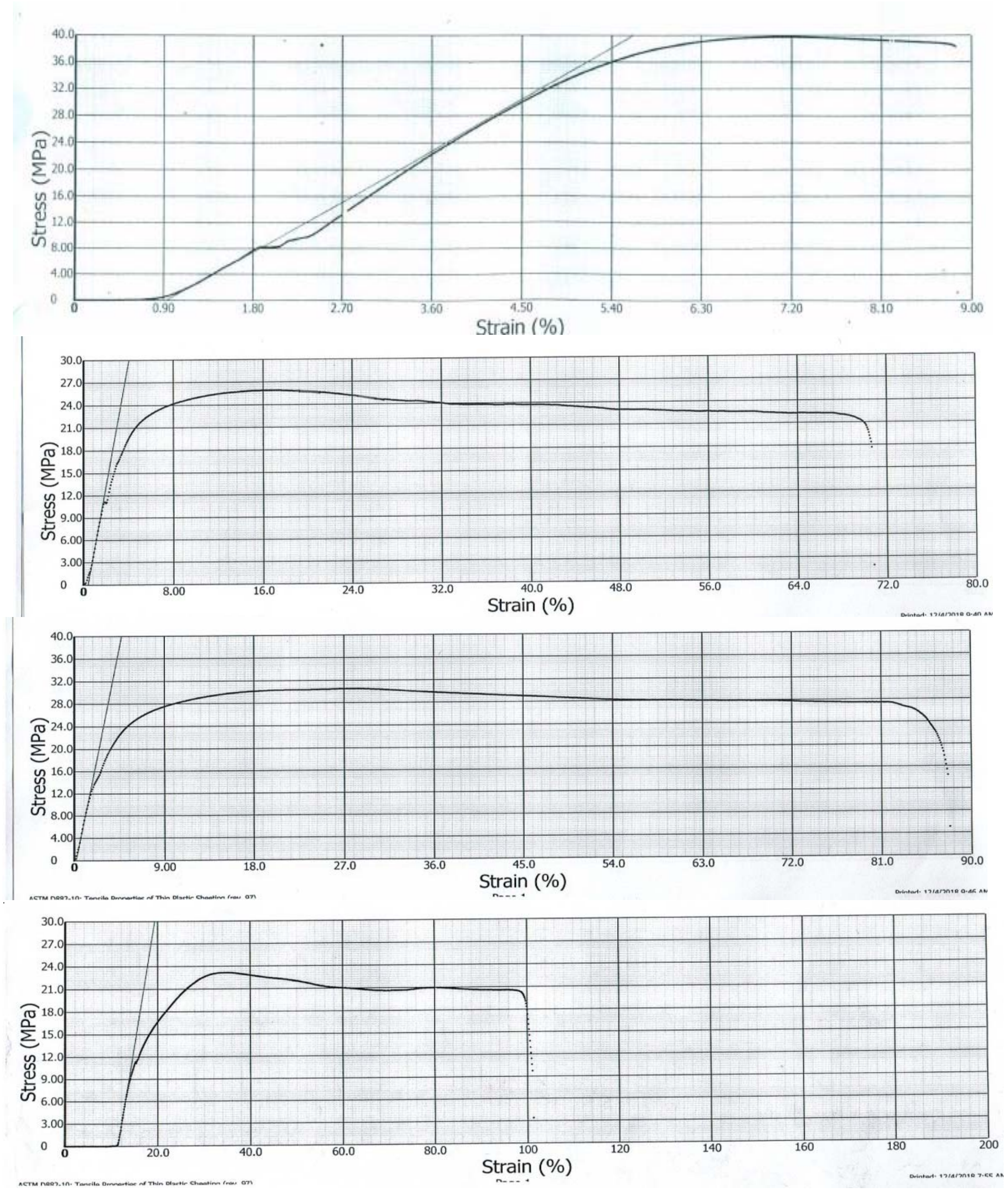

Fig.5: Mechanical properties of pure PLA and PLA/thymol /Biochar composites.

