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Understanding Some Properties of Linear Low-density Polyethylene/*Cornstalk Dracaena* Leaves Composites: Towards Effective Utilization of Agricultural Wastes

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Abstract: The indiscriminate disposals of waste packaging materials from fossil based plastics in our lands, canals, roads, waterways, rivers, oceans, etc has continued to pose great threat to our environment, economy, food security, human health over time due to their prolong shelf life, cost effectiveness, ease of processing and non-biodegradable characteristics. It is essential to search for the effective techniques to mitigate these consequences emanating from plastic based polluted environment. Hence, this research prepared linear low-density polyethylene/*cornstalk dracaena* leaves (LLDPE/CSD) composite samples using different particle sizes (75 – 600 μm), filler contents (0– 35 g) and temperature range of 110 - 120ºC with injection moulding technique. Some mechanical properties and biodegradable response of the prepared composite samples were subjected to material characterization. The results of tensile strength, tensile modulus, impact strength and hardness characteristics of the composite samples revealed gradual improvement with increase in filler content up till 25g and followed by gradual reduction. However, the response of filler content on the elongation at break properties for the composites samples was a reverse case. The soil burial result confirmed that presence of CSD leaves powder as filler within LLDPE matrix created favourable sites for microbial attack on the composite substrates. Also, amount of water absorbed by the composite samples presents the evidence of water-liking (hydrophilic) sites within the structure of the composite's samples. Finally, is it deduced from our result that composite samples produced has potentials in packaging applications, orthotics and fabrication of household items. Also, we deduce that filler content of 25 g gave the optimum value for the composites, and also the presence of *Cornstalk Dracaena* leaves powder as filler has the potentials to improve properties of LLDPE matrix and as well subject the matrix waste to biodegradation.

1. Introduction

Municipal solid waste (MSW) is regarded as solid waste emanate from industrials, households, offices, markets, industries, schools, churches, restaurants, hotels, etc. and waste products found in the municipal solid wastes include; scrap metals items, food items, clothing, wood or furniture, papers,

cans, glass, batteries, plastic materials, appliance, etc (Iorhemen *et al*., 2016), (Staley *et al*., 2009). In fact, MSW are broad range of waste materials that are challenging or handle and most times they are difficult to undergo effective recycling due to their different nature, complexities and potential negative environmental effect associated with them. Among these wastes, plastic waste materials from fossil fuels are one of the major contributors of total municipal solid wastes found in our water bodies (rivers, oceans), landfills, etc (Pattnaik *et al*., 2010), (Adnan *et al*., 2020). Waste materials from plastics are regarded as discarded plastic materials that are no longer needed for use, have lived out their shelf-life and are intended for disposal. The continuous pushing of these form of wastes to the environment pose threat to the environment, wildlife, ecosystem, human beings, etc. due their non-biodegradable characteristics and risk of consumption of microplastics by animals and in turn man (Momodu *et al*., 2021).Waste materials from plastics include; single-used plastics or one-time used item (e.g bottles, plastic bags, utensils, straws and packaging materials), plastic packaging materials (these are films or sheets used for packaging beverages, food, electronic appliances, consumer goods, and other products), discarded plastic containers (such as jars, tubs, trays, and blister packs, etc), discarded plastic items like toys, furniture, appliances, electronics, and construction materials. These wastes are difficult to sort and manage as they don't degrade easily and usually requires hundreds to thousands of years to initiate degradation and this is made worse by man's approach to waste management practices. Some effective waste plastic management involves effective strategies such as; reuse, recycling, proper disposal, plastic consumption reduction, etc. Reuse, recycling and alternative to one-time use plastics techniques possess the potentials to conserve depleting resources, reduce demand for production of new plastics, mitigate the negative environmental effect of plastics wastes and address the plastic pollution problem (Buttol *et al*., 2007), (Kwesiga *et al*., 2018), (Chun *et al*., 2012). However, these approaches require carefulness and stringent measures because allowing plastic waste materials to litter uncontrollable in the environment assist in generating and circulating hazardous substances that have adverse effects on the environment, economy, aquatic and man's health. Furthermore, many researchers have made concerted effort to minimize the problems of plastic wastes pollution through the use of reuse, recycling and incineration approaches, but these approaches are inefficient and unsustainable since recycling is not applicable in all polymers and incineration is less attractive since it releases toxic and corrosive gases to the environment (Moghadam *et al*., 2013), (Obasi *et al*., 2013), (Tanjung *et al*., 2023)

Recently, some researchers have proffered solutions to the problem of plastic wastes through the production and use of environmentally friendly and degradable polymers, especially for packaging purposes and for other end-use applications with the incorporation of filler from natural sources such as cellulose, starch, plant leaves, shells and bones from animals, etc (Obasi *et al*., 2013), (Monica *et al*., 2015), (Opara *et al*., 2023). The environmentally friendly, compostable and degradable polymers are materials engineered or modified with bio-fillers tend to undergo degradation process under composting conditions such as oxygen, micro-organisms, and sunlight (UV light), etc (Opara *et al*., 2023), (Oguzie *et al*., 2021), (Iyke *et al*., 2022). The demand for the use of biodegradable and compostable polymers for packaging applications as a replacement for fossil based polymers (Ochiagha *et al*., 2013) is still growing because much wastes are still being generated in our environment due to increase in the material usage caused by rapid increase in the world population, lack of effective government policies and regulations, lack of enforcement of few available policies and regulations, poor collaborative support from the academia in creating effective awareness on the dangers of plastic wastes in the environment. Globally, many researchers are being engaged in the synthesis of novel polymeric materials and processing techniques with natural fillers aimed at

improving the environmental quality of plastic products and as well as saving the environment by keeping it green (Jin *et al*., 2020). Polymer-natural filler composite has the potentials to offered a smart alternative to mitigating environmental problems associated with conventional polymers (Opara *et al*., 2023; Iyke *et al*., 2022; Eze *et al*., 2017; Die *et al*., 2023) and in the same vein ensure that the polymer filled composites are biodegradable and compostable, cost effective and possess enhanced stiffness require for some specific applications (Opara *et al*., 2023; Tabaght *et al*., 2023; Eze *et al*., 2017; Azzaoui *et al*., 2016). Linear low-density polyethylene (LLDPE) belongs to a class of polyethylene family and it is a thermoplastic polymer with linear molecular chemical structure with significant short chain branching (Shixaliyev *et al*., 2020). It is commercially produced by copolymerization of ethylene monomer and other higher alpha-olefins at low temperatures and pressures in the presence of metal catalysts (particularly Philips or Ziegler type) in either solution or gas phase reactor. The applications of LLDP are limited to agricultural films, stretch wraps, liners, pouches, packaging films or wrap, pipes, flexible tubing, lids, toys, covers and geo-membranes (Meiru *et al*., 2022) due to its unique properties including narrow molecular weight, rheological properties, high tensile and impact strength respectively, high puncture and stress cracking resistance, good resistance to chemicals and electrical properties, cost effectiveness, etc (Evode *et al*., 2021), (Zhang *et al*., 2024), (Jeyapragash *et al*., 2020)

