

STUDIES OF SOME MECHANICAL PROPERTIES OF
WATERMELON RIND/PAWPAW PEEL REINFORCED
POLYETHYLENE COMPOSITES

BY

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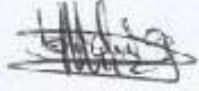
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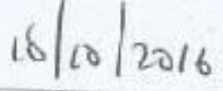
CERTIFICATION

This is to certify that this research work titled "Studies of Some Mechanical properties of Water Melon Rind/PawPaw Peel Reinforced Low Density Polyethylene and Linear Low Density Polyethylene composites" was carried out by Ezeibekwe, Stephen Uzodinma (20094769438). In partial fulfillment for the award of the Degree of Master of Science (M.Sc) in Polymer Science and Engineering in the department of Polymer and Textile Engineering, Federal University of Technology Owerri, Imo State.


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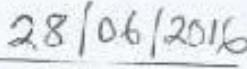
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DEDICATION

First of all to God Almighty who gave me the wisdom, good health and understanding to carry out this research work and secondly, to my parents Associate Prof. Sir and Lady Innocent Ezeibekwe.

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ABSTRACT

Some mechanical properties of water melon rind and pawpaw peel reinforced Low density polyethylene (LDPE) and Linear Low Density, (LLDPE) composites have been studied. Two sets of filler loaded LDPE and LLDPE composites were prepared using the injection moulding techniques at a processing temperature of 190⁰C. Dispersing agent, silicon oil, was added to the composite as a plasticizer to improve flow, processability and to reduce the brittleness of the product. A comprehensive range of mechanical properties: tensile strength, (modulus of elasticity, elongation at break, elongation at yield), impact energy test and hardness test were carried out. Tensile properties of the composite showed an increase in tensile modulus, impact energy test, hardness test, a decline, in elongation at yield and break with increasing filler loading. The tensile strength was enhanced with the incorporation of the two fillers up to 20% filler loading and then decreased with further addition of filler. The result obtained showed that pawpaw peel and water melon rind can be used as reinforcing fillers in thermoplastics and secondly, development of composites, enhances their mechanical properties.

KEYWORDS: Watermelon Rind, Pawpaw Peel, Silicon Oil, LDPE, LLDPE.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Investigation into novel properties of composites has been of deep interest to researchers for many years as evidenced by excellent reports (Obata, 2004).

Composite materials are formed by combining two or more materials that have quite different properties. The different materials work together to give the composite unique properties. The incorporation of more fibres into a single matrix, leading to the development of composites, offers a lucrative mode for fabricating products with reduced cost, high specific modulus, strength, corrosion resistance and in many cases excellent thermal stability. It is therefore generally accepted that the properties of these composites are controlled by factors such as nature of the matrix, length and relative composition of the reinforcements.

1.2 STATEMENT OF PROBLEM

It has been well documented that the general behaviour of adding fillers to polymers increase the viscosity and decrease melt elasticity of the polymer. Hence the study of the melt rheological will be necessary in controlling the filled polymer processing operation, in order to know how the flow behaves under different conditions of temperature, pressure, etc. as well as how, availability of water melon rind and pawpaw peels with variation in size, shape

and chemical structure will influence the flow of the composites system. Another important factor of the rheological study is helping one to carry out theoretical analysis of the mechanics of flow for rheologically complex polymeric material in various kinds of processing equipment. Such a theoretical study will be useful for designing better processing equipment and determining optimal processing conditions. Thus, the effect of filler loading type and treatment of the filler will be investigated with regards to the flow behaviour and the extrudate swell and melt fracture phenomena of the composite.

For years, fillers have been used extensively to improve the mechanical properties of polymeric materials. Besides the increment obtained in stiffness, hardness, abrasion resistance, and reduced cost of the filler material, the addition of fillers to polymer also modify their flow behaviour and consequently their processability. The use of watermelon rind/pawpaw peel as fillers in PE composite is not a common one. However, the use of watermelon /pawpaw has a trade on, in that water melon/papaw are cheaper, because they are planted and harvested within the country and some part of African countries. Also the PE composites used (low density polyethylene and linear low density polyethylene) are commodity polymer used every day in plastics manufacturing industries worldwide and are generally accepted.

1.3 OBJECTIVES OF STUDY

The main objective of this project is to study some mechanical properties of water melon rind/pawpaw peel reinforced low density polyethylene and linear low density polyethylene composites

The specific Objectives are:-

- a) To investigate the effect of different filler loading/ratio of the single filler and filler composites, and thus suggest a future application of this type of composite.
- b) To evaluate the mechanical properties of tensile strength, impact energy and hardness of the water melon/pawpaw peel reinforced polyethylene/linear low density polyethylene composites in different volume fractions.

1.4 JUSTIFICATION OF STUDY

The incorporation of pawpaw peel/watermelon rind in a single matrix (LDPE/LLDPE) is expected to offer a lucrative mode for fabricating products with reduced cost, high specific modulus, strength, corrosion resistance and in many cases excellent thermal stability.

1.5 SCOPE OF STUDY

The work is limited to

- The preparation and formulation of the samples as fillers in the research.
- Compounding and fabrication of the composites using injection moulding technique.
- Determination of mechanical properties such as tensile, impact and hardness properties.
- Water absorption test to determine the physical properties of the composites.

CHAPTER TWO: LITERATURE REVIEW

2.1 OVER VIEW OF COMPOSITES

Composite materials offer exciting advantages over traditional monolithic materials. Modern advanced composites are a success story from the view point of their widespread application, ranging from tennis rackets to advanced space vehicles. Aggressive research is being carried out worldwide to explore new composites with improved functional properties. This chapter outlines some of the recent reports published in literature on natural /bio-fibre reinforced composites and on the wear behaviour of polymer composites. Yamamoto et al (1989)

2.1.1 Characteristics of Composites

Advanced composite materials are generally characterized or determined by unusually high strength fibres with unusually high stiffness, or modulus of elasticity characteristics, compared to other materials, while bound together by weaker matrices.

These composites exhibit desirable physical and chemical properties that include light weight coupled with high stiffness, elasticity, and strength along the direction of the reinforcing fibre, dimensional stability, temperature and chemical resistance, flex performance and relatively easy processing. S.K Mazumdar (2004)

Composites are classified according to their matrix phase, they are:

- Polymer Matrix composites (PMCs)
- Ceramic Matrix composites (CMC's) and
- Metal Matrix Composites (MMC's)

Materials within these categories are often called “advanced” if they combine the properties of high (axial, longitudinal) stiffness values, with low weight, corrosion resistance, and in some cases special electrical properties.

Also fibre reinforced composites are characterized or determined by length, diameter, orientation, amount, and properties.

The specific properties of composites are listed below:

- Low Density
- High specific strength
- High specific modulus
- High thermal conductivity
- Good fatigue modulus
- Control of thermal expansion
- High abrasion and wear resistance.

2.1.2 Application/Uses of Composites

i. High Technology Applications:

- Advanced composites comprise of structural materials that have been developed for high technology applications, such as airframe structures for which other materials are not sufficiently stiff. In these materials,

extremely stiff and strong continuous or discontinuous fibres, whiskers, or small particles are dispersed in the matrix. A number of matrix materials are available including carbon, ceramic, glasses, metals, and polymers.

i. Commercial and Military Aircraft Components:

- Components fabricated from advanced organic matrix composites are used extensively on commercial air craft as well as for military transports, fighters, and bombers. The propulsion system which includes engines and fuel makes up a significant fraction of aircraft weight (frequently 50%) and must provide a good thrust-to-weight ratio and efficient fuel consumption.

ii. Truck and Automobile Components:

- Composites consisting of resin matrices reinforced with discontinuous glass fibres and continuous glass – fibre mats are widely used in truck and automobile components bearing light loads, such as interior and exterior panels, pistons for engines, drive shaft, rotors, brakes, lead springs, wheels, and clutch plates.

iii. Leisure and Sporting Products:

- Composites are also used for leisure and sporting products such as the frames of rackets, fishing rods, skis, golf club shaft, archery bows and arrows, sail boats, racing cars, and bicycles.

iv. Electrical and Electronic Applications:

- The excellent electrical insulation, formability, and low cost of glass-fibre-reinforced plastics have led to their wide spread use in electrical and

electronic applications ranging from motors and generators to antennas and printed circuit boards.

v. Cutting Other Applications:

- Advanced composites are used in a variety of other applications, including cutting tools for machining of super alloys and cast iron and laser mirrors for outer-space applications. They have made it possible to mimic the properties of human bone, leading to development of bio compatible prostheses for bone replacements and joint in plants. In engineering, composites are used as replacements for fibre – reinforced cements and cable for suspension bridges.

2.3 Overview of Fillers and Matrices Used

- **Watermelon Rind**

The term rind usually refers to the skin or peels of a fruit; in recipes the term rind mean the outer hard green skin and the white pulp of watermelon. The recipes will give instruction to cut away the outer green part. The recipes usually refers to the inner white part of the rind for consumption. It is usually considered to be a low pesticide fruit because of the hard skin and thick rind.

Uses of Watermelon Rinds

- Medicinal uses of water melon rind: An Agricultural Research service study has found that the rinds contain citrulline, an amino acid that plays

an important role in the human body's urea cycle which removes nitrogen from the blood and helps convert it to urine. Thus citrulline helps create arginine, amino acid – one in which some people are deficient. ;A.M Rimando et al;(June 2005).

- Since water melon rind has citrulline, which breaks down to become a vasodilator which relaxes blood vessels like Viagra, it could be used for a similar purpose. Science Daily:
- Water melon rind can be used for skin care treatment known as “**Water skin mask**”.
- A curry is made out of watermelon rind
- As watermelon rind spareribs soup; soup made with whitish rind.
- As watermelon Peel (rind) salad; salads are made using raw inner watermelon rind. Healthline Media(2005-2016).

Planting/Harvesting Dates: Watermelons are planted mid-December to February and harvested between mid- June to mid-July. Major competition in the market comes from Mexico, Arizona and Texas. Yields can be as high as 35 to 50 tons per acre under ideal conditions.

Pest and Disease control: Silver leaf whitefly, cutworms, aphids, spider mites, darkling ground beetles, leafhoppers, cabbage loopers, beet army worm, and leaf miners are the most serious insects' pests of watermelon. Neonicotinoid insecticides applied at planting or through the drip system followed by foliar

insecticide sprays are used to control whiteflies on melons. Rind scaring is a serious defect caused by worm feeding that reduces market value. Shaking the vines and turning them over to look for worms on the ground will give an indication of worm populations.

Rind necrosis can be a problem. The tissue discoloration rarely affects the flesh of the melon; however melons with necrosis may be discounted in price. Some researchers believe a bacterium may be involved in causing the disorder.

2.3 Pawpaw Peels

Pawpaw tree as discovered in 1541 by the Spanish explorer, Hernando Desoto, on excursion into the Mississippi valley, and he sent sample of this plant back to Europe.

Pawpaw peel is thin and edible and can vary in colour from a light green to a golden yellow, but in respect of this thesis, a green pawpaw peel that has not turned to yellow is required for positive results. (Canini, A., et al 2007)

Papaya (*Carica papaya* L.) belongs to the Caricaceae family and is grown in Thailand, Australia, Hawaii, the Philippines, Srilanka, South Africa, India, Bangladesh, Malaysia and a number of other countries in tropical America (Anuara et al., 2008), it originated in the lowlands of eastern central America, from Mexico to Panama, and now can be found in all tropical countries and many sub-tropical regions of the world (Canini et al., 2007). It was widely cultivated for its edible fruits or as vegetable. In Thailand, raw papaya fruit is used for papaya salad (Somtum) or prickled papaya. Thus, papaya has become a

waste product from restaurants and prickled papaya manufacture. Papaya waste amounts to more than one thousand tons per year. Many researchers have tried to transform this waste into valuable products.

Tongdeesoontom and Kanaswat (2004) studied the isolation of hemicellulose from raw papaya peel and determined its constituent sugars. Chaiwut et al. (2007) studied the properties and protein components of papaya peel. Rachtanapum et al. (2007a, 2008b and 2008) studied the synthesis of carboxymethyl cellulose from papaya peel and its applications.

2.6 Low Density Polyethylene (LDPE)

Low Density Polyethylene (LDPE) is a thermoplastic made from petroleum. It was the first grade of polyethylene product in 1933 by Imperial Chemical Industries (ICI) using a high pressure process through free radical polymerization. Its manufacture employs the same method today. LDPE is commonly recycled and has the number “4” as its recycling symbol. Despite competition from more modern polymers, LDPE continues to be an important plastic grade. In 2009, the world wide LDPE market reached a volume of 22.2 billion US – Dollars (15.9 billion Euros)

Properties

LDPE is defined by density range of 0.910-0.940 g/cm³. It is not reactive at room temperature except by strong oxidizing agents, and some solvents cause

swelling. It can withstand temperatures of 80°C continuously and 95°C for a short time. Made in translucent or opaque variations, it is quite flexible, and tough but breakable. LDPE has more branching (on about 2% of the carbon atoms) than HDPE, so its intermolecular forces (instantaneous – dipole induced – dipole attraction) are weaker, its tensile strength is lower, and its resilience is higher. Also, since its molecules are less tightly packed and less crystalline because of the side branches, its density is lower. LDPE contains the chemical elements carbon and hydrogen.