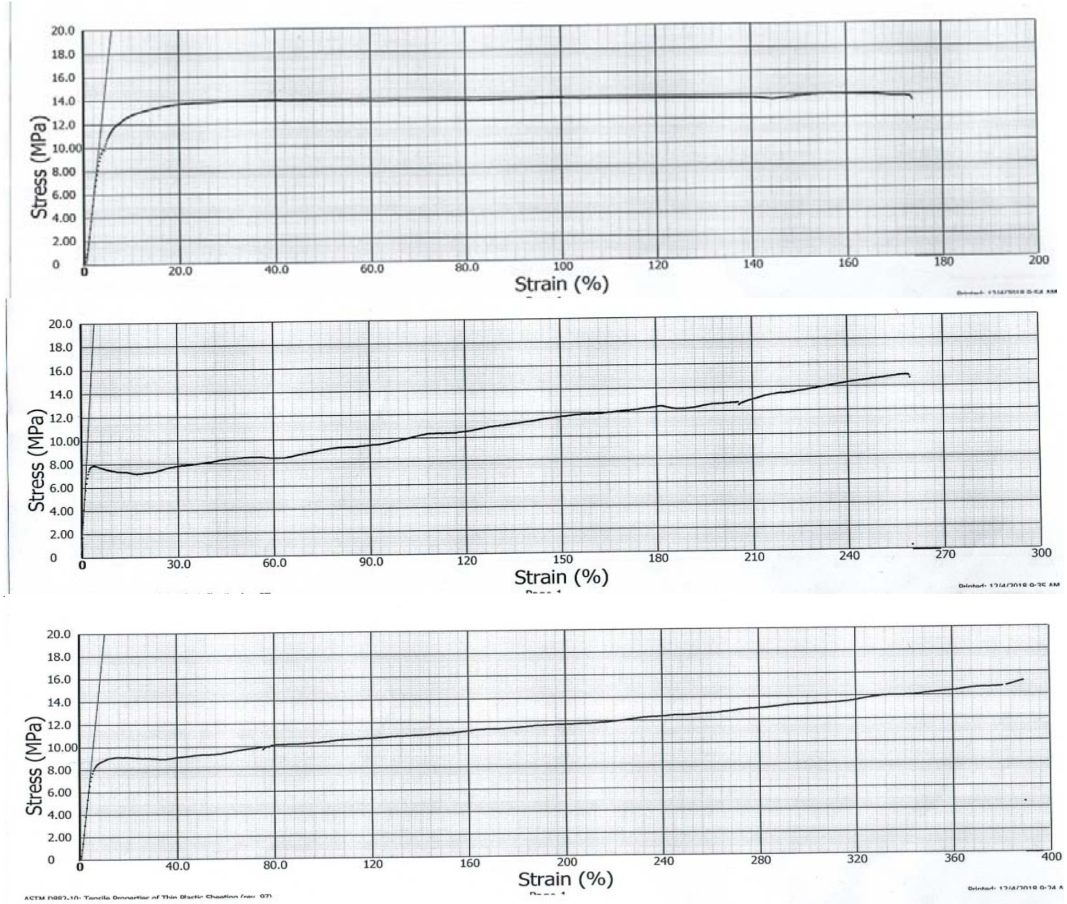

Fig.5: Mechanical properties of pure PLA and PLA/thymol /Biochar composites.

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 of 12.5 mN/mm. It is obvious that addition of thymol and biochar improvement in tear resistance between (13.4-25.7 mN/mm) dramatically by the incorporation of the biochar particles. This can be explained by considering that the biochar contain layers of graphite are able to inhibit or at least to slow down crack propagation by deviating their tear path.

Also Table 1 shows that increased the 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 97.10 when used plastizers thymol because appear more flexible plastic but causes a loss of strength and hardness (that direct proportion to tensile strength) between (97.53-88.76) the hardness in ductile materials decreased and also increased the contain of carbon.

Table 1: Mechanical properties of pure PLA, PLA/thymol and PLA/thymol /biochar.

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	13.4	97.60
PLA/Thymol/0.5%biocahr	1.94	13.1	97.53
PLA/Thymol/1%biochar	1.55	14.3	97.10
PLA/Thymol/ 3%biochar	1.30	16.5	96.53
PLA/Thymol/5%biochar	1.14	19.7	96.33
PLA/Thymol/10%biochar	1.09	25.7	88.76

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} Ω /cm) for an antistatic film [11].