Cornstalk Dracaena (Dracaena fragrans) is a species of flowering plant and shrub that grows at slow rate and found in forest habitats in tropical Africa. It has multi-stem at the base and mature specimen reaches about 15 m (49 ft) tall or more with narrow crown of slender and erect branches and stem of about 30 cm (12 in) diameter. The leaves are glossy green and lanceolate with length of 20–150 cm and width of 2–12 cm while larger leaves droop under their weight smaller leaves spread erect. The flower is produced in panicles and has diameter of about 2.5 cm with a six-lobed corolla. It is usually pink at first, has white opening with a fine red or purple central line on each lobes. The flowers give out high fragrant and produces orange-red berry fruit about 1–2 cm in diameter as shown in **Figure1** (Rojas-Sandoval *et al*., 2020), (Jiang *et al*., 2021).

Having considered the useful applications of LLDPE, its negative impact in the environment when the wastes are uncontrollably disposed and the fact that *Cornstalk Dracaena* is a flowering plant which does not provide food to man and animals at the time of this study, the development of composites using LLDPE and *Cornstalk Dracaena* leaves powder as filler is justifiable. The use of bio-filler from the *Cornstalk Dracaena* leaves has a lot to offer in the field polymer composite because it is non-toxic, renewable, readily available, cost effective, etc.

Therefore, the present study aimed at evaluating some mechanical and biodegradability properties of linear low-density polyethylene filled *cornstalk dracaena* leaves powder and predicts the specific applications for the composite developed and proffer solution to means of managing LLDPE packaging wastes.

2. Experimental Section

2.1 *Materials used*

Linear low-density polyethylene pellet served as polymer matrix with density of 0.920 kg/m^3 and melt flow index (MFI) of 14.7 g/10 min, and sourced from Pac-besh Chemicals and Applied products, a Chemical Shop located at Owerri Metropolis in Imo State Nigeria. The *Cornstalk Dracaena* (CSD) leaves powder used as bio-filler was obtained from Flowering Gardens located at Federal University of Technology, Owerri (FUTO) in Imo State Nigeria and identified at the Crop Production Department in FUTO. **Figure 1** below shows the different parts of *Cornstalk Dracaena* plant.

Leaves and stem

Fruit

Flower

Figure 1. Views of different parts of *Cornstalk Dracaena* plant (Rojas-Sandoval *et al*., 2020; Jiang *et al*., 2021)

2.2 Preparation of samples

(a) Bio-filler preparation

The leaves of *Cornstalk Dracaena* plant were cut and its outer covering (or bark) was removed. Also, it was cut to smaller sizes, cleaned with double distilled water, sun-dried and pulverized with locally fabricated machine, sieved to different particle sizes (75, 150, 300 and 600 μm), electric oven dried for 1 h at 60 ^{o}C and keep in an air-tight container for composite preparation.

(b) LLDPE/ *Cornstalk Dracaena* leaves composite preparation.

The LLDPE matrix (200 g) in pellet form was melted, homogenized and compounded with prepared *Cornstalk Dracaena* leaves powder at varying filler content of (0 – 35 g respectively) in an injection moulding machine maintained at temperature range of 110 – 120 ^{o}C. The injection moulding machine maintained its operation at an injection pressure of about approximate 10 MPa while the temperature of hopper and nozzle were maintained at 106 and 124 ^{o}C respectively. Finally, the resulting composites samples in sheet form were injection moulded with 150 x 150 x 3 mm dimension. The experimental flow process for the preparation of composite sample is presented in **Figure 2.**

2.3 Property characterization or assessment

The composite samples produced were subjected to mechanical, biodegradable and structural property assessment in order to predict the useful applications of the composites and effective means of handling LLDPE wastes.

2.3.1 Mechanical property assessment

Some of the mechanical property assessment tests carried out include the following;

(i) Tensile test: This is one of the material characterization test usually performed on the developed composite samples to predict their usefulness. In this research, the following tensile tests were carried out; tensile strength, tensile modulus, elongation at break, impact strength and hardness. Tensile tests on the prepared composite samples were performed according to ASTM D638 and ISO 527-1with a tensometer (Monsanto, TEK/2/11140 model) operating at a uniform speed rate of 26 mm/min. Three experimental runs or tests were conducted on each composite sample in determining the stated mechanical parameters of interest and average values of the three runs were recorded for reliability or error reduction.

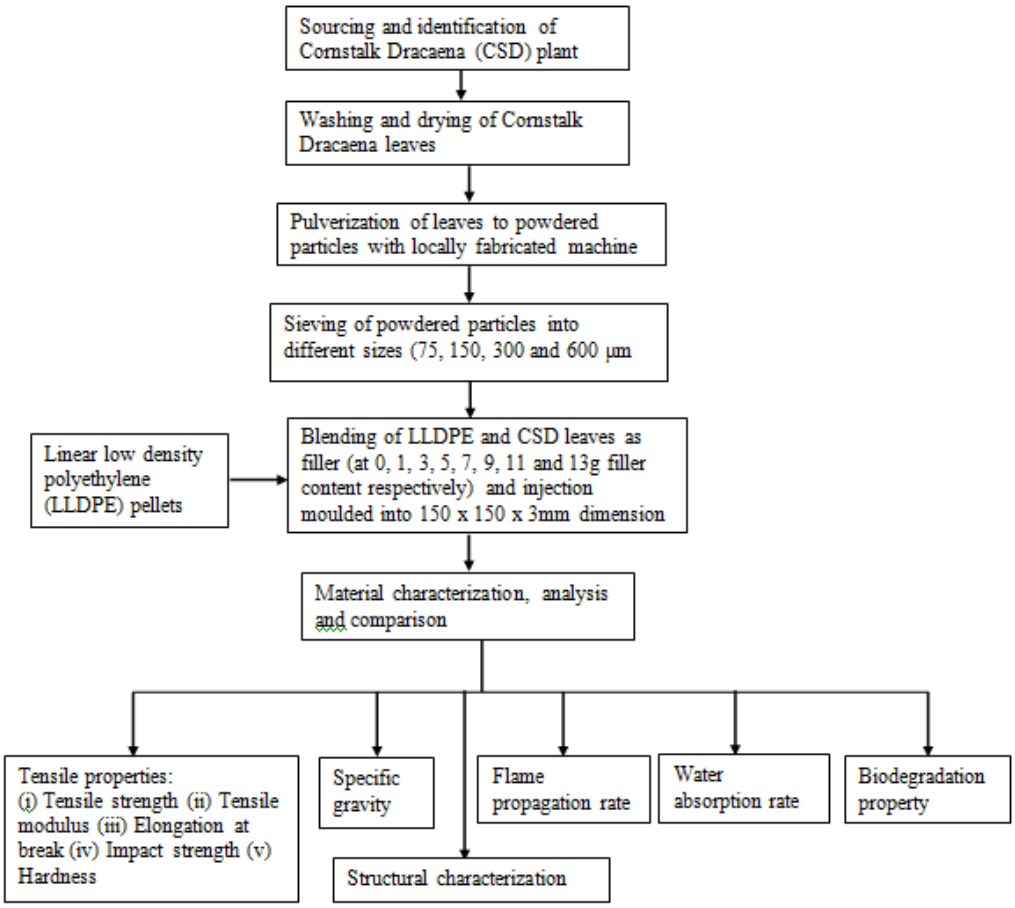


Figure 2. Flow process for the preparation of linear low-density polyethylene/ CSD leaves composite sheets