Chemical Resistance

- Excellent resistance (no attack) to dilute and concentrated acids, alcohols, bases and esters.
- Good resistance (minor attack) to aldehydes, ketones and vegetable oils.
- Limited resistance (moderate attack suitable for short term use only) to aliphatic and aromatic hydrocarbons, mineral oils, and oxidizing agents.
- Poor resistance, and not recommended for use with halogenated carbon.

Applications

LDPE is widely used for manufacturing various containers, dispensing bottles, wash bottles, tubing, plastic bags for computer components, and various molded laboratory equipment. Its most common use is in plastic bags. Other products made from it include:

- Trays and general purpose containers.
- Corrosion – resistant work surfaces.
- Parts that need to be weldable and machinable.
- Parts that require flexibility, for which it serves very well.
- Very soft and pliable parts.
- Six pack rings.
- Juice and milk cartons is made liquid packaging board, a laminate of paper board and LPDE (as water proof inner and outer layer), and often with a layer of aluminium foil (thus becoming aseptic packing).
- Parts of computer hardware, such as hard disk drives, screen cards, and optical disc drives.
- Play ground slides.
- Plastic wraps. (Massachusetts institute of Technology Kevlar).

2.5 Linear Low Density Polyethylene (LLDPE)

Linear low-density polyethylene (LLDPE) is a substantially linear polymer (polyethylene), with significant numbers of short branches, commonly made by copolymerization of ethylene with longer chain olefins. Linear low-density polyethylene differs structurally from conventional low-density polyethylene (LDPE) because of the absence of long chain branching. The linearity of LLDPE results from the different manufacturing processes of LLDPE and LDPE. In general, LLDPE is produced at lower temperatures and pressures by copolymerization of ethylene and such higher alpha-olefins as butene, hexene or

octene. The copolymerization process produces an LLPDE polymer that has a narrower molecular weight distribution than conventional LDPE and in combination with linear structure, significantly different rheological properties.

Production and Properties

The production of LLDPE is initiated by transition metal catalyst. The actual polymerization process can be done either in solution phase or in gas phase reactors. Usually, octane is the co-monomer in solution phase while butene and hexene are co-polymerized with ethylene in a gas phase reactor. LLDPE has higher tensile strength and higher impact and puncture resistance than does LDPE. It is very flexible and elongates under stress. It can be used to make thinner films, with better environmental stress cracking resistance. It has good resistance to chemicals, and good electrical properties. However, it is not as easy to process as LDPE, has lower gloss, and narrower range for heat sealing.

Processing

LDPE and LLDPE have unique theoretical or melt flow properties LLDPE is less shear sensitive because of its narrower molecular weight distribution and shorter chain branching. During a shearing process, such as extrusion, LLDPE remains more viscous and, therefore, harder to process than an LDPE of equivalent melt index. The lower shear sensitivity of LLDPE allows for a faster stress relaxation of the polymer chains during extrusion, and therefore, the physical properties are susceptible to changes in blow – up ratios. In melt extension, LLDPE has lower viscosity at all strain rate. This means it will not strain harden the way LDPE does when elongated. As the deformation rate of the polyethylene increases, LDPE demonstrates a dramatic rise in viscosity because of chain entanglement. This phenomenon is not observed with LLDPE because of the lack of long-chain branching in LLDPE which allows the chains to slide on one another upon elongation without becoming entangled. This characteristic is important for films application because LLDPE film can be down gauged easily maintaining high strength and toughness. The rheological properties of LLDPE are summarized as “stiff in shear and soft in extension”; it is not taken in most curbside pickups in communities. LLDPE can be recycled into other products like trash can liners, lumber, land scaping tiles, floor tiles, compost bins, and shipping envelopes.

Applications:

LLDPE penetrates almost all traditional markets for polyethylene. It is used for plastic bags and sheets (where it allows using lower thickness than comparable

LDPE). Plastic wrap, stretch wrap, pouches, toys, covers, lids, pipes, buckets and containers, covering of cable, geomembranes, and mainly flexible tubing. In 2009, the world market for LLDPE reached a volume of almost \$ 24 billion (~ € 17 billion) LLDPE is manufactured by using metallocene catalyst labeled Metallocene catalyst labelled MLLDPE.

CHAPTER THREE: MATERIALS AND METHODS

3.1 MATERIALS

The materials used in this research work are as follows:

- Low density Polyethylene (LDPE), obtained from Ceeplast Industries Aba, Abia State.
- Linear Low Density Polyethylene (LLDPE) also obtained from Ceeplast industries Aba, Abia State.
- Pawpaw peels, obtained from a local market in Owerri.
- Water melon Rind, obtained from a local market in Owerri
- Silicon oil, product of, Vickers Laboratory Limited, Burley – in – War Fedale West York, England.

3.2 EQUIPMENTS

- Testing machine(Charpy Machine-ASTME23 notched bar impact
- Electrical powered plate grinding machine. Bench type utility grinding machine
- Mesh sieve (250microns) obtained from Erosion Laboratory, Federal University of Technology, and Owerri.
- Injection molding machine. Plastic injection molding machine-DKM 500 for PVC.

3.3 METHODS

3.3.1 Preparation of the Fillers

Pawpaw peel: A large quantity of pawpaw peels was gotten from Pawpaw fruit and cut into small sizes. It was sun dried for 14 and then ground with electrical powered plate grinding machine to achieve fine particle size. A graduated mesh sieve of 250 microns was used to determine the particle size of the filler. The sieving was done at the Erosion Laboratory, Federal University of Technology, Owerri. Weight of the fresh pawpaw peel before sun drying was 200g, and then the weight after sun drying for 14 days was 72g.

Water Melon rind: A similar exercises was carried out on the water melon rind. It was sun dried for 14 days on intensive supervision and it was made sure that the water content dried up completely but before the drying commenced, the second layer (ie. the whitish layer containing water) was scraped entirely to avoid decay. After sun drying, it was thereafter ground using electrical powered plate grinding machine to achieve fine particle size. A graduated mesh sieve of 250microns was used to determine the particle size of the filler. The sieving was done at the Erosion Laboratory, Federal University of Technology Owerri. Weight of the water melon before sun drying was 210g. After sun drying for 14 days, the weight came down to 76g.

3.2.2 Preparation of the Composite

The fabrication of the Composite samples was carried out using the injection moulding technique. Separate sets of composites were prepared using low density polyethylene, and Linear Low density Polyethylene, while Pawpaw Peel and water melon rind served as fillers respectively. The filler loadings were varied from 0 to 25% while silicon oil, was added to every sample produced. These compounding agents are of commercial grade. The formulations for the low density polyethylene and LLDPE composites are shown in Tables 3.1 and 3.2.

Table 3.1: Formulations for the reinforced low density polyethylene composites

INGREDIENTS	CONTENT
LDPE	200g
Filler (melon rind)	0-25 % of weight (0, 5, 7.5, 10, 12.5)
Silicon oil	4cm ³

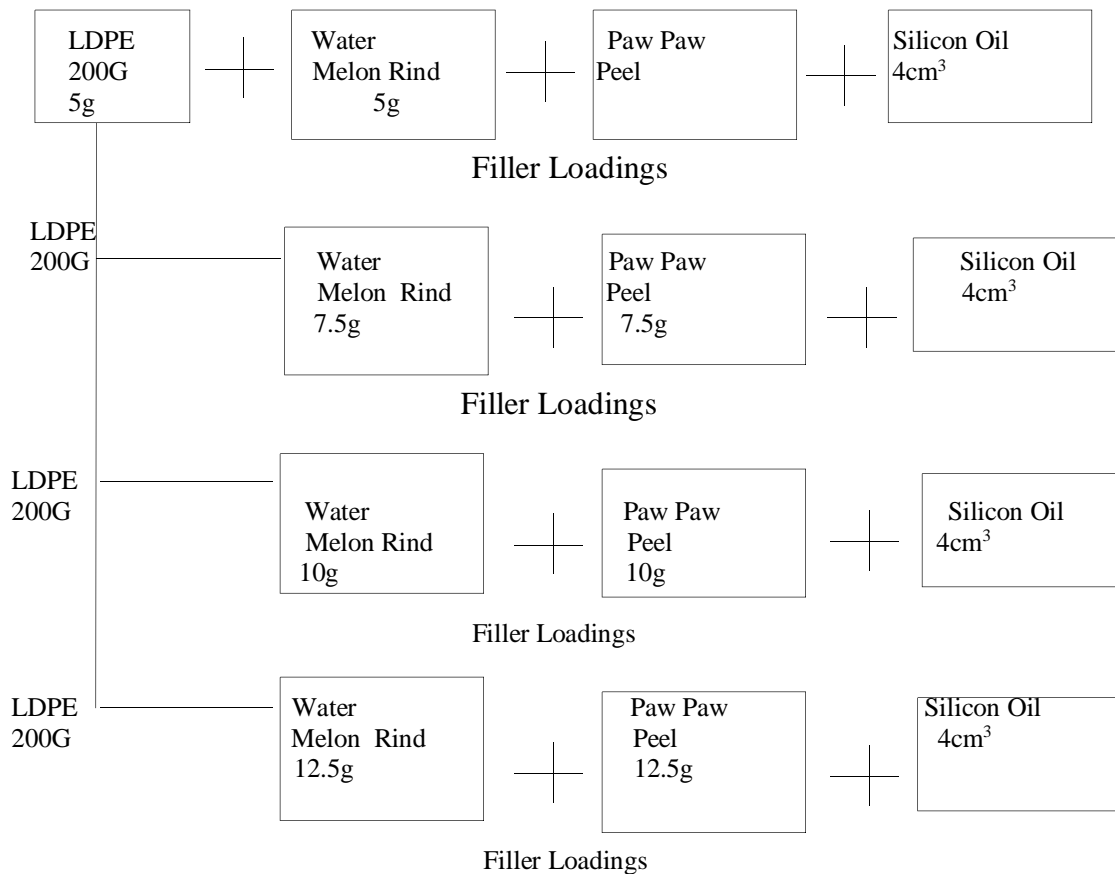
Table 3.2: Formulations for the reinforced linear low density polyethylene composites

INGREDIENTS	CONTENT
LLDPE	200g
Filler (pawpaw peel)	0-25% of weight
Silicon oil	4cm ³

Table 3.3: Formulations for the reinforced low density polyethylene composites with pawpaw peel and water melon fillers.

Sample code	Filler loading (%)	Formulations
A ₀	0	LDPE
5gWms/5gPps	10	200g LDPE + Wm + PP + Si oil
7.5g Wms/7.5g Pps	15	200 LDPE + Wm + PP + Si oil
10g Wms/10gPps	20	200g LDPE + Wm/pp + Si oil
12.5Wms/12.5g Pps	25	200g LDPE + Wm/Pp + Si oil

The flow chart below describes the formulations in Table 3.3



where:

W_{mr} = Water melon rind

A_o = Control

$5 W_{ms}/5P_{ps}$ = Water Melon & Pawpaw peel with silicon oil and 10% filler loading.

$7.5W_{ms}/7.5P_{ps}$ = Water melon & Pawpaw peel with silicon oil and 15% filler loading
 $10W_{ms}/10P_{ps}$ = water melon/pawpaw peel with silicon oil and 20% filler loading

$12.5 W_{ms}/12.5P_{ps}$ = Water melon/Pawpaw peel with silicon oil and 25% filler loading.

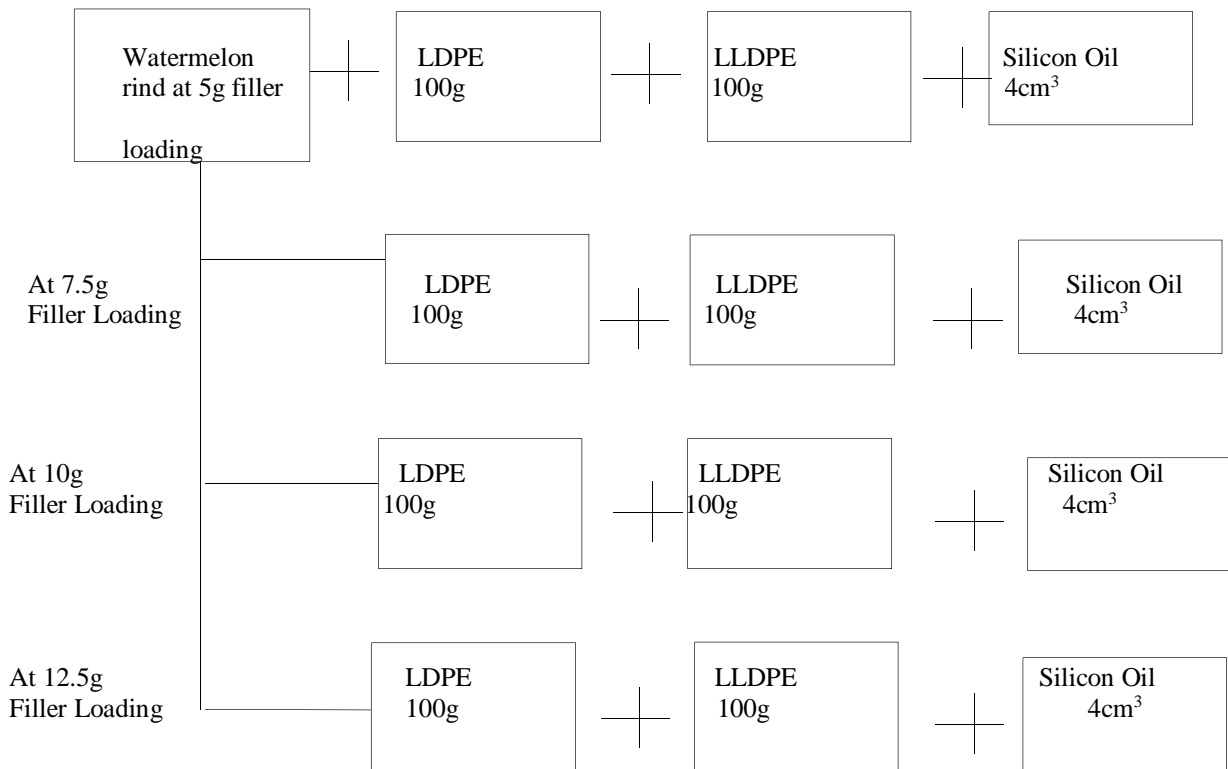
LDPE = Low Density polyethylene.