The electrical conductivity of the pure PLA is shown in Fig.6 and the conductivity is 1.39E-12(S/cm) because PLA is characterized by high resistivity and insulator materials, a tendency toward static electricity. The conductivity of PLA/ thymol / biochar composites increased by increasing the content of biocarbon due to the decreased insulated space between biocarbon particles and matrix polylactic acid. Depending on the processing increased temperature, bio-carbon can be a good conductor of electricity. The nongraphic structures of biochar held abundant functional groups that have the potential to form more bonds with a polymer matrix. The surface area of nano biochar allowed for stable matrices to develop at the polymer-filler interface to positive effects in terms of electrical conductivity and increased between (2.31 E-12 S/cm to 6.09 E-12 S/cm) at room temperature appear in Table 2.

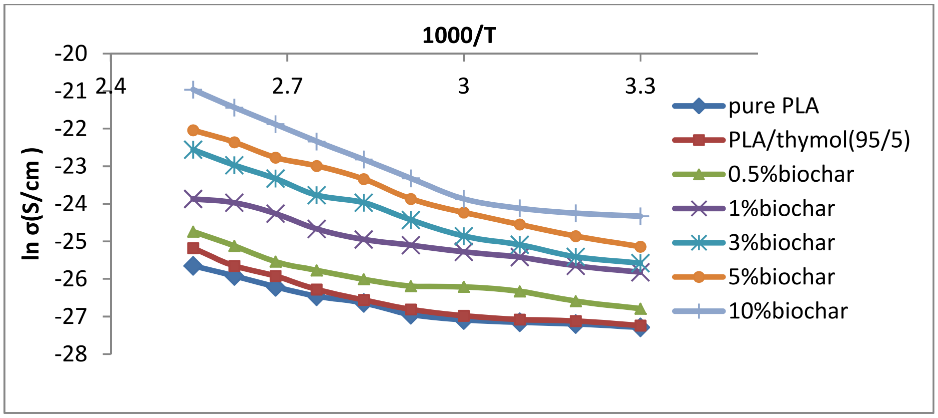

Fig.6: Electrical conductivity of pure PLA and PLA/thymol/biochar composites.

Table 2: Electrical conductivity values of pure PLA and PLA/thymol/biochar 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% biocahr	2.31 E-12
PLA/Thymol/1%biochar	2.52 E-12
PLA/Thymol/ 3%biochar	3.86 E-12
PLA/Thymol/5%biochar	4.13 E-12
PLA/Thymol/10%biochar	6.09 E-12

Contact angle

The 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 is biomaterials that have relative hydrophobic surfaces with approximate 83˚ from Fig.7.