(ii) Specific gravity test:

In determining the specific gravity of the polymer composite samples, a physical technique known as hydrostatic weighing method was employed. Gasoline, a less dense liquid was used for the test in place of water because the samples were observed to float in water. The composite sample was initially suspended in air and later in gasoline with the aid of thin string fixed to a responsive spring balance. The weight of the sample in air was recorded as W_1 while weight in gasoline was recorded as W_2. These experimental runs were performed three consecutive times and average results were taken and the specific gravity of the composite sample with respect to gasoline was determine using the expression stated below;

$$SG_g = \frac{W_1}{W_1 - W_2} \quad \text{Eqn.1}$$

In order to determine actual specific gravity of the composite sample (that is, relative to water), Equation (1) was multiplied with the specific gravity of gasoline which 0.74 as expressed in Equation (2) below;

$$SG_g = \frac{W_1}{W_1 - W_2} \text{ x } 0.74 \quad \text{Eqn.2}$$

(iv) Flame rate propagation (FRP) test:

This is a physical parameter used to predict the rate at which the material burns when ignited or comes in contact with open flame and the test was performed according to ASTM D 4804. In performing the test, a prepared composite sample of 150 x 10 x 3 mm^3dimension with 90 mm mark

along the length was horizontally clamped in a retorted stand and the marked length (D_l= 90 mm) protruded out of the clamp. A lighter was used to ignite the free end of the composite sample and initial time of ignition (t_1) was recorded and the composite sample was allowed to burn up to 90 mm mark before the flame was quenched and the finishing time (t_2) was recorded. The experimental runs were carried out three consecutive times and average results were taken. Mathematically, the rate of burning of composite sample was determined from the expression stated below;

$$\text{FRP}\ (\text{mm/s}) = \frac{D_l}{T_2 - T_1} \qquad \text{Eqn.3}$$

Where D_l represents distance propagated flame (mm) and $T_2 - T_1$ represents propagated flame time (s).

(v)Water absorption test

The test was performed according to procedure of ASTM D 1037-99. The prepared sample was cut to 30 x 30 x 3 mm^3 dimensions and weight of the dry (D_w) composite sample was recorded. Then, the sample was placed in a 250 ml capacity plastic beaker containing 200 ml of water, closed with filter paper and kept in safe environment. The sample was allowed to remain in the water for 10 days at room temperature (± 28 ^oC) and reweighed to obtain the weight of the wet sample (W_w), and this continued for 90 days progressively. The water adhered on the surface of composite surface was removed carefully with filter paper and the experimental runs were performed in triplicates and average results were taken. The percentage of water adsorption of the composite sample was computed from Equation (4) stated below;

$$W_A(\%) = \left[\frac{W_w - D_w}{W_d}\right] \text{ x } 100 \qquad \text{Eqn.4}$$

Where $W_w - D_w$ = weight of water absorbed by the composite after 24 h

2.3.2 Biodegradable property assessment

This was ascertained using soil burial test which is a traditional and standard method carried out on a laboratory scale to ascertain the extent of degradation or biodegradability on the polymer composite samples exposed to actual waste disposal conditions (that is, in a soil environment). The biodegradability assessment on the polymer composite samples was evaluated using weight loss technique according to Equation (5) stated below. Initially, the samples were cut to definite sizes and weighed using electronic weighing machine, and later buried for 90 days in wet alluvial soil (at a depth of 12 cm from the surface) contained in a plastic bowl with tiny perforated holes round the bowl for proper air circulation. The plastic bowl was kept outside the room environment and the soil was subjected to moist condition (to keep micro-organisms active which are normally present in the soil) throughout the test period. The samples were retrieved after the test, washed carefully with double distilled water and dried for 24 h in oven at 70 ^oC and subjected for examination according to Equation (5) stated below;

$$\text{Weight loss (g)} = \left[\frac{W_i - W_d}{W_i}\right] \text{ x } 100 \qquad \text{Eqn.5}$$

Where W_d and W_i represent the dry and initial dry weight of the composite sample respectively

2.3.3 Structural/morphological property assessment

The composite samples produced were subjected to scanning electron microscopy (SEM) analysis to evaluate the extent of physical interaction (in terms of interfacial, adhesion and homogeneous interaction) between the matrix and filler particles.

3.0 Results and Discussion

3.1 Mechanical property results

The results of mechanical properties of polymer composite samples obtained by compounding linear low polyethylene and fibre particle of *Cornstalk Dracaena* leaves at different contents are presented below as follow:

(i) Tensile strength result

Figure 3 below presents the comparative effect of varying CSD bio-filler contents and filler particle size on the tensile strength between the LLDPE matrix and filled LLDPE. Careful analysis on **Figure 3** illustrated that presence of CSD bio-filler within the composite samples increased the tensile strength of LLDPE matrix, and this result is similar with the report of Obasi *et al*. (2013). Also, it was observed that the increment in the tensile strength of composite sample was dependent on filler content and filler particle size. Hence, higher filler particle size associates with improved tensile strength of the composite samples. In addition, it was observed that the increment in the tensile strength was short-lived, that is, it did not continue with increase in filler content. In fact, the composite samples with 75 and 150 μm particle size exhibited maximum tensile strength at filler content of 25g while composite samples with 300 and 600 μm particle size exhibited maximum tensile strength at filler content of 20g. This suggests better adhesion and dispersion with strengthened effect caused by increased filler particle size on the composite samples (Gholampour *et al*., 2020) and reveals the proper amount or content of filler required for the production composite. The decrease in the tensile strength of composite samples observed after 20 and 25 g filler addition respectively revealed that excessive filler content within the polymer composite samples weakens or reduces adhesive strength of the polymer matrix thereby resulting to composite with reduced strength. In addition, the presence of filler with brittle nature created very weak bonding along the matrix surface causing poor interfacial bonding (Yi *et al*., 2006), (Nwanonenyi *et al*., 2013) micro-pore spaces (voids) within the composite structure and obstruction of even spread or distribution of stress leading to decreased strength as reported by Onuegbu *et al*. (2011). This suggests poor dispersion and adhesion between the filler and matrix with formation of filler particle aggregates at the matrix surfaces as reported by Chun *et al*. (2012). The order of increment in the tensile strength with respect to particle size is as follow; 75 > 150 > 300 > 600 μm.