Si oil = Silicon oil

Table 3.4: Formulations for the reinforced low density polyethylene and linear low density polyethylene composite with water melon rind filler

Sample code	Filler loading (%)	Formulations
A ₀	0	LDPE and LLDPE
5g Wmrs	5	LDPE + LLDPE +Wm + Si oil
7.5g Wmrs	7.5	LDPE + LLDPE + Wm + Si oil
10g Wms	10	LDPE + LLDPE + Wm + Si oil
12.5Wms	12.5	LDPE + LLDPE + Wm + Si oil

The flow chart below describes the formulations in Table 3.4



where:

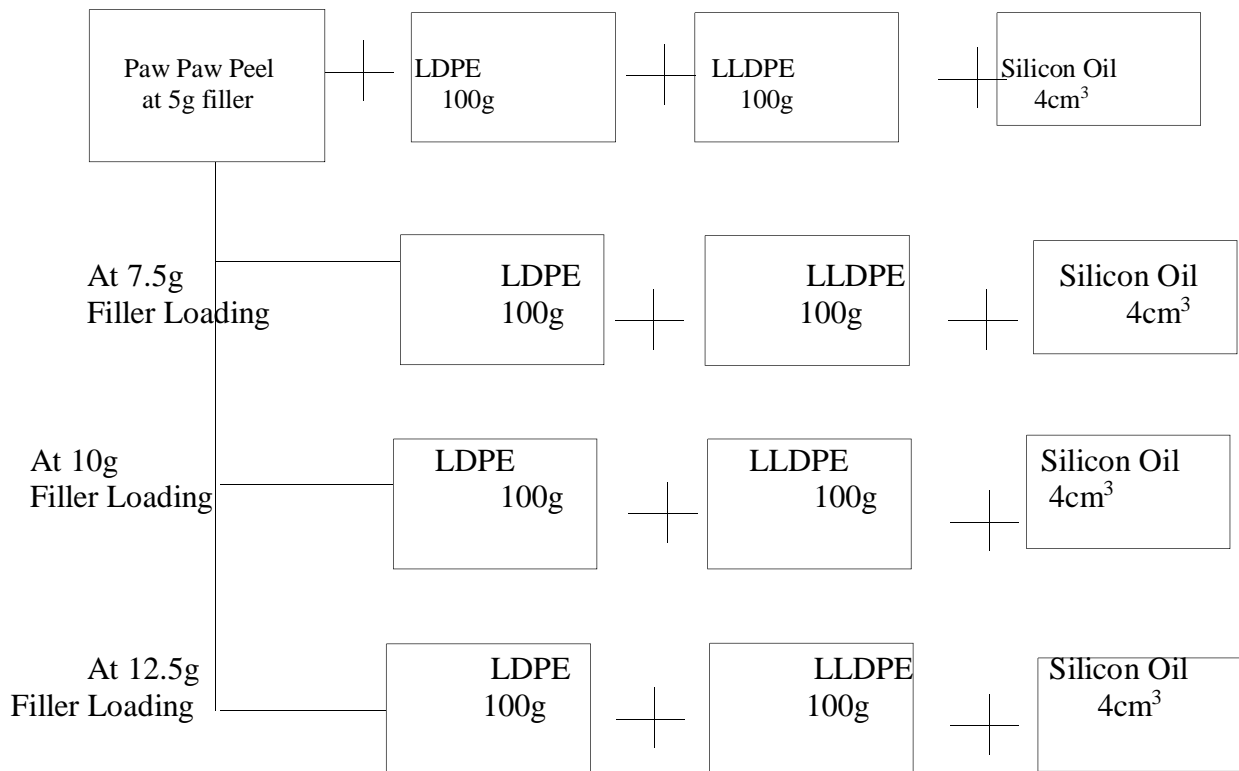
Wmrs = Water Melon rind

Ao =	Control
5Wmr =	Water melon rind with silicon oil, LDPE and LLDPE and 5% filler loading
7.5 Wmrs =	Water melon rind with silicon oil, LDPE and LLDPE and 7.5% filler loading.
10 Wmrs =	Water melon rind with silicon oil, LDPE and LLDPE and 10% filler loading
12.5Wrs =	Water melon rind with silicon oil, LDPE and LLDPE and 12.5% filler loading.
LDPE =	Low Density Polyethylene
LLDPE =	Linear Low Density Polyethylene
Si oil =	Silicon Oil

Table 3.5: Formulations for the reinforced low density polyethylene and linear low density polyethylene composite with pawpaw peel filler

Sample code	Filler loading	Formulations
Ao	0	LDPE and LLDPE
5g Pps	5	LDPE + LLDPE + Pp + Si oil
7.5g Pps	7.5	LDPE + LLDPE + Pp + Si oil
10g Pps	10	LDPE + LLDPE + Pp + Si oil
12.5 Pps	12.5	LDPE + LLDPE + Pp + Si oil

The flow chart below describes the formulations in Table 3.5



where:

5Pps = Pawpaw peel with silicon oil, LDPE and LLDPE and 5% filler loading

7.5 Pps = Pawpaw peel with silicon oil, LDPE and LLDPE and 7.5% filler loading

10 Pps = Pawpaw peel with silicon oil, LDPE and LLDPE and 10% filler loading

12.5Pps = Pawpaw peel with silicon oil, LDPE and LLDPE and 12.5% Filler loading.

LDPE = Low Density polyethylene

LLDPE = Linear low density polyethylene

Si oil = Silicon oil

3.3 MECHANICAL ANALYSIS OF COMPOSITES

After fabrication of composites, the test specimens were prepared into different forms and shapes from the materials in sheet, and subjected to various mechanical tests as per American standards for testing materials (ASTM) standards.

TENSILE STRENGTH TEST

Tensile strength, also known as ultimate strength, is a measure of force per unit of original cross sectional area at the time of rupture. The tensile test was carried out on the dumbbell shaped specimens. A uniaxial load was applied through both ends of the dumbbell shaped samples until they ruptured. The tests were done using the method in ASTM-D 638. The overall length and width of the dumbbell

shaped samples were 120mm and 20mm respectively. The gauge length was 60mm, width of narrow section 10mm, and gripping length, 20mm. Tensile strength TS is given by the expression

$$TS = \frac{FA}{A}$$

A

where: FA= force in Nm^{-2}

A =cross sectional area

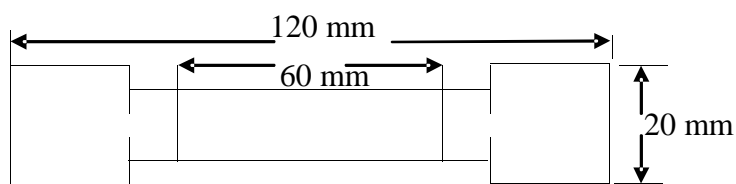


Fig 3.1 The dumbbell shape

EXTENSION AT BREAK

The ultimate extension of an engineering material is the percentage increase in length that occurs before it breaks under tension. The amount of ductility is an important factor when considering forming operations such as rolling and extrusion. It also provides an indication such of how visible overload damage to a component might become before the component fractures. The conventional measures of ductility are the engineering strain at fracture (usually called the elongation) and the reduction of area at fracture.

Both of these properties are obtained by fitting the specimen back together after fracture and measuring the change in length and cross-sectional area. Elongation

is the change in axial length divided by the original length of the specimen or portion of the specimen. It is expressed as a percentage.

Because an appreciable fraction of the plastic deformation will be concentrated in the necked region of the tensile specimen, the value of elongation will depend on the gauge length over which the measurement is taken.

MODULUS OF ELASTICITY

The slope of the line in the stress-strain graph where stress is proportional to strain is called the modulus of elasticity or Young's modulus which (E) defines the properties of a material as it undergoes stress, deforms, and then returns to its original shape after the stress is removed. It is a measure of the stiffness of a given material.

The modulus of elasticity applies specifically to the situation of a component being stretched with a tensile force.

IMPACT ENERGY TEST

The impact energy test carried out to determine the resistance a material will offer to shock, and show its ability to withstand stress concentration. A Charpy machine was used to carry out the impact energy test. The Charpy test is most commonly used to evaluate the relative toughness or impact toughness of materials and as such is often used in quality control applications where it is a fast and economical test. The test samples were cut into rectangular shapes of 100mm by 8mm (with a 'V' notch at the centre) for the impact tests. When the striker impacts the sample, the sample will absorb energy until it yields. At this point, the sample will begin to undergo plastic deformation at the notch. The

notch in the sample affects the results of the impact test, thus it is necessary for the notch to be of regular dimensions and work hardens at the plastic zone of the notch. When the sample can absorb no more energy, fracture occurs.

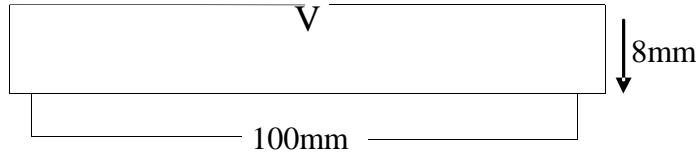


Fig 3.2 The V notched rectangular test shape

HARDNESS TEST

Hardness is the relative resistance of the surface to indentation by an indenter of specified dimension under a specified load. A Tensometer of type 'W' by Monsanto was used to perform Brinell hardness test.

The test sample as cut in rectangular shapes of 50mm by 30mm and placed in the machine. Each sample was inserted and the Brinell Ball Bolster was adjusted up to zero reading for the mercury gauge.

The load was then applied to the sample. The mercury level was kept at the zero reading for 15 seconds, thus giving the desired indentation to the samples. The sample is then removed from the machine and the diameter of the indentation measured with Brinell reading microscope to obtain the Brinell Hardnes number.

The Brinell hardness Number (BHN) is expressed as

$$\text{BHN} = \frac{2p}{\pi D (D - \sqrt{D^2 - d^2})}$$

where:

P=applied force (kgf)

D=diameter of indenter (mm)

d= diameter of indentation (mm)

N.B: The Brinell Ball is made of carbon steel.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 TENSILE STRENGTH

4.1.1 Effects of Filler Loading on Tensile Strength

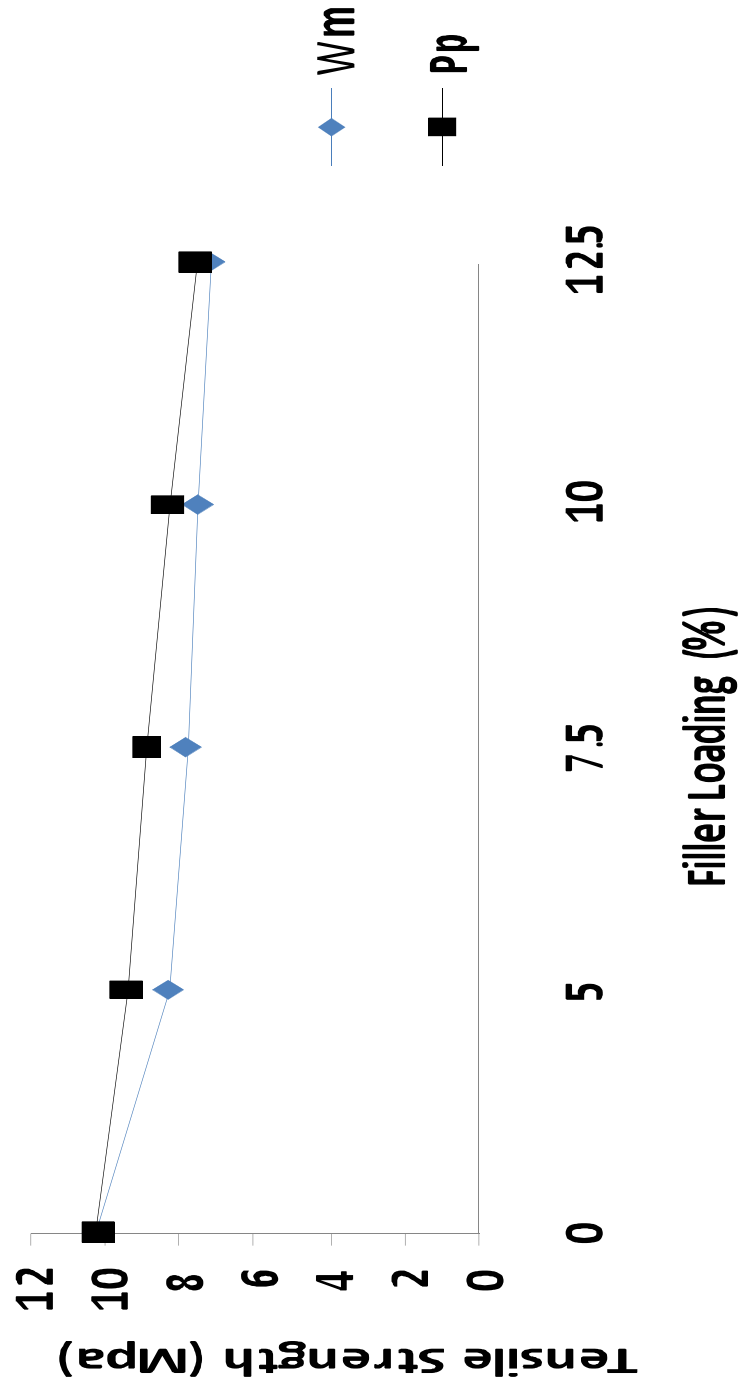


Fig 4.1 Tensile Strength against Filler Loading for water melon rind and pawpaw peel fillers

