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Effect of Starch from Ficus Polita (Morecere) Fruit Powder on the Mechanical and Biodegration Properties for Automobile Bumper Application

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Abstract: *The polymer blends composed of Starch have been extensively investigated. However, even though much works have been done on the starch-polyblends, no data were reported on the blends of ficus polita seed powder as filler for poly-blends formulation. This study shows detailed of the physico-chemical properties, physico-mechanical properties, of starch synthesized form ficus polita fruit powder and standard corn starch filled PMMA/PVAc blends in relation to structure properties relationship was conducted to assess its applicability in plastics Industries for automobile bumper application. The research covers the Preparation of PMMA/PVAc blends of varying compositions with and without filler by dry blending and pressing in a compression moulding machine, generation of data analysis of the data obtained, measurement of the mechanical properties. The films were characterized spectroscopically using FTIR which illustrated that the decrease of the intensity of transmission spectra of (50/50 PMMA/PVAc) blend after exposure to UV radiation for 24 hours was lower than that of PMMA and PVAc. Consequently, (50/50 PMMA/PVAc) blend has improved the hardness of its homopolymer. Furthermore, effect of starch from ficus polita (morecere) fruith powder and standard corn starch have improved the hardness of the polymer blends.*

***Keywords**: Starch, Fruit Powder, Mechanical, Biodegration, Automobile Bumpe Introduction*

Introduction

Blending procedures had been employed since time immemorial. The principle of blending is geared towards achieving property averaging. A blend is therefore the physical mixture of two or more substances, without a chemical bond. Polymer blends, that is, physical mixture of structurally different polymers which interact with secondary forces such as hydrogen bonding (Abba *et al.,* 2020) with or without the formation of covalent bonding. Polymer blends have been widely used in the industry because of their ability to combine in a unique material the properties of their components, at a relatively low cost when compared to the development of a new polymer. It is well-known that the properties of polymer blends are greatly influenced by the morphology that is developed during the mixing process. The physical properties of polymer blends are controlled generally by many factors such as the nature of polymer (Mudigoudra *et al.,* 2012), blend composition (Taghizadeh, 2012) and interfacial properties such as interfacial adhesion (Jacob *et al.,* 2019; Abba *et al.,* 2020) and dispersed phase size and shape which are developed during solution blending. Likewise, the morphology of binary blends is also influenced by thermodynamics and kinetic factors. In comparison with single polymer-filler composites, binary polymer system can be viewed technologically as one of the present generation in multiphase polymer system and the fundamental aspect of polymer blends, which have substantial commercial significance as adhesives and coating materials (Chen *et al.,* 2011; Ali *et al.,* 2018)**.** Properties of a given polymer can be improved in various ways such as blending with other polymers or by incorporation of reinforcing fillers (Mamza, 2011). Poly-methyl methacrylate (PMMA) has been widely used in architecture, automobile, air and railway transport systems due to its mechanical and superior optical properties. These wide range of applications of PMMA can be enhance by incorporation of filler into the PMMA matrix, because well dispersed filler may enhance various mechanical and physical properties of PMMA (Abdullah, *et al*., 2015 and Hasan, *et al*., 2017). Blending of polymers provides an efficient way of developing new materials with tailored properties, and thus has received much attention from academia and industry. By blending different polymers, several properties can be improved, while retaining some of the original properties. However, the desire of polymer scientists and engineers to produce improved products by blending a particular pair of polymers is often frustrated by their low compatibility. The incompatibility between polymer pairs and their consequently poor phase morphology are responsible for the poor mechanical properties of most polymer blends. As a result, there is a strong need to enhance compatibility, and the compatibilization of polymer blends by the addition of block or graft copolymer has become an important feature of polymer science and technology, (Siengchin and Road, 2012). The chemical interactions with plastics materials can be categorized into direct chemical attack, preferential chemical attack and environmental stress cracking (ESC), surface attack and swelling (Siengchin and Road, 2012). Combined effects of stress cracking and photodegradation in polystyrene was recently reported by (Siengchin and Road, 2012). Poly(vinyl acetate) (PVAc) is a polymer that is widely used in many applications, such as paints, surface coatings, food additives and adhesives for wood, paper and cloth. PVAc, with its advantageous properties, can be considered a "green" material suitable for overcoming a range of environmental challenges. First, PVAc can be produced from renewable resources. Its monomer, vinyl acetate, can be synthesized from bioethanol, which is extracted from the biomass refining process, and then further treated by dehydration, oxidation and vinylation. Second, PVAc is predominantly synthesized by emulsion polymerization, with the use of water as the dispersion medium during processing (Abba et al., 2020). This type of synthesis is a nontoxic, non-flammable and low-cost system, which is more environmentally friendly than other polymerization methods. Finally, it has been reported that PVAc is principally biodegradable which means that it was modified, hydrolysed, metabolized and finally assimilated by microbial organisms under specific conditions. However, several drawbacks of PVAc, including deficient mechanical properties, a high water or humidity sensitivity and a poor performance at elevated temperatures, pose limitations in some applications. During the last few decades, many studies have focused on improving the properties of PVAc. One of the most famous reports from 1940 by Perrin et al.7 has described in detail, for the first time, copolymerization of ethylene with vinyl-acetate: The product poly(ethylene-co-vinylacetate) has then been widely used in various types of commercial products due to its much higher ductility and lower water sensitivity compared to pure PVAc (Habeeb, 2017). Recently, Studied on the effect of nano-clay and nano-cellulose on the mechanical properties of nanocomposites with improved properties achieved by adding nanosized reinforcements into PVAc, have received a great attention as (Habeeb, 2017) studied the effects of admixing of nanoclays and cellulose nanocrystals on the adhesive properties of PVAc, especially at elevated temperatures and in wet conditions. According to (Geng *et al.,* 2017) concluded that there was improvement in the adhesive strength and toughness of PVAc dramatically by adding only 0.1 vol% of grapheme in the the PVAcmatrix this was also confirmed by other groups such involved Mathew *et al.,* (2018), investigated the moisture absorption and its effect on the mechanical properties of PVAc reinforced by cellulose nanocrystals, (Geng *et al.,* 2017) studied the viscoelastic properties and toughness of PVAc nanocomposites with cellulose nano-fibers. Biodegradation for materials exposed to natural environment means fragmentation, deterioration of mechanical property or chemical modifications through the action of microorganisms (Kumar, *et al.,* 2016). Biodegradation is a natural process by which organic chemicals in the environment are converted to simpler compounds, mineralized and redistributed through elemental cycles such as the carbon, nitrogen, and sulfur cycles (Kumar, *et al.,* 2016).