(ii) Tensile modulus result

Tensile modulus is a parameter that gives accurate information on the stiffness of a material subjected to stretching or deformation. In fact, it is used to evaluate the relationship existing between stress and strain within the linear elastic region for a material subjected to stress/strain condition. Also, it is one of the bulk properties of interest in the study of polymer composites because its' usefulness in determining end-use applications or mechanical performance of the composite. **Figure 4** illustrates the effect of CSD leaves powder on the tensile modulus of LLDPE composite. The tensile modulus of the LLDPE composite increased as observed with increase in the filler content for all particles sizes to a reasonable extent. This was as result of stiffening effect of the filler which caused gradual reduction in the movement of matrix chain. Hence, the order of performance of the modulus property of the composite considering the particle size is as follow 75 > 150 > 300 > 600 μm. This entails that surface morphology of the filler played significant role in the determining performance of the tensile property of a composite. Also, it is inferred that from the results presented in **Figure 4** that presence of filler with 75 μm particle size revealed better matrix/filler dispersion and distribution within the matrix (Normurodov *et al*., 2022), (Mohamad *et al*., 2017) and homogenization compared to other particle

sizes. Furthermore, it is observed that the prepared composite samples with 75 and 150 μm particle sizes attained their tensile modulus maximum value at filler content of 25 g while other composites samples with 300 and 600 μm particle size had their maximum value at filler content of 20 g. This indicates that beyond this filler content the tensile modulus property of the composite starts to decline and it will serve as a guide for researchers in field of polymer composites. It is worthy to note that CDS powered filler is not a reinforcing filler to LLDPE composite rather it is an extending filler

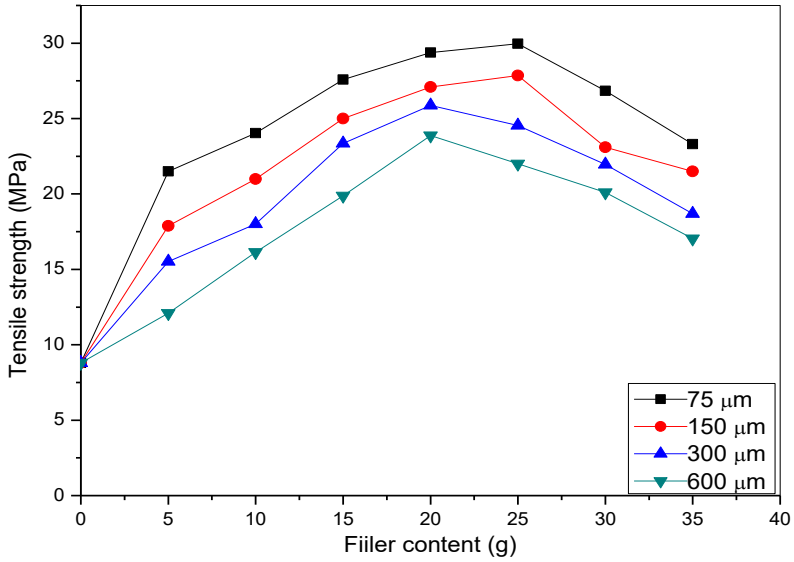


Figure 3. Plot of tensile strength versus filler content for LLDPE/CSD leaves composites at different particle size

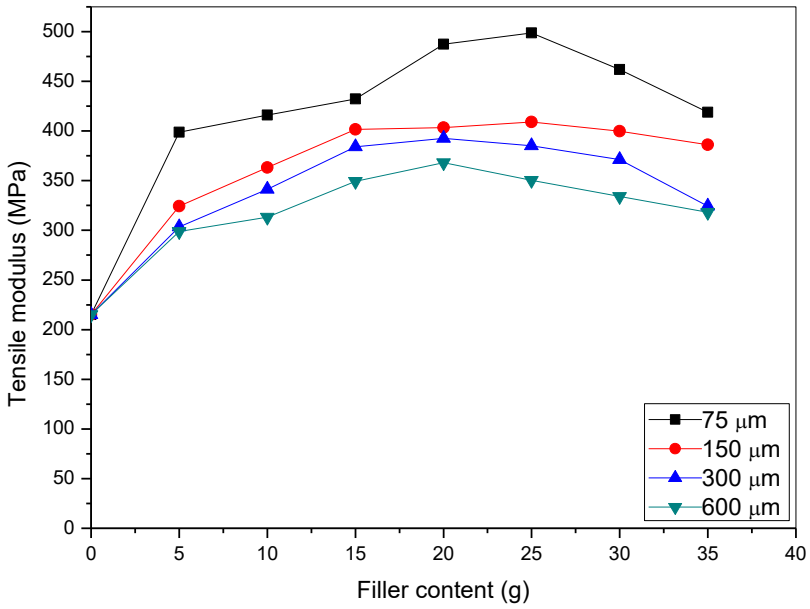
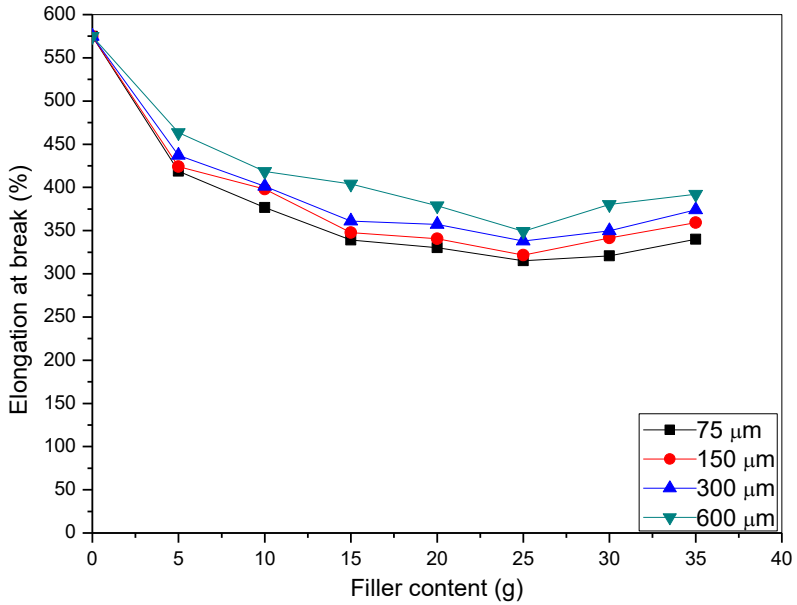


Figure 4. Plot of tensile modulus versus filler content for LLDPE/CSD leaves composites at different particle sizes