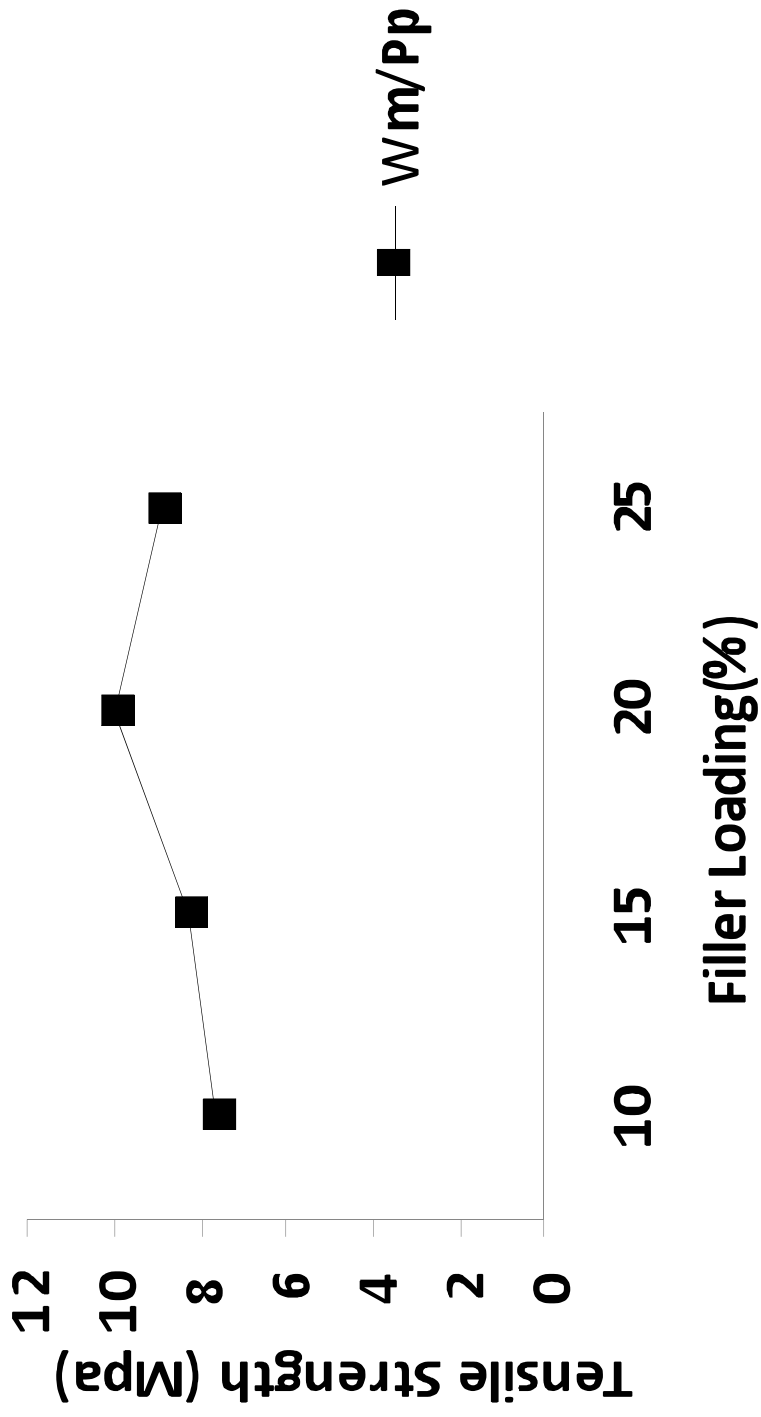


Fig. 4.2 Tensile Strength against Filler Loading for water melon rind/pawpaw peel fillers

Figures 4.1 and 4.2 show the tensile strengths of the blended composite materials. Figure 4.1 shows that the tensile strength decreased with the increase of filler contents for the two cases considered. This could be as attributed to poor bonding between the fillers and the matrix; their capability to support stress transmitted from the polymer matrix is rather poor. Nonetheless, fibres may be folded such that there is no bonding between the folded and unfolded portions of fibre which may result in a lower strength.

According to Yang et al. (2004), as the filler loading increased, thereby increasing the interfacial area, the worsening interfacial bonding between filler (hydrophilic) and matrix polymer (hydrophobic) slightly decreased the tensile strength. Also fibre entanglement may contribute to reduce the strength (Joseph et al., 2002). However, in Figure 4.2, the tensile strength of the composite increased as the filler loading is being increased. A maximum tensile strength was recorded at 20% of filler loading, after which the tensile strength decreased. It is believed that, the incorporation of two fillers sufficient to provide the reinforcing effect to the composite system stress is transferred efficiently from matrix to the fibre (Norshahida et al., 2013). Tensile strength tended to decrease due to excessive content of the fillers which caused the discontinuity of the matrix (Sharma et al., 2001). Weight fraction is perhaps the most important factor, since most mechanical properties increase with increase in the amount of fibre, until a maximum amount, because at higher reinforcement loading, low dispersion of fibres in the matrix occurs (Ramire et al. 2011).

4.2 EXTENSION AT YIELD

4.2.1 Effect of Filler Loading on Extension at Yield

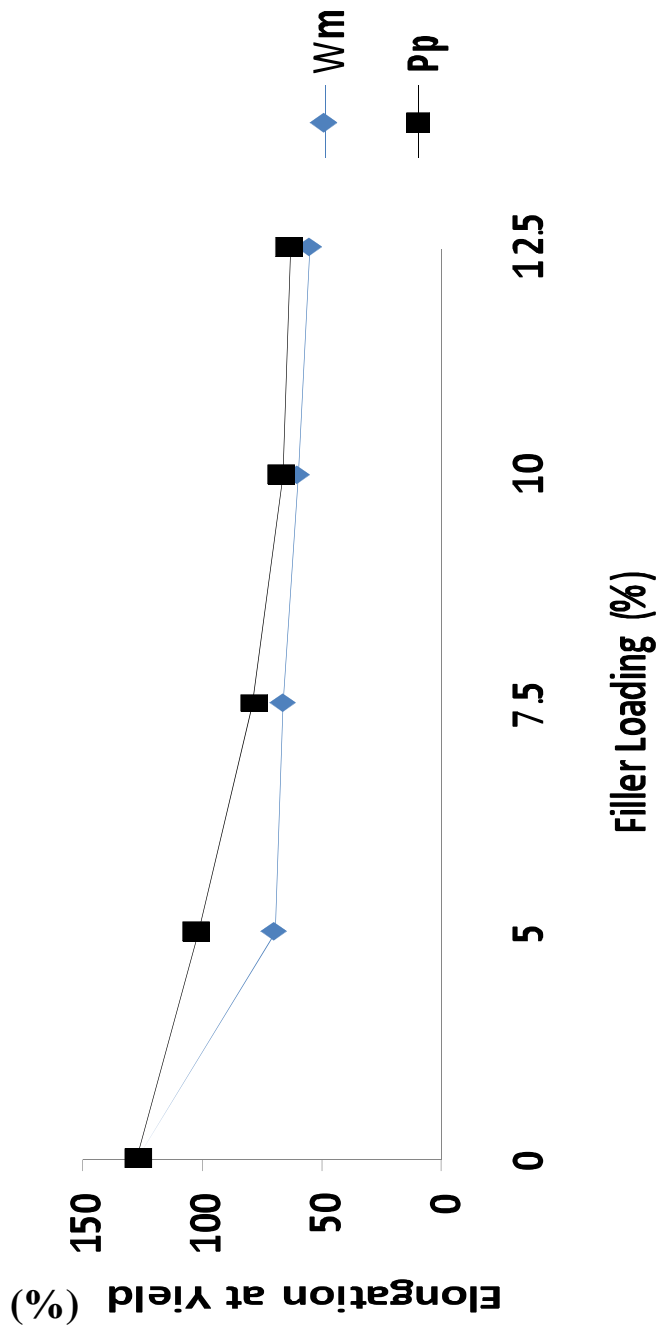


Fig. 4.3 Elongation at Yield against Filler Loading for water melon rind and pawpaw peel fillers

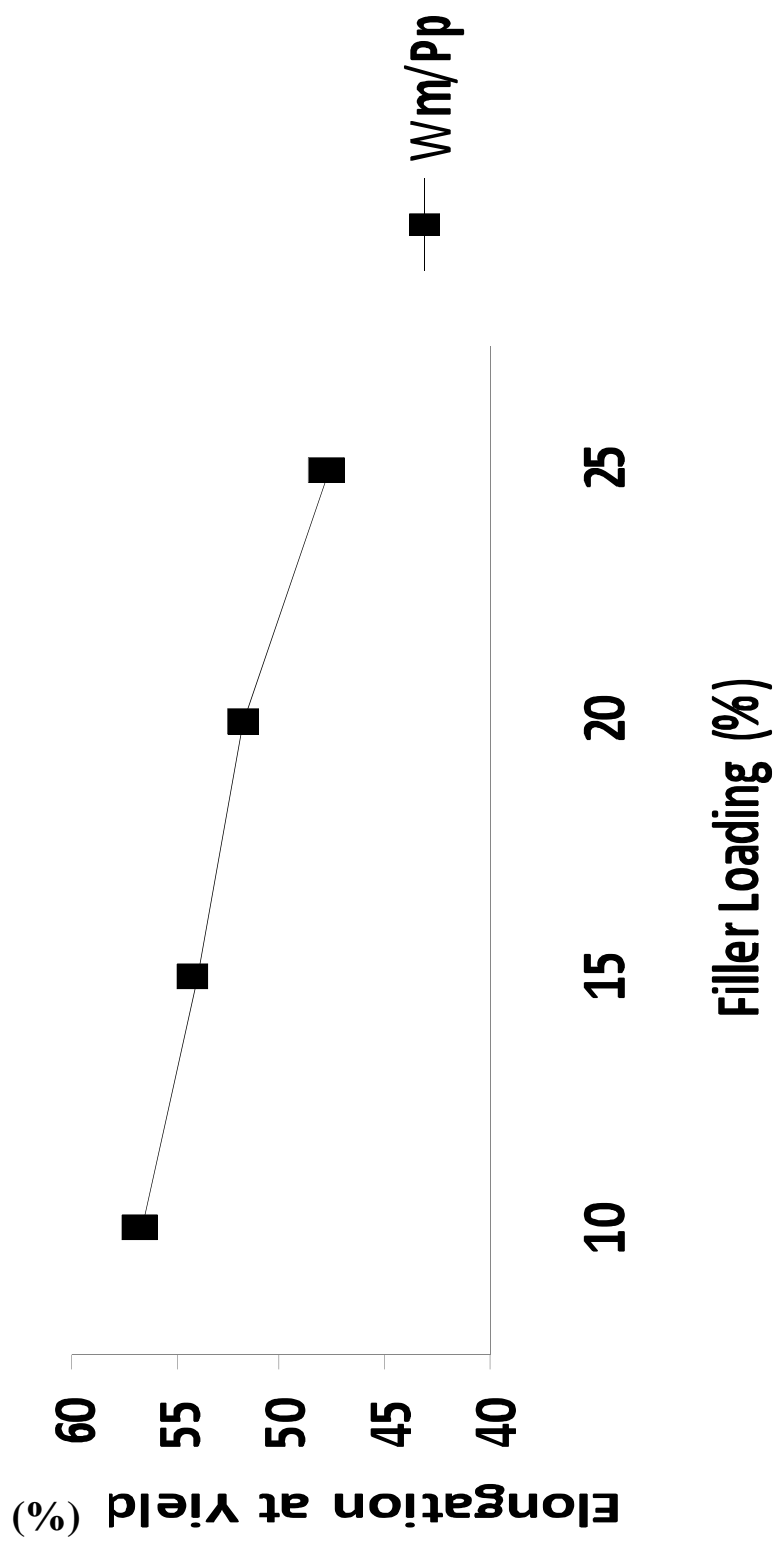


Fig. 4.4 Elongation at Yield against Filler Loading for water melon rind/pawpaw peel fillers

The results of extension at yield of all composite, with different filler loading are shown in Tables A1, A2 and A3. Figures 4.3 and 4.4 present the extension at yield of pawpaw/water melon + LDPE, pawpaw + LDPE/LLDPE and water melon + LDPE/LLDPE. The extension at yield from the data reveals that there was a decrease with increase in filler loading.