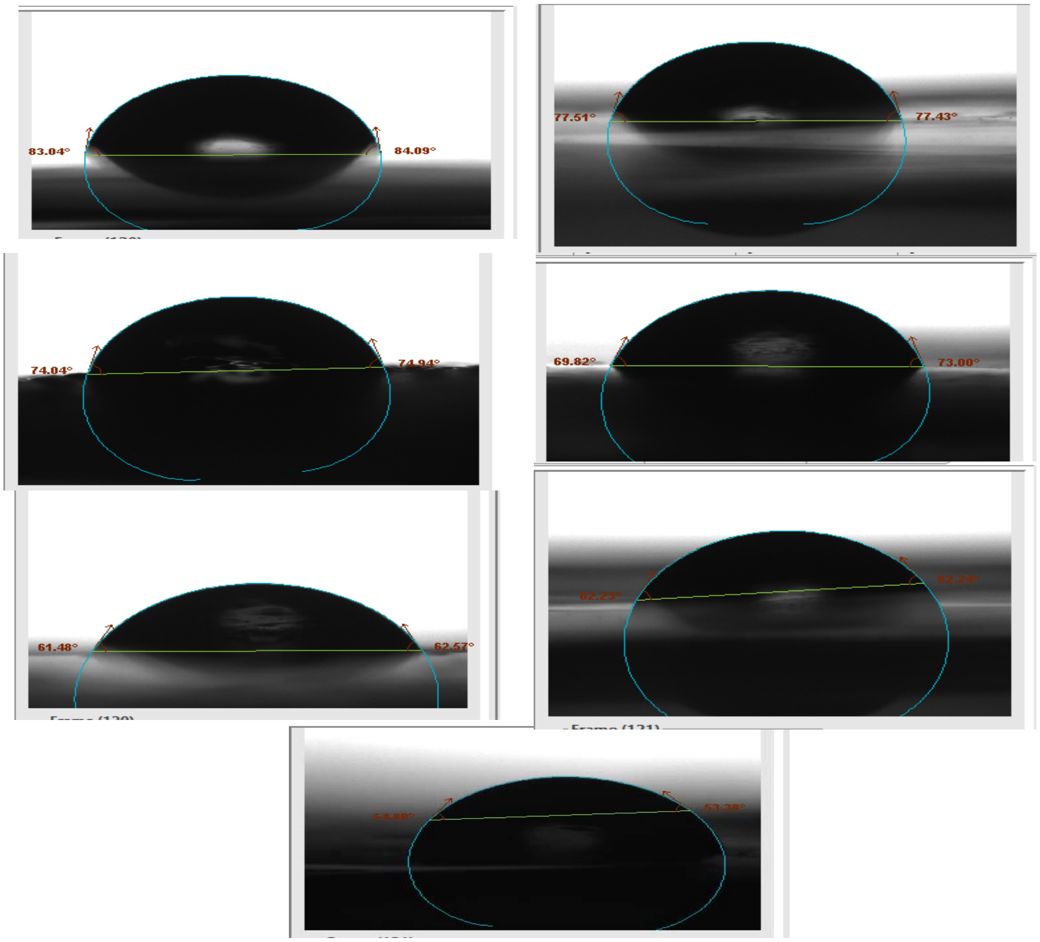

Fig.7: Contact angle of pure PLA and PLA/thymol/biochar composites.

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 that 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.

The water contact angle of pure PLA and PLA/thymol /biocarbon composites with different is shown in Fig.7 and Table 3. The water contact angle decreased from 80°-54° with the addition of thymol and biocarbon up to 10%; this was due to the hydrophilicity of biocarbon and high porosity.

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

Sample	Contact angle
Pure PLA	83.9°
PLA/thymol (95/5)	77◦
PLA/thymol /biocahar 0.5%	74°
PLA/thymol /biocahar 1%	69°
PLA/thymol /biocahar 3%	61°
PLA/thymol/biocahar 5%	56°
PLA/thymol/biocahar 10%	54°

Color and brightness

Color is important factors to be considered in packaging since it could influence consumer acceptance and commercial success of the product, the addition of biochar to the film shifts slightly the L* coordinate from white to black. PLA is highly transparent and colorless in the visible region of the spectra (400–700 nm) that have transparent is 90.05% and 88.87 of PLA/thymol seen in Table 4. Brightness is percentage reflectance of light at wavelength 457 nm show that high brightness in pure PLA that is 80.88% and 88.47% for PLA/thymol, that because 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. Plasticizers thymol was colorless and semi-transparent also increased in transparent, and brightness of the differences among samples was not perceptible to the human eyes.

Table 4: Color properties of pure PLA and PLA/thymol/biochar composite.

Sample	L^*	Brightness%
Pure PLA	90.05	80.88
PLA/thymol (95/5)	89.87	88.47
PLA/thymol/0.5%biochar	85.18	80.36
PLA/thymol /1%biochar	79.96	75.22
PLA/thymol/3% biochar	76.04	70.64
PLA/thymol/5% biochar	66.30	60.41
PLA/thymol /10% biochar	-11.75	-65.99

Table 4 shows Color parameter of pure PLA and LA/thymol/biochar composites decreased in L* (Transparency) between in (85.18-66.30) and brightness in (80.36-60.41)% because that biochar consists of amorphous carbon in structures and turbostratically stacked sheet of graphene and when used maximum amounts of biochar in composites produces a slight variation and the film become opacity and give black color to film.

Conclusion

Biocarbon (biochar, charcoal) structures have gained much attention owing to the hierarchical architecture of their cellular pore structures and the ability to produce complex shapes; the nano biochar is prepared by a spray-drying method with 21.7 nm diameter. The sheet of graphite of carbon has a significant impact on its properties, i.e., the electronic, mechanical, contact angle and color test. In this work, the electrical conductivity of PLA/thymol/bio-char composites is increased, resulted in bio-carbon reinforced composites that have biochar increased the elongation, and Tear resistance but reduced Tensile Strength and Tensile Modulus and hardness. Contact angle decreased when used plasticizers and biochar because became hydrophilic 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% biochar.