(iii) Elongation at break result

The results of elongation at break for the polymer composite samples produced are presented in **Figure 5** below:



Figures 5. Plot of elongation at break versus filler content for LLDPE/CSD leaves composites at different particle sizes

Elongation is regarded as percentage increase in length of a material sample over the original length when the material finally breaks under tensile forces or stress. This is physical parameter that assesses or evaluates the plastic deformation ability of a material subjected to tensile forces prior to rupturing. It provides information on the extent to which a composite can be stretched or elongated before breaking finally. It is a useful property when considering the application where ductile and flexible properties are needed. Mathematically, it is estimated from the expression stated below;

$$\text{Elongation at break (\%)} = \left[\frac{L_f - L_i}{L_i}\right] \text{x } 100 \qquad \text{Eqn.6}$$

Where, L_i and L_f represent initial and finally length of the material. It is observed that the presence CSD powdered filler with the LLPDE caused gradual reduction in the flexible and ductile property of LLDPE. The observed characteristics were dependent on the filler particle size because the order of reduction is as follow; 75 > 150 > 300 > 600 μm. Hence, the characteristic reduction property in the composite samples observed could be attributed the modification of ductile and flexible behaviour of LLDP structure by the presence of stiff CSD powdered filler (Normurodov *et al*., 2022). Also, the CSD powdered filler that meant to support the matrix in stress bearing applications was never reinforcing rather it transferred all the stresses on the matrix. The resulting effect was weakening of the matrix chain with gradual reduction of its flexible and ductile performance.

(iv) Impact strength

This is a physical parameter that evaluates the capability a material to absorb energy and resist fracture when exposed either to sudden or high impact load. In fact, it is a useful property of interest in composite study because it is considered a stake holder in determining applications where dynamic and sudden loads are paramount. It provides accurate information on the toughness and ability of a material in withstanding sudden or dynamic force impact without failing. The impact strength of polymer composite is dependent on the following factors; nature of matrix and filler respectively, fibre/matrix interface, temperature, environmental conditions, etc.

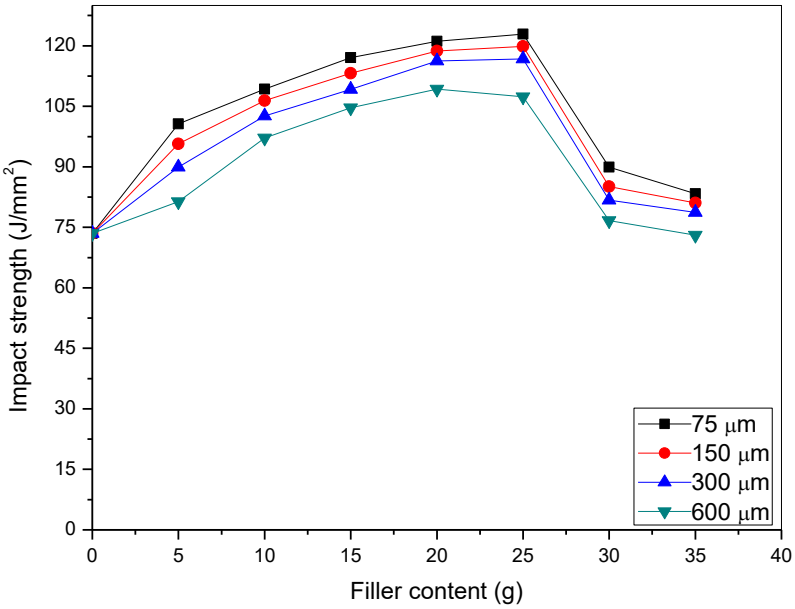


Figure 6. Plot of impact strength versus filler content for LLDPE/CSD leaves composites at different particle sizes

Figure 6 presents the results of impact strength of LLDPE filled CSD leaves powder. It is obviously seen that presence of powdered CSD leaves at different particle sizes supported the improvement of impact strength of the composite samples to certain extent, though the order of improvement is as follows; 75 > 150 > 300 > 600 μm. The filler from powdered CSD leaves is associated with stiff characteristic nature whereas LLDPE has flexible and ductile properties; hence incorporation of the filler into LLDPE matrix modified its physical structure with improved stiff and hardened structure. As seen in **Figure 6**, the different samples of composite produced with the filler content of 5 to 35 g have the ability to resist fracture which is attributed to effective dispersion and adhesive of filler particles within the matrix structure. Equally, it is observed that beyond 25 g filler addition into the polymer matrix there was a recorded sharp drop or decrease in the impact strength value, thus indicating abrupt change in the physical structure (poor filler distribution, dispersion and adhesion (Obidiegwu, *et al*., 2014), (Eze, *et al*., 2013), (Eze *et al*., 2017) with negative implications in fracture resistance as result of excess filler volume within the composite.

(v) Hardness test result

Hardness is a physical parameter used to evaluate the ability of a material to either resist or withstand deformation, indentation or scratching. It gives information on mechanical properties of a material and it is influenced by the following factors; type of matrix, nature and content of filler, processing and environmental conditions, etc. It plays significant role in determining the material performance under different service conditions and its suitability in various applications. **Figure 7** presents the results of effect of CSD leaves powder on the hardness of LLDPE. It is observed that the filler from green sources at different particle sizes improved that hardened property of the polymer composite. Hence, the order of improvement is as follow; 75 > 150 > 300 > 600 μm. The improvement recorded with the addition of filler evidenced proper mixing, homogeneous adhesion and dispersion of filler within the matrix structure together with the distributed characteristic stiff nature of the filler within the composite system. Thus, this resulted to composite samples with somewhat abrasion resistance characteristics (Mohamad *et al*., (2017), (Kumar *et al*., 2010).

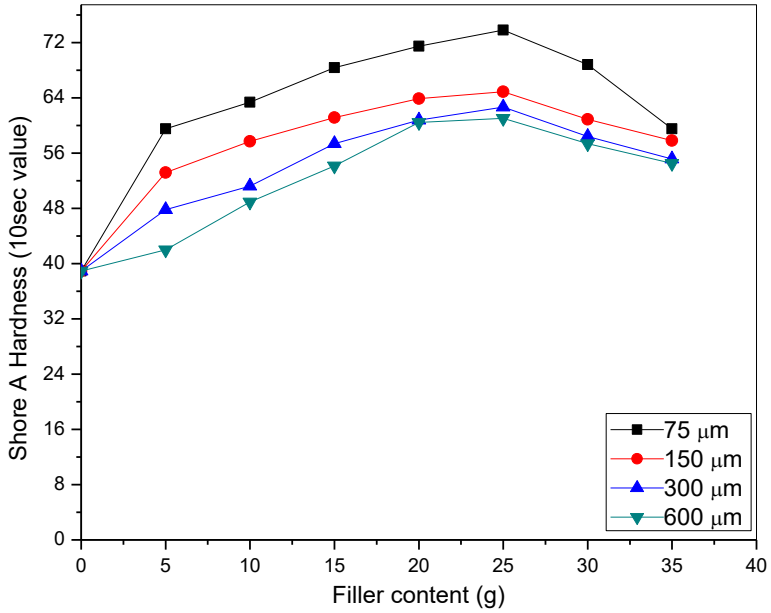


Figure 7. Plot of hardness versus filler content for LLDPE/CSD leaves composite at different particle sizes