Decreased deformability of the rigid interface between the filler and the matrix, which leads to an inevitable decrease in the degree of ductility of material, can be attributed to the decrease in elongation at yield with increase in filler loading.

The incorporation of the fillers weakens the forces between LDPE layers and also, water melon rind and pawpaw peel has lower elongation than LDPE. Since there is no chemical interaction between both constituents, the inclusion forms discontinuity, resulting in lower elongation (Puglia et al., 2003).

4.3 EXTENSION AT BREAK

4.3.2 Effect of Filler Loading on Extension at Break

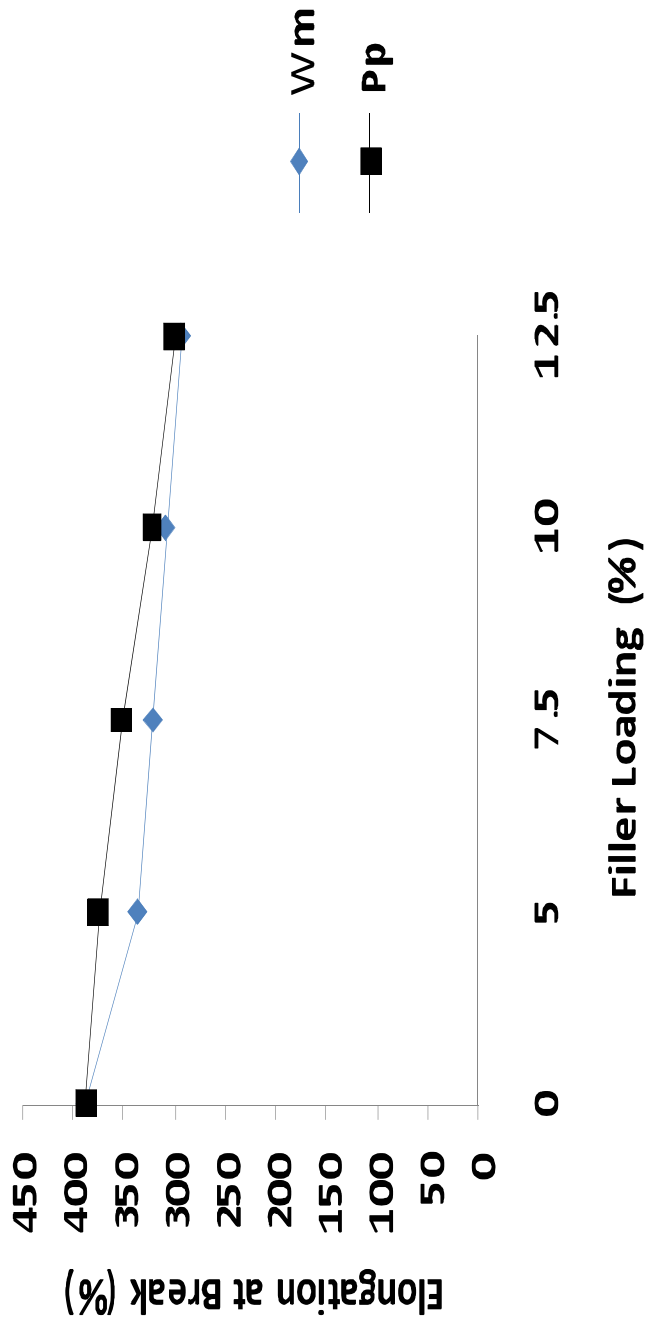


Fig. 4.5 Elongation at Break against Filler Loading for water melon rind and pawpaw peel fillers

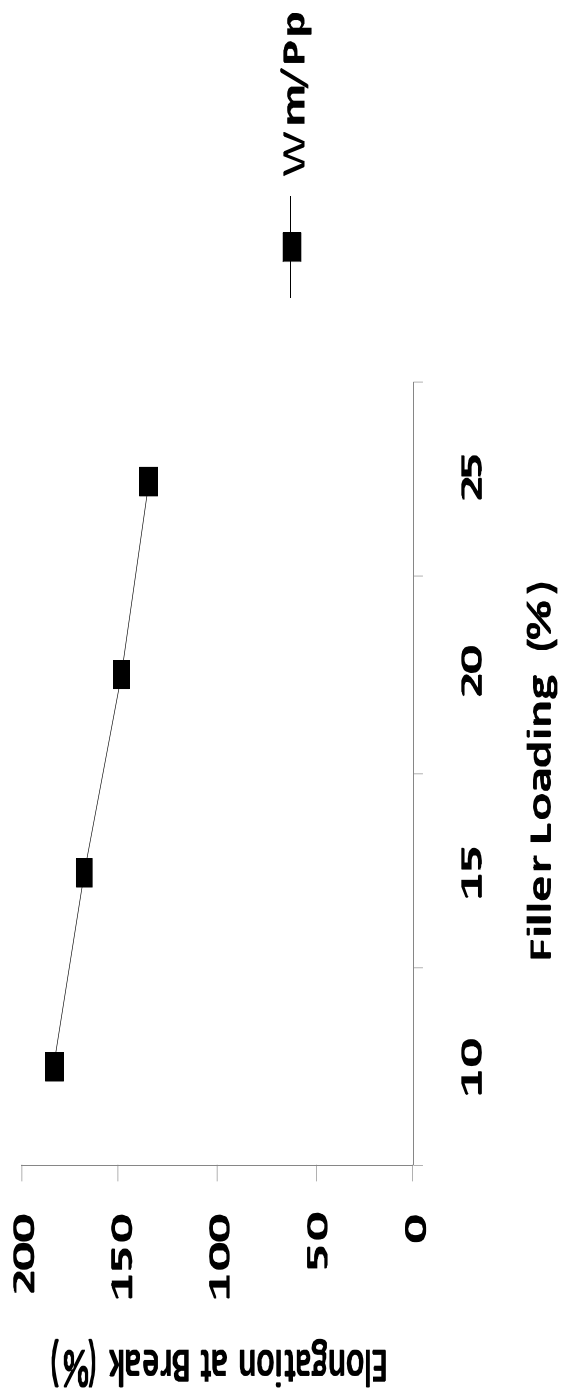


Fig. 4.6 Elongation at Break against Filler Loading for water melon rind/pawpaw peel fillers

The effects of filler loading on the extension at break of pawpaw + LDPE and LLDPE and watermelon + LDPE and LLDPE, pawpaw/watermelon + LDPE of different filler loadings are shown in Figures 4.5 and 4.6.

Increase in filler loading gave rise to the stiffening and hardening of the composites thus making the elongation at break to decrease as filler loading is increased. Nielson, (1974) reported that the elongation at break for rigid particulate polymers decreases as the filler percentage increases due to on loading. The matrix is the only phase to strain, such that as the filler volume fraction is increased, then the matrix under strain effectively decreases which, for an equivalent load, represents a greater stress.

The characteristic behaviour for filled polymer composites and hence applicable models for the elongation at break depend on the characteristic fracture surface of the composite, which is a function of the adhesion between the phases. For good adhesion the matrix cracking jumps from particle to particle, producing a rough fracture surface, while poor adhesion failure results in a smooth fracture surface. For poor adhesion the effect of the filler is to provide interference to the matrix mobility and / or deformation, similar to that discussed for modulus properties (Nielson, 1974).

4.4 MODULUS OF ELASTICITY

4.4.1 Effect of Modulus of Elasticity on Filler Loading

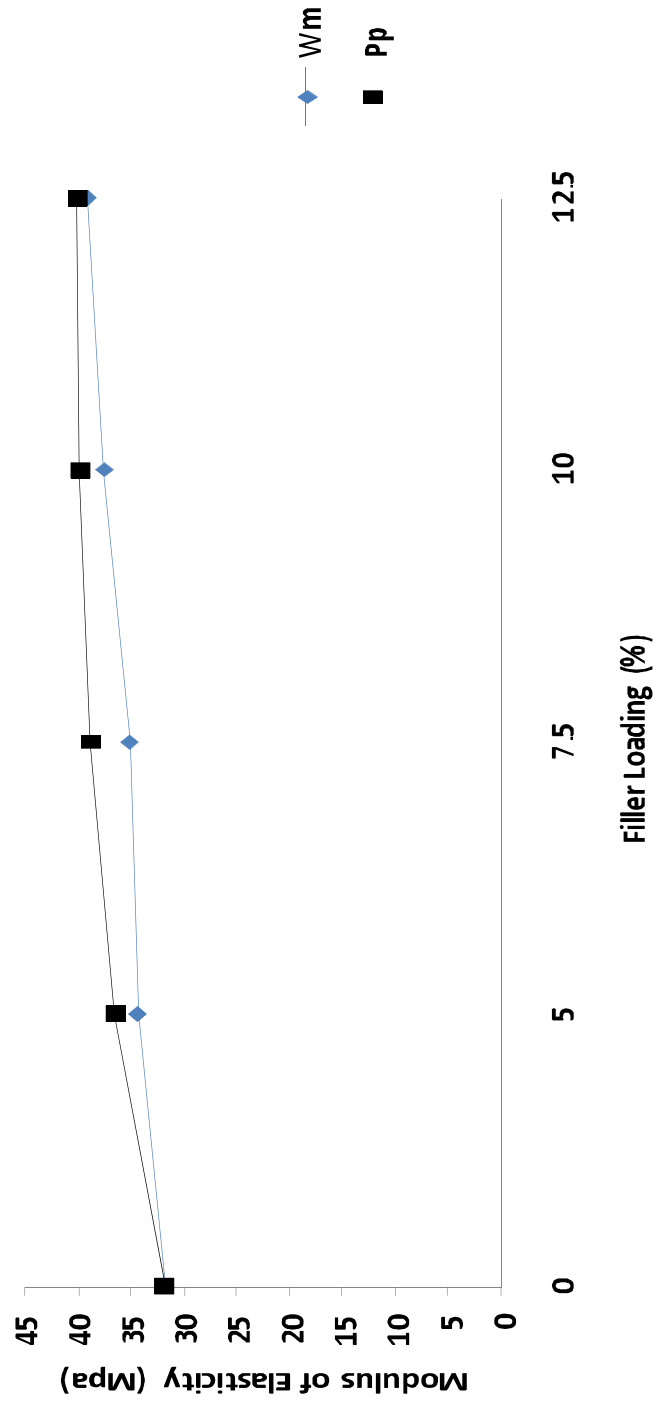


Fig. 4.7 Modulus of Elasticity against Filler Loading for water melon rind and pawpaw peel fillers

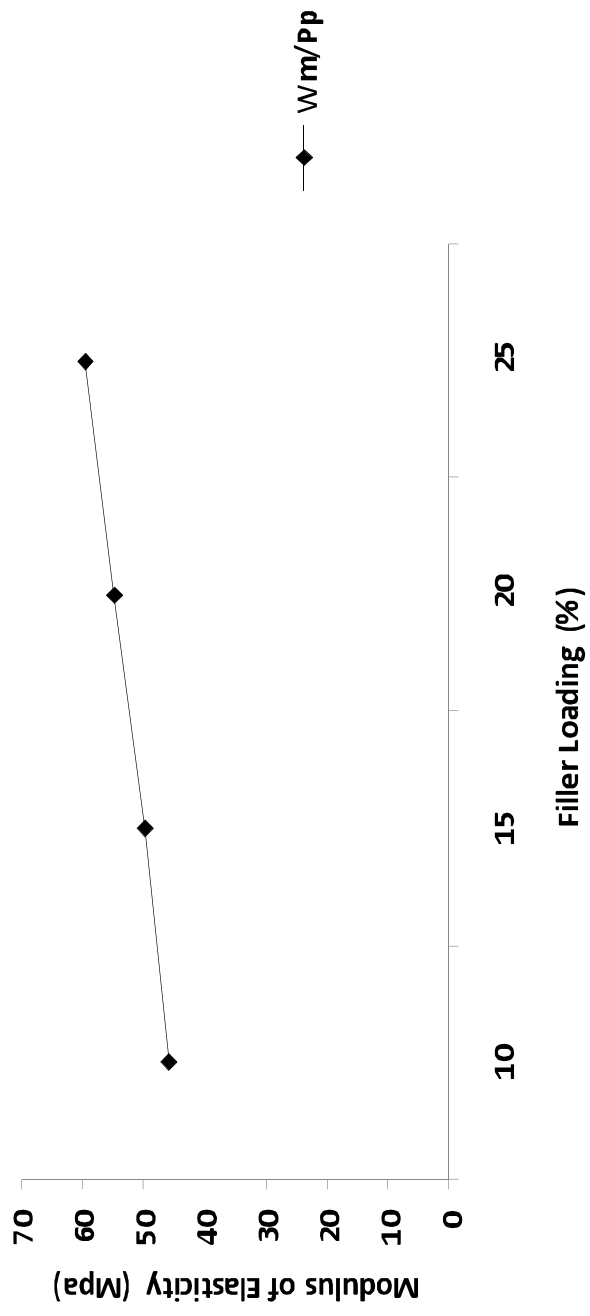


Fig. 4.8 Modulus of Elasticity against Filler Loading for water melon rind/pawpaw peel fillers

Figures 4.7 and 4.8 present the Modulus of elasticity of pawpaw + LDPE and LLDPE and watermelon + LDPE and LLDPE, pawpaw and watermelon + LDPE.