Review of the Related Literatures

Over the past 30 years greater attention has been focused on the development of biodegradable blends and composites for the sustained of friendly and healthy environment. In recent times, biodegradable materials have gained importance particularly for the protection of the environment from ever increasing plastic waste (Okada, M. *et al.,* 2000 and 2004 Srabayeeta, B.R. *et al.,* 2015). A number of biological materials may be incorporated into biodegradable polymer. The main characteristic of biodegradable polymers is that they are biodegradable through the action of the microorganism in appropriate environmental conditions. When in contact with the biodegradable polymer, the microorganisms produce enzymes that break the material in progressively smaller segments reduces its average molecular mass, favouring its degradation in the environment. Biodegradable materials can be completely degraded into natural ecosystems such as active sludge, natural soil, lake and marine. Petroleum-based synthetic polymers are widely used in modern society. Many of the mechanical, physical and chemical properties of plastics make them ideal materials for a variety of products and applications. Various approaches to render synthetic polymers biodegradable have been considered. However, the annual worldwide disposal of approximately 150 million tons of petrochemical plastics in commonly used commodities such as polyolefin in packing, bottle and moulding products is a significant environmental problem, especially with the continuously increasing production and consumption of these materials. Most widely used alkane-derived plastics have poor biodegradability and may have lifetime of hundreds of years when buried in typical solid-waste sites. The most attractive renewable natural polymer resource is starch because of its low cost, wide spread availability and potential for mass production from renewable resources. Research on biodegradable plastics based on starch began in the 1970s and continues even today at various laboratories all over the world. Starch satisfies the requirements of having adequate thermal stability with minimum interference in melt properties and negligible disturbance of product quality. Starch is the mixture of amylase and amylopectin. The most important industrial sources of starch are wheat, corn, tapioca, potato and rice. The use of starch to partially replace synthetic plastics will not only reduce the dependence on petrochemicals but also reduce plastic waste. However, biodegradable plastics from starch cannot compete with conventional petroleum-based plastics because of their poor mechanical properties. It is known that starch must be combined with other materials, like synthetic polymers, to produce satisfactory plastics because starch alone is brittle, moisture susceptible and difficult to process (Liu *et al.,* 2003). Although, various approaches have been attempted to utilize starch commercially for making biodegradable plastics, almost all have involved compounding starch in some form with synthetic thermoplastics. Incorporation of starch into a polyolefin matrix was proposed by Griffin as an effective means of accelerating the deterioration of plastics under biotic environmental exposure conditions (Srabayeeta, B.R. *et al.,* 2015 and Mondal, R. 2016). The development of polymer science and technology adds to traditional disciplines a new knowledge and its application for practical purposes of increasing importance. In one of the previous works, conducted using Scanning electron microscopy (SEM) and differential scanning calorimetry (DSC) by (Gao, J., *et al.,* 2012), poly (vinylacetate) (PVAc), (10 wt%) has enhanced both mechanical and compatibility of PPC and PLA blends . *Ficus polita* is a tropical African evergreen shrub or small tree belonging to the family Moraceae, and usually growing up to 15 metres tall, and sometimes to 40 meters tall. The leaves are occasionally harvested from the wild for food. Traditionally the fruit and young leaf are chewed for dyspepsia (Kuete *et al*., 2011). The young leaves are also edible and the bark and roots infusions are used in treatment of infectious diseases, abdominal pain, dyspepsia and diarrhoea like many of the species of the Moraceae family (Etkin and Ross, 1982; Kamga *et al*., 2010; Kuete *et al.