(vi) Water absorption rate

This is a physical parameter used to access or evaluate the water absorption ability of a composite when subjected to a humid condition or totally immersed in water for a stipulated period. Thus, this parameter directly or indirectly influences both the thermal and mechanical properties of a composite sample. **Figure 8** presents the results of effect of CSD leaves powder on the absorption potentials of LLDPE. It is clearly seen that the presence of filler from agricultural waste created hydrophilic sites within the composite internal structural system, thus giving the composite room to susceptible for water absorption and swelling. In fact, the hydrophobic nature of LLDPE was modified, thus indicating the possible means for conversion of LLDPE to biodegradable material. Within the early days of submersion of composite samples in water, there was sharp percentage of water adsorption which later took gradual path till equilibrium of absorption was achieved. Also, it was observed that percentage water absorption exhibited by the composite samples were dependent on filler content, that is, the rate at which water diffused into the LLDPE/CSD leaves composite was directly proportional to filler contents regardless of the particle size. It was observed that characteristic water absorption property of LLDPE filled composite does not depend strongly on the particle sizes like other property parameters discussed. Also, it was observed that equilibrium water absorption was recorded beyond 70 days and this is could be attributed to inability of the composite samples to acquire more water because the pores within the composite system has been saturated and there was no room for arrangement of polymer chain (Obasi *et al*., 2013), (Nwanonenyi *et al*., 2013), (Kumar *et al*., 2010). Furthermore, it was observed that hydrophilic attributes of CSD leaves powder altered hydrophobic polyethylene chain structure (Moghadam e*t al*., 2013). Hence, it is a fact that water absorption may lead to a reduction in the end-use applications of the composites, but the understanding of the limitations and benefits of this property is essential in plastic product formulation and its handling.

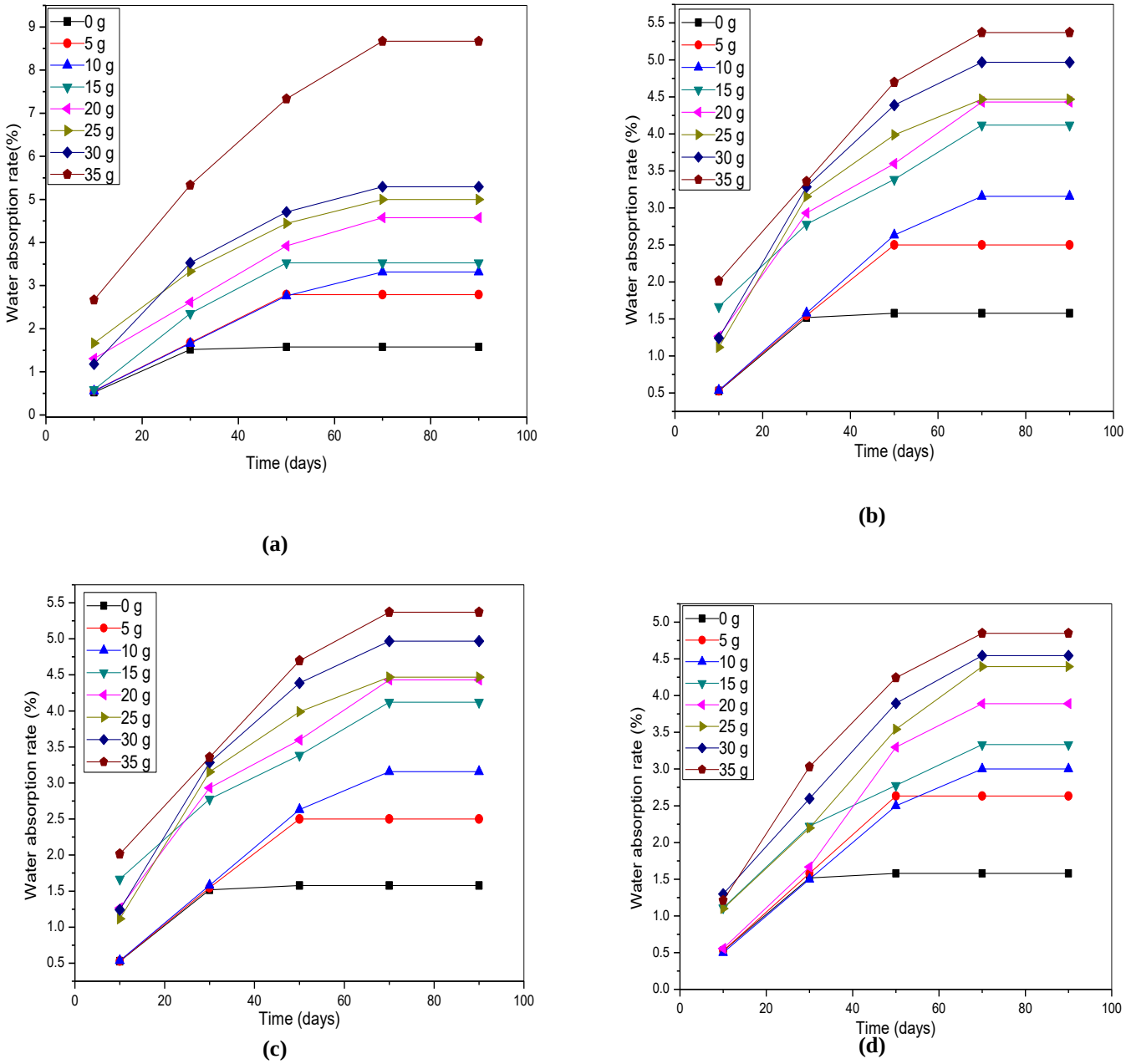


Figure 8. Water absorption versus time for LLDPE/CSD leaves composites at different filler contents: (a) 75 µm particle size (b) 150 µm particle size (c) 300 µm particle size and (d) 600 µm particle size

(vii) Specific gravity result

The effect of CDS leaves powder on the specific gravity of LLDPE filled composite was presented in **Figure 9**. It is observed that presence of CDS leaves powder within the LLDPE structure increased the specific gravity of composite, the increment was dependent of filler content and particle size and values of specific gravity obtained for composite samples were greater compared to neat LLDPE at any given filler particle size considered. The observed behaviour could be attributed to high characteristic density nature of CSD leaves powder compared to 0.93 g/cm^3 for LLDPE. It is expected that density of CSD leaves powder used as green filler should be higher that of the polymer matrix. In addition, the observed behaviour suggests that the formulation of LLDPE filled composite with CSD leaves powder encourages the relative density of LLDPE to be raised. These results exhibited in **Figure 9** evidenced the efficient distribute and improved packing of the filler particles within the matrix system.