References

[1] Justine Muller, Chelo González-Martínez, Amparo Chiralt, Materials, 10, 8 (2017) 1-22.

[2] M.A. Bonifacio, S. Cometa, M. Dicarlo, F. Baruzzi, S. De Candia, A. Gloria, E. De Giglio, Carbohydr. Polym., 166 (2017) 348-357.

[3] J. Valdez-Garza, C. Avila-Orta, V. Cruz-Delgado, P. Gonzalez-Morones, G. Hurtado-Lopez, M. Waldo-Mendoza, Z. Quinones-Jurado, J. Perez-Medina, Boletín del Grupo Español del Carbón, 44 (2017) 8-9.

[4] Kanchana Boonruang, Wannee Chinsirikul, Bongkot Hararak, Noppadon Kerddonfag, Vanee Chonhenchob, MATEC Web of Conferences, 67 (2016) 1-7.

[5] Peter Quosai, Andrew Anstey, Amar K. Mohanty, Manjusri Misra, ”Characterization of biocarbon generated by high- and low-temperature pyrolysis of soy hulls and coffee chaff: for polymer composite applications” R Soc Open Sci., 5, 8 (2018) 1-16.

[6] A. Anstey, S. Vivekanandhan, A. Rodriguez-Uribe, M. Misra, AK. Mohanty, Sci. Total Environ., 550 (2016) 241-247.

[7] W. Suliman, JB. Harsh, NI. Abu-Lail, AM. Fortuna, I. Dallmeyer, M. Garcia-Perez, Biomass Bioenergy, 84 (2016) 37-48.

[8] CH. Chia, A. Downie, P. Munroe, 2015. In Biochar for environmental management (eds Lehmann J, Joseph S.), pp. 89–109, 2nd edn New York, NY: Taylor and Francis.

[9] F. You, X. Li, L. Zhang, D. Wang, C. Shi, Z. Dang, RSC Adv., 7 (2017) 6170-6178.

[10] W. Bauhofer, J.Z. Kovacs, Compos. Sci. Technol., 69 (2009) 1486-1498.

[11] Zoe Vineth Quiñones-Jurado, Miguel Ángel Waldo-Mendoza, José Manuel Mata-Padilla,Pablo González-Morones, Juan Guillermo Martínez-Colunga, Florentino Soriano-Corral, Víctor Javier Cruz-Delgado, Ronald Francis Ziolo, Carlos Alberto Avila-Orta, Polymers, 10, 55 (2018) 1-12.

[12] Nan Nan, David Devallance, Xinfeng Xie, Jingxin Wang, Journal of

Composite Materials, 50, 9 (2016) 1161-1168.

[13] Ville Liimatainen, Maja Vuckovac, Ville Jokinen, Veikko Sariola, Matti J. Hokkanen, Quan Zhou, Robin H.A. Ras, Nat. Commun., 8, 1798 (2017) 1-7.

[14] Arijit Basu, Michael Nazarkovsky, Rohan Ghadi, Wahid Khan, Abraham J. Domb, Polym. Adv. Technol., 28 (2016) 919-930.

[15] Mina Davoodi, Gholamreza Kavoosi, Raheleh Shakeri, International Journal of Biological Macromolecules, 104 (2017) 173-179.

[16] P.P. Tsai, R.R. Bresee, Journal of Applied Polymer Science, 82, 11 (2001) 2856-2862.

[17] ASTM D882 (2010) Standard Test Method for Tensile Properties of Thin Plastic Sheeting Volume: 08.01.

[18] ASTM D1938 (2014)Standard Test Method for Tear-Propagation Resistance (Trouser Tear) of Plastic Film and Thin Sheeting by a Single-Tear Method.

[19] ASTM D2240-15e1(2010) Standard Test Method for Rubber Property—Durometer Hardness.

[20] Handbook of Polymer Applications in Medicine and Medical Devices Published by Elsevier, 2014.

[21] ASTM D7334 - 08(2013) Standard Practice for Surface Wettability of Coatings, Substrates and Pigments by Advancing Contact Angle Measurement.