*, 2011). The plant is commonly known as Hartblaarvy, Heart-leaved fig, polish fig, rubber plant, wild rubber fig, wild rubber tree (SANBI, 2015). Locally, it is called durumi in Hausa. Hasan, H.M, (2017), also investigated in his research titled "Black Carbon Incorporation Effect on Optical Properties of Polymethylmethacrylate Films" and concluded that the dielectric constant increased with increasing carbon content compared with the pure sample. This research will focus on investigating the effect of *ficus polita* and standard corn starch on the mechanical and biodegradation properties of PMMA/PVAc blend in order to assess its applicability in industrial and domestic use. The nanotechnology field of study is one of the most popular areas for present researches and improvement in mostly all Science and technical disciplines, this obviously includes polymer science and technology, the investigations cover a broad range of research topics (Paul, 2008). It is a novel science which evolved as it was observed that substances displayed significantly different classification at sizes in a nanometer as compared to the characterization of the same substance at micro-particle sizes. It will make possible the improvement of novel substances providing the basis for the design and development of new characterization and structures which will result in increased performance, reduced cost of manufacturing, maintenance and enhanced functionality (Hind *et al.,* 2019). Presently, assessment on polymer blends filled filler to form nanocomposites have attracted much attention because of their wide spectrum of applications in the field of polymer science and nanotechnology. The polymer nanocomposites heavily rely on geometry, size distribution, aggregation and surface chemistry of organic nanoparticles such as starch from different sources as well as matrix-nanoparticle interactions. The properties of nanocomposites were found to depend on the type of nanoparticles, the content of nanofillers and nature to bridge chemically and physically with the polymer matrix (Hashim and Basim, 2019). Polymers are largely used in automobile bumper and architectural applications. In previous works, polymers have been used as insulators because of their dielectric properties and high non conducting properties. Polymers have several advantages, such as low cost, secure processing, high strength, flexibility, and excellent mechanical properties. The [(poly-methyl methacrylate (PMMA)/Polyvinylacetate (PVAc)] blend filled standard corn starch and derived starch from *ficus polita* fruit powder with nanoparticles can be considered a quite promising composite material for automotive, environmental and industrial applications such as: vehicular bumper, antibacterial, biosensors, lens, electronics gates, transistors, and transportation.

Materials

The following materials was used

1. Polymethylmethacrylate (PMMA)
2. Polyvinylacetate (PVAc)
3. Standard Corn Starch (SCS)
4. *Ficus Polita* (Morecere) Seed Powder (FPSP)
5. Toluene and dicholoro methylene
6. Dil. Hydrochloric acid, Sodiumhydroxide, and Acetone

Apparatus to be used

The following apparatus was used during the Experimental work

1. Mould
2. Hand gloves
3. Mixing knife
4. Weighing balance (triple beam balance, model 2016 MB)
5. Stop watch
6. Specimen Bottles
7. Density bottle
8. Oven
9. Sam paper
10. Microsrew gauge
11. Sieve
12. Petri dish

Table 1: Equipment and Location

S/N	Equipment	Specification	Location
1.	Two roll-mill	Reliable Rubber and Plastic Machine Company New York Jersey, U.S.A (model 5189)	Nigerian Institute of Leather and Science Technology (NILEST)