The plots clearly indicate that the modulus increases with increasing level of fillers in the mixture. This result suggests that the stiffening effect had occurred because of the existence of fibre inside the composites. This increased modulus corresponds to more filler where its intrinsic properties, exhibits high stiffness (modulus) compared to polymer matrix. This is because at high filler loading, the composite will be able to withstand greater loads. Therefore filler increase improves the modulus of the composite more so, pawpaw/ watermelon contains an appreciable amount of fibre to give a stiff structure, thereby improving the modulus of the composite.

Comparing the plots in Figure 4.7 and Figure 4.8, the composition of water melon/pawpaw peel filled LDPE has the highest modulus of elasticity as compared to water melon filled LDPE + LLDPE and pawpaw peel filled LDPE + LLDPE. This could be as a result of reinforcement provided by both fillers which forms large percentage of stiffness.

4.5 IMPACT ENERGY

4.5.1 Effect of Filler Loading in Impact Energy

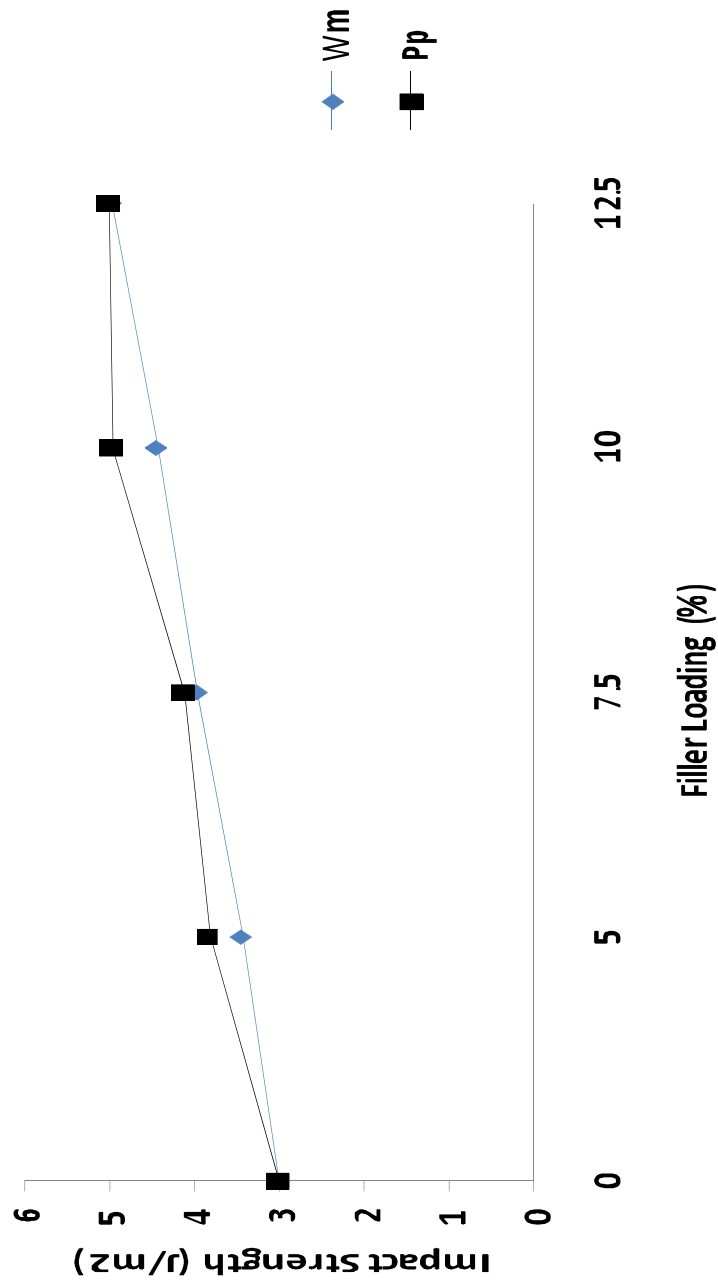


Fig. 4.9 Impact Strength against Filler Loading for water melon rind and pawpaw peel fillers

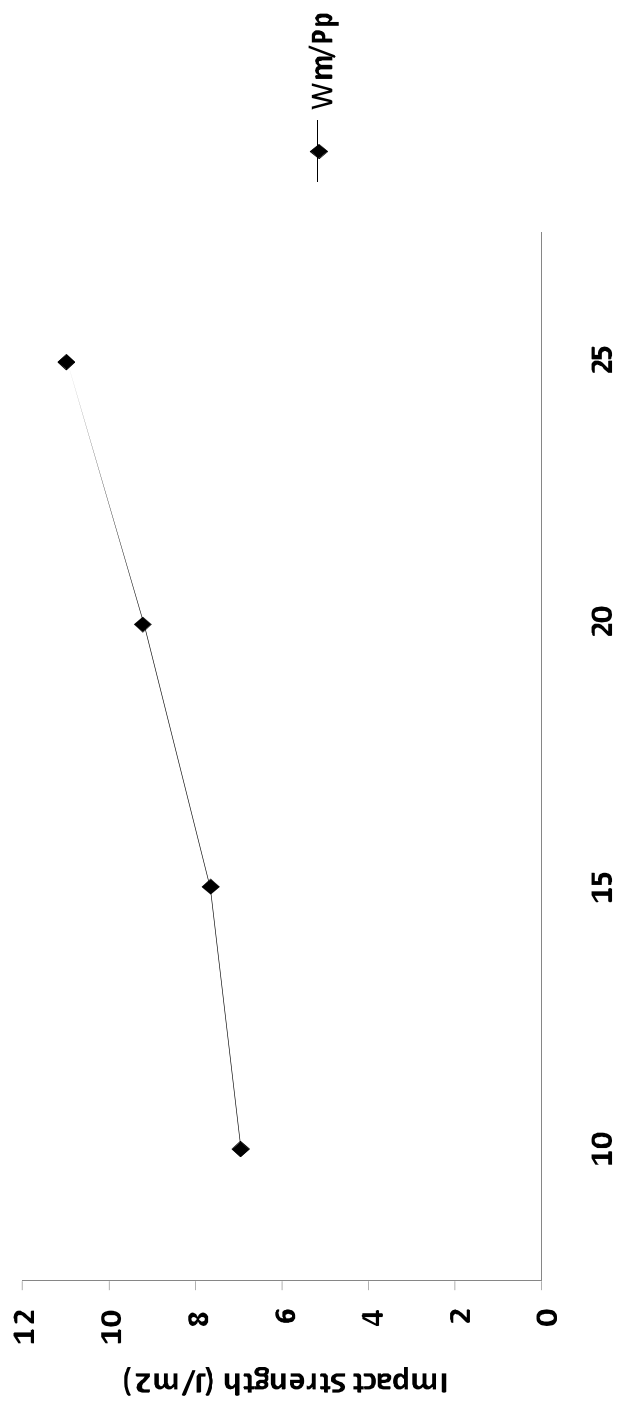


Fig. 4.10 Impact Strength against Filler Loading for water melon rind /pawpaw peel fillers

The result of the impact test conducted on the samples to determine the variation of the impact energy absorbed by samples with different fillers, filler compositions and filler loading were recorded in Tables A7 and A8 and A9.

Figures 4.9 and 4.10 show the Charpy impact strength of pawpaw + LDPE/LLDPE and watermelon + LDPE/LLDPE, and pawpaw and watermelon + LDPE. The increased filler loading resulted in the stiffening and hardening of the composite thereby increasing the impact energy of the composite.

When compared to pawpaw + LDPE/LLDPE and watermelon + LDPE/LLDPE composites the combination of pawpaw and watermelon + LDPE expressed very high impact strength. The highest impact strength of 10.98kJ/m^2 was recorded at filler loading of 25% . The impact resistance of unfilled LDPE sample was observed to be 3.01kJ/m^2

High strain rates or impact loads may be expected in many engineering applications of composite material. The suitability of a composite for such application should therefore be determined not only by usual design parameters, but by its impact or energy absorbing properties.

Impact energy is dissipated by debonding, fibre and/or matrix fracture and fibre pull out. Fibre fracture dissipates less energy compared to fibre pull out. The former is common in composites with strong interfacial bond while the occurrence of the latter is a sign of a weak bond (Paul et al., 2003). Hence, fibres possess very good impact strength.

4.6 HARDNESS

4.6.1 Effect of Filler Loading on Hardness

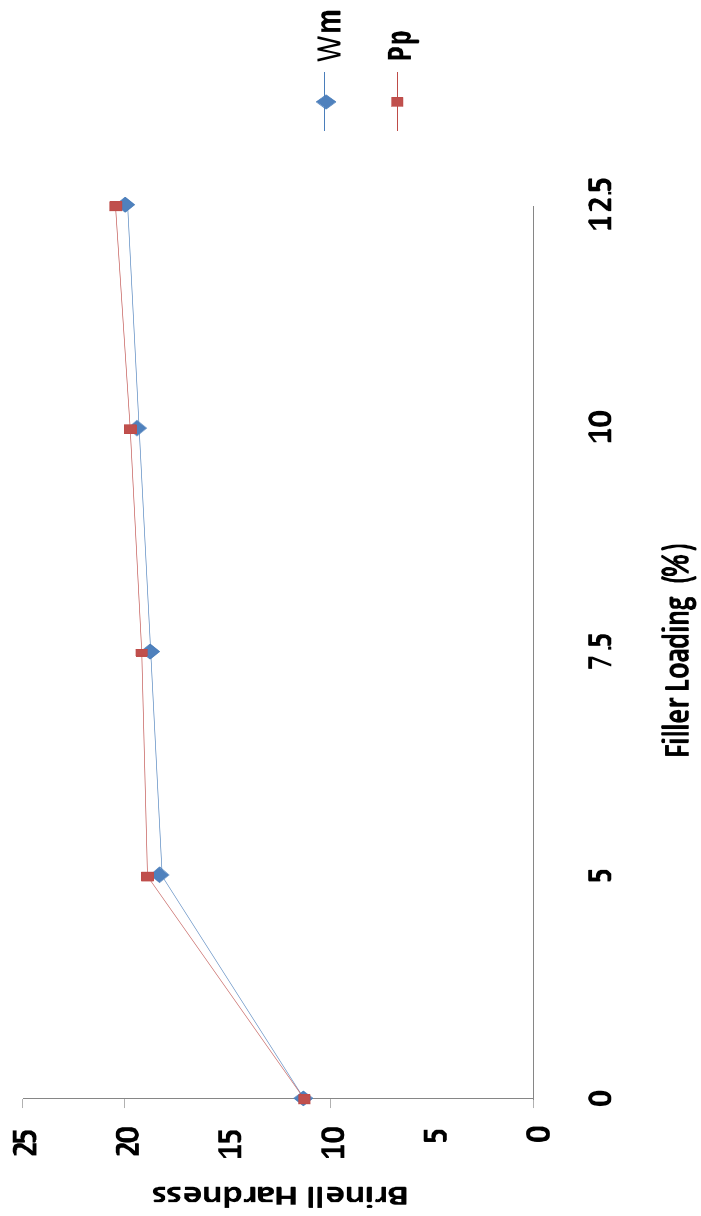


Fig. 4.11 Hardness test against Filler Loading for water melon rind and pawpaw peel fillers

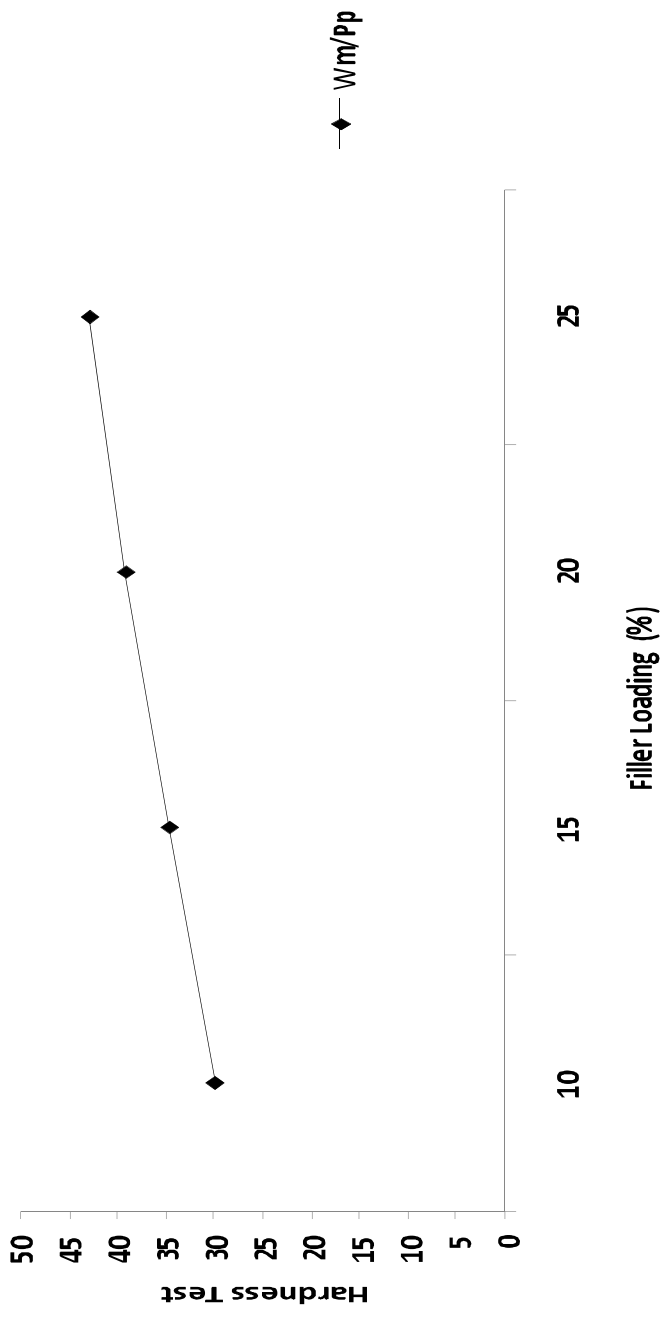


Fig. 4.12 Hardness test against Filler Loading for water melon rind/pawpaw peel fillers