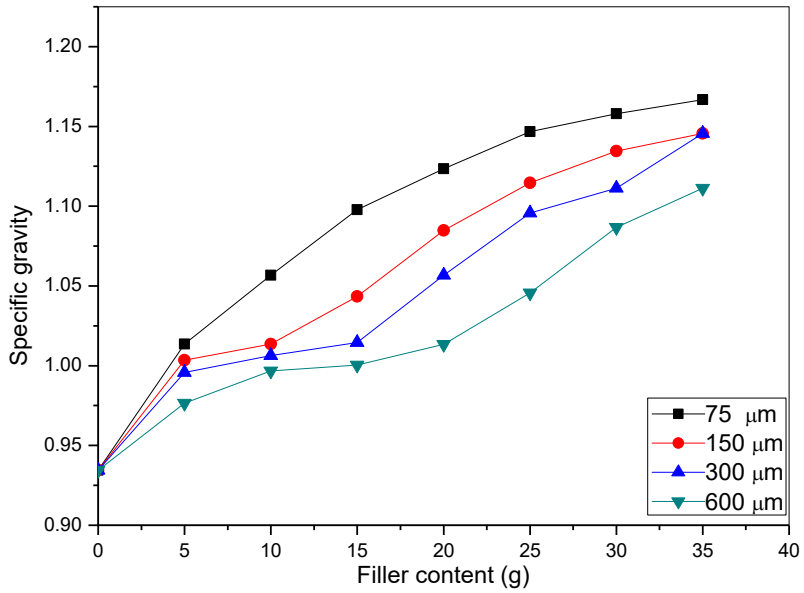


Figure 9. Plot of specific gravity versus filler content for LLDPE/CSD leaves composite at different particle sizes

(viii) Flame rate propagation (FRP) result

This is a physical parameter that evaluates the rate at which flame spreads or moves along a marked dimension (specified length) of a composite. The FRP of LLDPE/CSD leaves powder composite is shown in **Figure 10**.

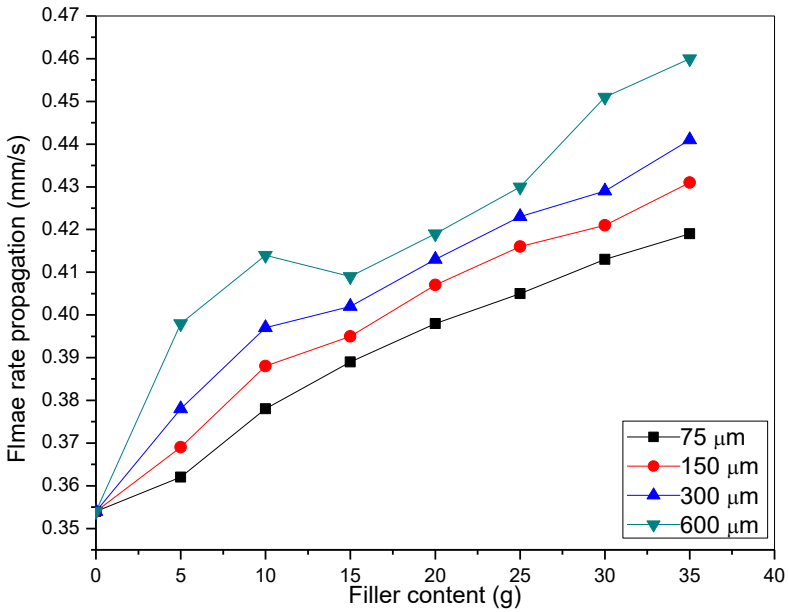


Figure 10. Plot of flame rate propagation versus filler content for LLDPE/CSD leaves composite at different particle size

It is shown that rate flame spread propagates with increase in filler content and decrease with the particle size at any given composite samples. The enhanced flame propagation rate could be attributed to cellulose nature of the filler used. Hence, the presence of CSD leaves powder enhanced the combustion of LLDPE. Furthermore, higher flame rate propagation was recorded at high filler content

because more cellulose particles were involved in the burning process but at 75 µm filler particle size rate of flame propagation was decreased even at high filler content. This indicates better dispersion and efficient packing of fibre which closes the pores within the composite and did not allow air particle to flow and spread the flame as well.

3.2 Soil Burial Test:

The biodegradable behaviour of LLDPE/CSD leaves powder composites is shown in **Figure 11**. It is observed that presence of filler within the composite system influenced the percentage weight loss across all the particle sizes studied. This observed behaviour indicates the action of micro-organisms in the soil initiating a reaction at the polar site of the causing biodegradation on the composite samples. The presence of CSD leaves powder within LLDPE structure created a hydrophilic site on the structure which influenced physiochemical properties of the LLDPE filled composite and enhanced its tendency to hydrolyze leading to swelling of the matrix, and promotes microbial activity on the samples (Obasi *et al*., 2013), (Nawang *et al*., 2001), (Borghei *et al*., 2010). The rate of degradation was observed increase gradually and this observation could be attributed to the activities of micro-organisms such as fungi and bacteria available in the soil environment that were created by eating up the bio-filler alongside the matrix structure (Opara *et al*., 2023), (Obasi *et al*., 2021). This affirms that filler from *cornstalk dracaena* leaves powder was effective in causing biodegradation of the polymer matrix making its disposal less cumbersome after end use.

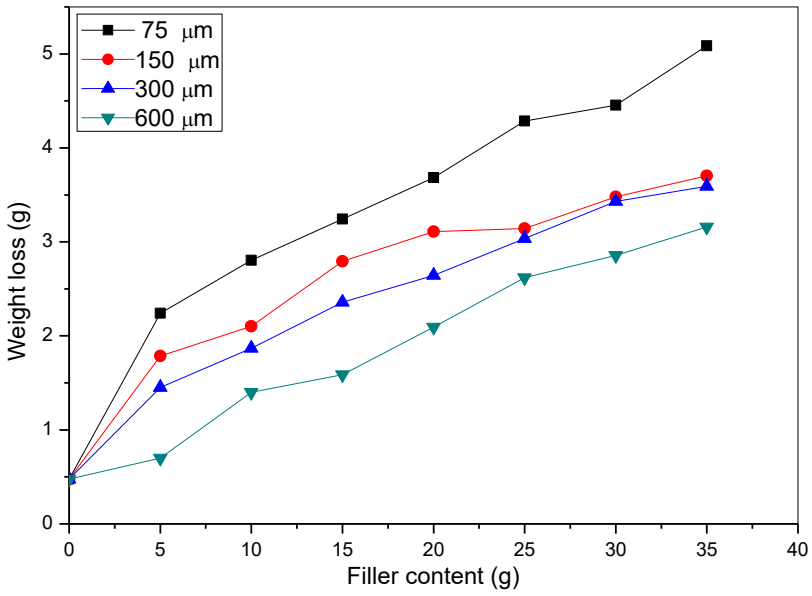


Figure 11. Plot of weight loss versus filler content for LLDPE/CSD leaves composites at different particle sizes