2.	Hydraulic press	Carver Inc., Wabah U.S.A (model 3851-0)	Nigerian Institute of Leather and Science Technology (NILEST)
3.	Hardness Tester	Show A hardness tester model number 5019	Nigerian Institute of Leather and Science Technology (NILEST)
4.	Tensometer	Monsator Tensometer model number 9875 type W	Department of Mechanical Engineering Faculty of Engineering Ahmadu Bello University, Zaria
5.	Scanning Electron microscope Machine	Phenom World	Department of Chemical Engineering Faculty of Engineering Ahmadu Bello University, Zaria
6.	X-diffraction machine (XRD)	Shimadzu 6000 X-ray diffractometer	National Steel Raw Materials and Exploration Agency No:18 Rabah Road, Malali Kaduna
7.	Charpy Impactor	Cat. Nr, 15J x 25J	Department of Material Science and Metallurgical Engineering Faculty of Engineering Ahmadu Bello University, Zaria

Methods

Samples Collection and Preparation

Poly (methyl methaacrylate) (PMMA), Polyvinylacetate (PVAc) and Standard Corn Starch was used whereas the local *ficus polita* seeds was collected from Samaru-Zaria dried and kept for filler preparation.

Preparation of filler

The proposed filler *ficus polita* seeds (FPS) was collected from the processing point in Samaru, Sabon Gari Local Government Area, Kaduna State, Nigeria and was dried at room temperature. When it is dried it would then be grounded to powder with a mechanical grinder and sieved through a sieve of mesh size 70µm.The sieved sample was stored separately in plastic container and labeled appropriately after which the hybrid filler shall be prepare according to the following table.

Mixing of the Compound

Two roll was used, it was switched on and the PMMA and PVAc processing temperature was set and that of PMMA at 200℃ and PVAc at 150^{o}C respectively. The nip of the rollers was adjusted and material was poured on the nip, after total melting had been attained, both fillers (SCS and FPSP) was incorporated and then cross-mixed until a homogeneous mixture is achieve and the compound was sheeted out for further processing. The compounding was done base on the formulation proposed by Mamza, (2011), according to the following table.

S/No	Mass of Ingredients (g)	1	2	3	4	5	6	7	8	9
1	Poly (methylmethacrylate)	100	90	80	70	60	50	40	30	20
2	Poly (vinylacetate)	0	10	20	30	40	50	60	70	80
3	PMMA/PVAc	100	90	80	70	60	50	40	30	20
4	SCS	0	10	20	30	40	50	60	70	80
5	PMMA/PVAc	100	90	80	70	60	50	40	30	20
6	FPSP	0	10	20	30	40	50	60	70	20

Film Casting and Measurement

Films of PMMA/PVAc, PMMA/PVAc/SCS or PMMA/PVAc/FPSP blends was prepared by solution casting: 6 g of polymethylmethacrylate (PMMA) supplied from Sigma-Aldrich company was dissolved in 20 ml of toluene and dicholoro methylene to obtain films without filler of the blends, then the same amount of the blends solutions was added to 0.1,0.2, and 0.3 of the standard corn starch and *ficus polita* seeds powder to prepare the different filling blends, these homogeneous solutions was spread on a glass plate and allow to evaporate the solvent slowly in air at room temperature for $24h$. The thickness of the films was measured with micrometer srew guage in the range of (100 – 470mm), and it was calculated as averages. As proposed by mamza, (2012) and Hasan H.M, (2017)

CHARACTERIZATION

Hardness test.

The hardness test was carried by first placing the specimen on the hard-flat surface of the machine. The indentor for the instrument will then be pressed in to the specimen (6.4 mm) and the hardness readings was manually recorded as the pointer of the hardness tester stop at a ven calibration of the machine under specified force and time. (ASTM D2240-082018).

Summary

Blend films of PMMA and PVAc with different concentrations have been prepared by casting method, and they were exposed to UV and filtered radiation for 24 hours. The films were characterized spectroscopically using FTIR which illustrated that the decrease of the intensity of transmission spectra of (50/50 PMMA/PVAc) blend after exposure to UV radiation for 24 hours was lower than that of PMMA and PVAc. Consequently, (50/50 PMMA/PVAc) blend has improved the hardness of its homopolymer. Furthermore, effect of starch from *ficus polita* (*morecere*) fruith powder and standard corn starch have improved the hardness of the polymer blends.

Recommendation

Further research to be carried out to explore wide varieties of starch sources from food and fruits in polymer blends in identifying wide range of properties for use in various field of application.

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