The results of hardness test on pawpaw and watermelon + LDPE, watermelon + LDPE/LLDPE and pawpaw + LDPE/LLDPE are shown in Tables A4, A5 and A6. A gradual increase in hardness with the weight fraction of fibre was noticed in Figures 4.11 and 4.12. It clearly indicates that inclusion of pawpaw peel improves the load bearing capacity and the ability to withstand indentation on the composites. Similar observations have been reported by (Harsha et al., 2005) for other fibre reinforced thermoplastics such as polyaryletherketone composites. It is well known that the hardness originally depends on some important factors such as: type of the linking forces between the molecules and types of the surface and other effective conditions. However, a comparative plot of the three composite formulations against filler loading (Figures 4.11 and 4.12) shows that the pawpaw and watermelon + LDPE combination had a marked improvement in the hardness of the composites.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.2 CONCLUSION

At the end of the study, the following conclusions were derived:

- Pawpaw peel and water melon rind can be used as reinforcing fillers in thermoplastics.
- Increase in the composition of pawpaw peel and water melon rind in LDPE/LLDPE matrix caused the elongation at yield and elongation at break of the specimen to decrease.
- The elastic modulus of pawpaw peel and water melon filled LDPE/LLDPE increased with increasing filler loading.
- The elastic modulus of pawpaw peel filled LDPE/LLDPE is higher compared to the corresponding water melon filled LDPE/LLDPE.
- The hardness of the composites increased with increasing filler loading with the combination of pawpaw peel and water melon filled LDPE recording higher hardness values.
- Development of the composites enhanced the mechanical properties.
- Impact strength of pawpaw peel and water melon filled LDPE increased with increasing filler loading.
- The optimum filler content for pawpaw peel and water melon combination was found to be 20% where the drop in tensile strength occurred.

5.3 RECOMMENDATION

The utilization of agricultural waste for fabrication of thermoplastic composites is an economically worthwhile venture providing great waste to wealth transformation since the use of these wastes as manure alone cannot solve the environmental pollution they constitute.

This study leaves wide scope for future investigations. It can be extended to:

- ◆ Newer composites using other reinforcing phases and the resulting experimental findings can be similarly analyzed.
- ◆ Finding the physical properties of the composites as the quantity of fibre is further increased.
- ◆ Compounding the composite at different pressures – to determine the effect of pressure on the properties.

CONTRIBUTION TO KNOWLEDGE

This research work has made us understand that pawpaw peel and water melon rind can be used as reinforcing fillers in thermoplastics, especially when combined with polymers with unique properties.

Secondly when designing a fibre-reinforced composite, certain factors must be considered because it is generally accepted that the properties of composites

are controlled by factors such as nature of matrix,length and relative composition of the reinforcement.

Thirdly, this research has also made it clear that “the development of the composites enhances their mechanical properties.

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APPENDICES

Tables showing results measurement of the various Mechanical properties test on the samples using.

Pure LDPE

	Length (mm)	Width (mm)	Thickness (mm)	Area (mm ²)
1	65.00000	3.00000	10.00000	0.30000

	Maximum Load (N)	Tensile strain at Maximum Load (%)	Tensile stress at Maximum Load (MPa)	Tensile strain at Yield (Zero Slope) (%)
1	306.58802	127.28144	10.22436	43.89459

	Tensile strain at Break (Standard) (%)	Tensile stress at Yield (Zero Slope) (MPa)	Tensile stress at Break (Standard) (MPa)	Tensile extension at Yield (Zero Slope) (mm)
1	341.49826	8.02819	0.41242	127.41656

	Tensile extension at Break (Standard) (mm)	Energy at Yield (Zero Slope) (J)	Energy at Break (Standard) (J)	Load at Yield (Zero Slope) (N)
1	250.29980	6.41745	61.70481	299.27501

	Load at Break (Standard) (N)	Extension at Maximum Load (mm)	Extension at Yield (Zero Slope) (mm)	Tensile extension at Maximum Load (mm)
1	15.37411	79.49999	127.41656	79.49999

	True strain at Break (Standard) (mm/mm)	True stress at Break (Standard) (MPa)	True strain at Maximum Load (mm/mm)	True stress at Maximum Load (MPa)
1	1.48500	1.82082	0.82102	18.69245

	True strain at Yield (Zero Slope) (mm/mm)	True stress at Yield (Zero Slope) (MPa)	Modulus (Automatic) (MPa)
1	0.36391	11.55213	31.75817

5g of water melon +LDPE+LLDPE

	Length (mm)	Thickness (mm)	Width (mm)	Area (cm ²)
1	65.00000	3.00000	10.00000	0.30000

	Modulus (Automatic) (MPa)	Energy at Break (Standard) (J)	Extension at Yield (Zero Slope) (mm)	Extension at Break (Standard) (mm)
1	34.36766	130.59898	70.08342	500.00006

	Load at Yield (Zero Slope) (N)	Load at Break (Standard) (N)	Tensile stress at Yield (Zero Slope) (MPa)	Tensile stress at Break (Standard) (MPa)
1	250.93395	280.73359	8.36446	9.35779

	Tensile strain at Yield (Zero Slope) (mm/mm)	Tensile strain at Break (Standard) (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)	Tensile strain at Maximum Tensile extension (mm/mm)
1	1.07821	7.69231	10.18395	7.69249

	Tensile extension at Yield (Zero Slope) (mm)	Tensile extension at Break (Standard) (mm)	True strain at Yield (Zero Slope) (mm/mm)	True strain at Break (Standard) (mm/mm)
1	70.08343	500.00006	0.73151	2.16244

	True stress at Yield (Zero Slope) (MPa)	True stress at Break (Standard) (MPa)	Maximum Tensile extension (mm)	Poisson's Ratio (Chord)
1	17.38309	81.34077	500.0121	-----

	Energy at Maximum Tensile extension (J)	Load at Maximum Tensile extension (N)	Tensile strain at Maximum Tensile extension (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)
1	130.60264	305.51862	7.69249	10.18395

5g of pawpaw + 5g water melon + LDPE

	Length (mm)	Thickness (mm)	Width (mm)	Area (cm ²)
1	65.00000	3.00000	10.00000	0.30000

	Modulus (Automatic) (MPa)	Energy at Break (Standard) (J)	Extension at Yield (Zero Slope) (mm)	Extension at Break (Standard) (mm)
1	38.83596	85.35192	56.74984	376.44994

	Load at Yield (Zero Slope) (N)	Load at Break (Standard) (N)	Tensile stress at Yield (Zero Slope) (MPa)	Tensile stress at Break (Standard) (MPa)
1	228.44328	-4.47149	7.61478	-0.14905

	Tensile strain at Yield (Zero Slope) (mm/mm)	Tensile strain at Break (Standard) (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)	Tensile strain at Maximum Tensile extension (mm/mm)
1	0.87307	5.79154	-0.14905	5.79154

	Tensile extension at Yield (Zero Slope) (mm)	Tensile extension at Break (Standard) (mm)	True strain at Yield (Zero Slope) (mm/mm)	True strain at Break (Standard) (mm/mm)
1	56.74984	376.44995	0.62758	1.91568

	True stress at Yield (Zero Slope) (MPa)	True stress at Break (Standard) (MPa)	Maximum Tensile extension (mm)	Poisson's Ratio (Chord)
1	14.26304	-1.01228	376.4500	-----

	Energy at Maximum Tensile extension (J)	Load at Maximum Tensile extension (N)	Tensile strain at Maximum Tensile extension (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)
1	85.35192	-4.47149	5.79154	-0.14905

5g of pawpaw + LDPE + LLDPE

	Length (mm)	Width (mm)	Thickness (mm)	Area (mm ²)
1	65.00000	10.00000	3.00000	0.30000

	Maximum Load (N)	Tensile strain at Maximum Load (%)	Tensile stress at Maximum Load (MPa)	Tensile strain at Yield (Zero Slope) (%)
1	366.95888	100.19735	9.84384	100.19735

	Tensile strain at Break (Standard) (%)	Tensile stress at Yield (Zero Slope) (MPa)	Tensile stress at Break (Standard) (MPa)	True stress at Break (Standard) (MPa)
1	242.02137	9.84384	0.55205	1.88812

	Tensile extension at Yield (Zero Slope) (mm)	Tensile extension at Break (Standard) (mm)	Energy at Yield (Zero Slope) (J)	Energy at Break (Standard) (J)
1	62.58327	151.16655	20.45981	51.45193

	Load at Yield (Zero Slope) (N)	Load at Break (Standard) (N)	Extension at Maximum Load (mm)	Extension at Yield (Zero Slope) (mm)
1	366.95888	20.57921	62.58327	62.58327

	Tensile extension at Maximum Load (mm)	True strain at Break (Standard) (mm/mm)	True strain at Maximum Load (mm/mm)	True stress at Maximum Load (MPa)
1	62.58327	1.22970	0.69413	19.70711

	True strain at Yield (Zero Slope) (mm/mm)	True stress at Yield (Zero Slope) (MPa)	Modulus (Automatic) (MPa)	Modulus (E-modulus) (MPa)
1	0.69413	19.70711	53.49947	-----

	Energy to X-Intercept at Modulus (Automatic) (J)	Y-Intercept at Modulus (Automatic) (MPa)	Energy to X-Intercept at Modulus (E-modulus) (J)	X-Intercept at Modulus (E-modulus) (mm/mm)
1	-----	0.61575	-----	-----

	Y-Intercept at Modulus (E-modulus) (MPa)	X-Intercept at Modulus (Automatic) (mm/mm)
1	-----	-0.01151

7.5g water melon + LDPE + LLDPE

	Length (mm)	Thickness (mm)	Width (mm)	Area (cm ²)
1	65.00000	3.00000	10.00000	0.30000

	Modulus (Automatic) (MPa)	Energy at Break (Standard) (J)	Extension at Yield (Zero Slope) (mm)	Extension at Break (Standard) (mm)
1	33.12084	129.45555	66.16686	500.00006

	Load at Yield (Zero Slope) (N)	Load at Break (Standard) (N)	Tensile stress at Yield (Zero Slope) (MPa)	Tensile stress at Break (Standard) (MPa)
1	236.71670	273.96833	7.89056	9.13228

	Tensile strain at Yield (Zero Slope) (mm/mm)	Tensile strain at Break (Standard) (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)	Tensile strain at Maximum Tensile extension (mm/mm)
1	1.01795	7.69231	10.14022	7.69249

	Tensile extension at Yield (Zero Slope) (mm)	Tensile extension at Break (Standard) (mm)	True strain at Yield (Zero Slope) (mm/mm)	True strain at Break (Standard) (mm/mm)
1	66.16686	500.00006	0.70208	2.16244

	True stress at Yield (Zero Slope) (MPa)	True stress at Break (Standard) (MPa)	Maximum Tensile extension (mm)	Poisson's Ratio (Chord)
1	15.92276	79.38057	500.0119	-----

	Energy at Maximum Tensile extension (J)	Load at Maximum Tensile extension (N)	Tensile strain at Maximum Tensile extension (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)
1	129.45915	304.20672	7.69249	10.14022

7.5g pawpaw + LDPE + LLDPE

	Length (mm)	Thickness (mm)	Width (mm)	Area (cm ²)
1	65.00000	3.00000	10.00000	0.30000

	Modulus (Automatic) (MPa)	Energy at Break (Standard) (J)	Extension at Yield (Zero Slope) (mm)	Extension at Break (Standard) (mm)
1	38.81323	147.00964	65.99983	500.00006

	Load at Yield (Zero Slope) (N)	Load at Break (Standard) (N)	Tensile stress at Yield (Zero Slope) (MPa)	Tensile stress at Break (Standard) (MPa)
1	268.12777	327.76436	8.93759	10.92548

	Tensile strain at Yield (Zero Slope) (mm/mm)	Tensile strain at Break (Standard) (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)	Tensile strain at Maximum Tensile extension (mm/mm)
1	1.01538	7.69231	11.92621	7.69249