3.3. Structural analysis

Figure 12 the scanning electron microscopy (SEM) presents 150x, 500x, and 1000x magnification observed changes in surface morphology of LLDPE/ CSD leaves powder composite. The SEM images revealed that reduction or decrease in particle size gives better dispersion and packing effect of the filler within the composite system. Hence, SEM images at 75µm and 150 µm particle size gave a better filling effect compared to 300µm and 600 µm respectively. This is attributed to the uniformity and homogeneity that existed between the matrix and the bio-filler improving the surface area as the embedded bio-filler was not exposed. In addition, the observed behaviour could be due to the formation

of hygroscopic nature or the agglomeration of the bio-filler on the matrix (Mohamad *et al*., 2017). Thus, higher particle size of the bio-filler created reduction in homogeneity giving rise to appearance of large cracks and void on the surface of the matrix (Kumar *et al*., 2010), (Kormin et al., 2019) as observed in the composite samples. Finally, it is believed that surface of filler has significant role to play in the determination end-use applications of the composite and its ability to degrade when disposed into environment.

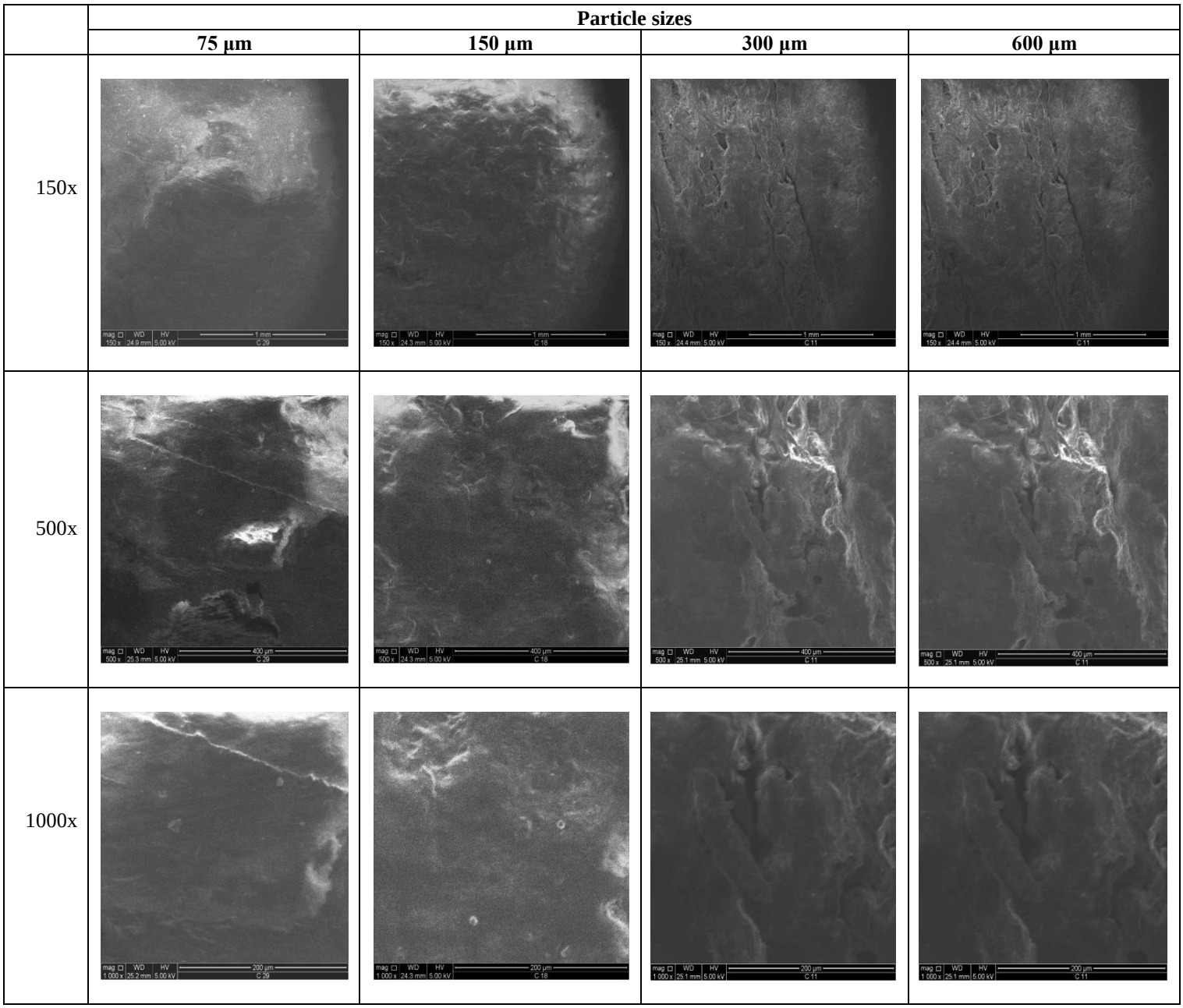


Figure 12. Scanning electron micrograph for LLDPE/CSD leaves powder composite samples at different particle size and magnification (150x, 500x and 1000x) and 20 g filler content

Conclusion

Linear low density polyethylene filled with CSD leaves powder at filler content of 0 – 35 g and 75 - 600 µm was produced using injection moulding technique and subjected to some physical properties characterization. The presence of filler within the matrix structure improved tensile strength, tensile

modulus, impact strength and hardness of the neat polymer. These physical properties were found to be dependent on filler content as well as particle size (surface area). The observed increase in modulus and decrease in elongation at break justified the hardening and stiffening of the composite following the corresponding decrease in the flexible and ductile properties of the composite. The results of flame rate propagation, specific gravity and water absorption showed that the use of CSD leaves powder to produce LLDPE filled composite improved these properties compared to neat LLDPE. In addition, these properties were found to be dependent on filler content and particle size for all the composite samples investigated. The filler introduced somewhat weight to LLDPE matrix but could cause flame propagation while water absorption properties were not deterred. Evidently, the result of burial rest is a strong indication that the introduction of CSD leaves powder into the LLDPE matrix is an effective means of managing the waste that may accrue from LLDPE packaging. Therefore, the composite product obtained from LLDPE and CSD leaves powder is mostly suitable for indoor packaging applications specifically where stiffness and light weight will be required but not open flame and moisture or humid conditions.

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Conflict of Interest: The authors wish to declare that no form of conflicts of interest exits in the course of carrying out this research

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