	Tensile extension at Yield (Zero Slope) (mm)	Tensile extension at Break (Standard) (mm)	True strain at Yield (Zero Slope) (mm/mm)	True strain at Break (Standard) (mm/mm)
1	65.99982	500.00006	0.70081	2.16244

	True stress at Yield (Zero Slope) (MPa)	True stress at Break (Standard) (MPa)	Maximum Tensile extension (mm)	Poisson's Ratio (Chord)
1	18.01266	94.96763	500.0116	-----

	Energy at Maximum Tensile extension (J)	Load at Maximum Tensile extension (N)	Tensile strain at Maximum Tensile extension (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)
1	147.01377	357.78638	7.69249	11.92621

7.5g pawpaw + 7.5g water melon + LDPE

	Length (mm)	Thickness (mm)	Width (mm)	Area (cm ²)
1	65.00000	3.00000	10.00000	0.30000

	Modulus (Automatic) (MPa)	Energy at Break (Standard) (J)	Extension at Yield (Zero Slope) (mm)	Extension at Break (Standard) (mm)
1	33.72422	31.97018	71.16671	139.25013

	Load at Yield (Zero Slope) (N)	Load at Break (Standard) (N)	Tensile stress at Yield (Zero Slope) (MPa)	Tensile stress at Break (Standard) (MPa)
1	247.93991	10.05914	8.26466	0.33530

	Tensile strain at Yield (Zero Slope) (mm/mm)	Tensile strain at Break (Standard) (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)	Tensile strain at Maximum Tensile extension (mm/mm)
1	1.09487	2.14231	0.32018	2.14297

	Tensile extension at Yield (Zero Slope) (mm)	Tensile extension at Break (Standard) (mm)	True strain at Yield (Zero Slope) (mm/mm)	True strain at Break (Standard) (mm/mm)
1	71.16671	139.25012	0.73949	1.14496

	True stress at Yield (Zero Slope) (MPa)	True stress at Break (Standard) (MPa)	Maximum Tensile extension (mm)	Poisson's Ratio (Chord)
1	17.31342	1.05363	139.2933	-----

	Energy at Maximum Tensile extension (J)	Load at Maximum Tensile extension (N)	Tensile strain at Maximum Tensile extension (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)
1	31.97060	9.60540	2.14297	0.32018

10g water melon + LDPE + LLDPE

	Length (mm)	Thickness (mm)	Width (mm)	Area (cm ²)
1	65.00000	3.00000	10.00000	0.30000
	Modulus (Automatic) (MPa)	Energy at Break (Standard) (J)	Extension at Yield (Zero Slope) (mm)	Extension at Break (Standard) (mm)
1	23.52519	135.57279	111.33342	500.00006
	Load at Yield (Zero Slope) (N)	Load at Break (Standard) (N)	Tensile stress at Yield (Zero Slope) (MPa)	Tensile stress at Break (Standard) (MPa)
1	263.63779	289.88875	8.78793	9.66296
	Tensile strain at Yield (Zero Slope) (mm/mm)	Tensile strain at Break (Standard) (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)	Tensile strain at Maximum Tensile extension (mm/mm)
1	1.71282	7.69231	10.45394	7.69249
	Tensile extension at Yield (Zero Slope) (mm)	Tensile extension at Break (Standard) (mm)	True strain at Yield (Zero Slope) (mm/mm)	True strain at Break (Standard) (mm/mm)
1	111.33342	500.00006	0.99799	2.16244
	True stress at Yield (Zero Slope) (MPa)	True stress at Break (Standard) (MPa)	Maximum Tensile extension (mm)	Poisson's Ratio (Chord)
1	23.84008	83.99342	500.0119	-----
	Energy at Maximum Tensile extension (J)	Load at Maximum Tensile extension (N)	Tensile strain at Maximum Tensile extension (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)
1	135.57651	313.61806	7.69249	10.45394

10g pawpaw + LDPE + LLDPE

	Length (mm)	Thickness (mm)	Width (mm)	Area (cm ²)
1	65.00000	3.00000	10.00000	0.30000

	Modulus (Automatic) (MPa)	Energy at Break (Standard) (J)	Extension at Yield (Zero Slope) (mm)	Extension at Break (Standard) (mm)
1	30.84158	137.14862	77.99999	500.00006

	Load at Yield (Zero Slope) (N)	Load at Break (Standard) (N)	Tensile stress at Yield (Zero Slope) (MPa)	Tensile stress at Break (Standard) (MPa)
1	249.90670	301.02306	8.33022	10.03410

	Tensile strain at Yield (Zero Slope) (mm/mm)	Tensile strain at Break (Standard) (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)	Tensile strain at Maximum Tensile extension (mm/mm)
1	1.20000	7.69231	11.00130	7.69249

	Tensile extension at Yield (Zero Slope) (mm)	Tensile extension at Break (Standard) (mm)	True strain at Yield (Zero Slope) (mm/mm)	True strain at Break (Standard) (mm/mm)
1	77.99998	500.00006	0.78846	2.16244

	True stress at Yield (Zero Slope) (MPa)	True stress at Break (Standard) (MPa)	Maximum Tensile extension (mm)	Poisson's Ratio (Chord)
1	18.32649	87.21951	500.0121	-----

	Energy at Maximum Tensile extension (J)	Load at Maximum Tensile extension (N)	Tensile strain at Maximum Tensile extension (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)
1	137.15258	330.03886	7.69249	11.00130

10g pawpaw + 10g water melon + LDPE

	Length (mm)	Thickness (mm)	Width (mm)	Area (cm ²)
1	65.00000	3.00000	10.00000	0.30000

	Modulus (Automatic) (MPa)	Energy at Break (Standard) (J)	Extension at Yield (Zero Slope) (mm)	Extension at Break (Standard) (mm)
1	54.81109	19.51694	48.75015	76.87186

	Load at Yield (Zero Slope) (N)	Load at Break (Standard) (N)	Tensile stress at Yield (Zero Slope) (MPa)	Tensile stress at Break (Standard) (MPa)
1	299.35362	25.72184	9.97845	0.85739

	Tensile strain at Yield (Zero Slope) (mm/mm)	Tensile strain at Break (Standard) (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)	Tensile strain at Maximum Tensile extension (mm/mm)
1	0.75000	1.18264	0.85739	1.18264

	Tensile extension at Yield (Zero Slope) (mm)	Tensile extension at Break (Standard) (mm)	True strain at Yield (Zero Slope) (mm/mm)	True strain at Break (Standard) (mm/mm)
1	48.75015	76.87187	0.55962	0.78054

	True stress at Yield (Zero Slope) (MPa)	True stress at Break (Standard) (MPa)	Maximum Tensile extension (mm)	Poisson's Ratio (Chord)
1	17.46232	1.87139	76.8719	-----

	Energy at Maximum Tensile extension (J)	Load at Maximum Tensile extension (N)	Tensile strain at Maximum Tensile extension (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)
1	19.51694	25.72184	1.18264	0.85739

12g of water melon +LDPE+LLDPE

	Length (mm)	Thickness (mm)	Width (mm)	Area (cm ²)
1	65.00000	3.00000	10.00000	0.30000

	Modulus (Automatic) (MPa)	Energy at Break (Standard) (J)	Extension at Yield (Zero Slope) (mm)	Extension at Break (Standard) (mm)
1	33.10519	132.93327	75.08343	489.91683

	Load at Yield (Zero Slope) (N)	Load at Break (Standard) (N)	Tensile stress at Yield (Zero Slope) (MPa)	Tensile stress at Break (Standard) (MPa)
1	255.73988	19.00889	8.52466	0.63363

	Tensile strain at Yield (Zero Slope) (mm/mm)	Tensile strain at Break (Standard) (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)	Tensile strain at Maximum Tensile extension (mm/mm)
1	1.15513	7.53718	0.63338	7.53769

	Tensile extension at Yield (Zero Slope) (mm)	Tensile extension at Break (Standard) (mm)	True strain at Yield (Zero Slope) (mm/mm)	True strain at Break (Standard) (mm/mm)
1	75.08343	489.91684	0.76785	2.14443

	True stress at Yield (Zero Slope) (MPa)	True stress at Break (Standard) (MPa)	Maximum Tensile extension (mm)	Poisson's Ratio (Chord)
1	18.37175	5.40941	489.9500	-----

	Energy at Maximum Tensile extension (J)	Load at Maximum Tensile extension (N)	Tensile strain at Maximum Tensile extension (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)
1	132.93389	19.00132	7.53769	0.63338

12g of pawpaw +LDPE+LLDPE

	Length (mm)	Thickness (mm)	Width (mm)	Area (cm ²)
1	65.00000	3.00000	10.00000	0.30000

	Modulus (Automatic) (MPa)	Energy at Break (Standard) (J)	Extension at Yield (Zero Slope) (mm)	Extension at Break (Standard) (mm)
1	27.13851	141.85873	102.16670	500.00006

	Load at Yield (Zero Slope) (N)	Load at Break (Standard) (N)	Tensile stress at Yield (Zero Slope) (MPa)	Tensile stress at Break (Standard) (MPa)
1	274.28968	270.22189	9.14299	9.00740

	Tensile strain at Yield (Zero Slope) (mm/mm)	Tensile strain at Break (Standard) (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)	Tensile strain at Maximum Tensile extension (mm/mm)
1	1.57180	7.69231	10.82398	7.69250

	Tensile extension at Yield (Zero Slope) (mm)	Tensile extension at Break (Standard) (mm)	True strain at Yield (Zero Slope) (mm/mm)	True strain at Break (Standard) (mm/mm)
1	102.16670	500.00006	0.94460	2.16244

	True stress at Yield (Zero Slope) (MPa)	True stress at Break (Standard) (MPa)	Maximum Tensile extension (mm)	Poisson's Ratio (Chord)
1	23.51390	78.29507	500.0122	-----

	Energy at Maximum Tensile extension (J)	Load at Maximum Tensile extension (N)	Tensile strain at Maximum Tensile extension (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)
1	141.86266	324.71928	7.69250	10.82398

12.5g of pawpaw +12.5g of water melon +LDPE

	Length (mm)	Thickness (mm)	Width (mm)	Area (cm ²)
1	65.00000	3.00000	10.00000	0.30000

	Modulus (Automatic) (MPa)	Energy at Break (Standard) (J)	Extension at Yield (Zero Slope) (mm)	Extension at Break (Standard) (mm)
1	46.57212	20.96925	54.66687	87.58327

	Load at Yield (Zero Slope) (N)	Load at Break (Standard) (N)	Tensile stress at Yield (Zero Slope) (MPa)	Tensile stress at Break (Standard) (MPa)
1	266.70615	19.71899	8.89021	0.65730

	Tensile strain at Yield (Zero Slope) (mm/mm)	Tensile strain at Break (Standard) (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)	Tensile strain at Maximum Tensile extension (mm/mm)
1	0.84103	1.34743	0.65586	1.34831

	Tensile extension at Yield (Zero Slope) (mm)	Tensile extension at Break (Standard) (mm)	True strain at Yield (Zero Slope) (mm/mm)	True strain at Break (Standard) (mm/mm)
1	54.66687	87.58327	0.61032	0.85332

	True stress at Yield (Zero Slope) (MPa)	True stress at Break (Standard) (MPa)	Maximum Tensile extension (mm)	Poisson's Ratio (Chord)
1	16.36712	1.54297	87.6400	-----

	Energy at Maximum Tensile extension (J)	Load at Maximum Tensile extension (N)	Tensile strain at Maximum Tensile extension (mm/mm)	Tensile stress at Maximum Tensile extension (MPa)
1	20.97037	19.67567	1.34831	0.65586

TABLE A1: Tensile Strength, Elongation at Yield, Elongation at Break and Modulus of Water Melon rind + LDPE +LLDPE

FILLER	COD	TENSILE	EXTENSIO	EXTENSIO	MODULUS
LOADIN	E	STRENGT	N AT	N AT	OF
G (%)		H (Mpa)	YIELD	BREAK	ELASTICIT
				(%)	Y (Mpa)
5	5w	8.364	70.080	338.46	34.367
7.5	7.5w	7.89	66.166	323.07	35.12
10	10w	7.56	60.330	310.76	37.52
12.5	12.5w	7.24	55.080	295.38	39.10

TABLE A2: Tensile Strength, Elongation at Yield, Elongation at Break and Modulus of Pawpaw peel + LDPE +LLDPE

FILLER	COD	TENSILE	EXTENSIO	EXTENSIO	MODULUS
LOADIN	E	STRENGT	N AT	N AT	OF
G (%)		H (Mpa)	YIELD	BREAK	ELASTICIT
				(%)	Y (Mpa)
5	5 P	9.44	102.166	376.92	36.499
7.5	7.5 P	8.93	77.99	353.84	38.813
10	10 p	8.33	65.99	323.07	39.84
12.5	12.5p	7.56	62.583	300.00	40.138

TABLE A3: Tensile Strength, Elongation at Yield, Elongation at Break and Modulus of Water Melon rind +Pawpaw peel + LDPE

FILLER	CODE	TENSILE ON AT STRENGT H (Mpa)	EXTENSI ON AT YIELD	EXTENSI OF BREAK (%)	MODULUS ELASTICI TY (Mpa)
10	5p5w	7.614	56.748	183.76	45.835
15	7.5p7.5w	8.264	54.166	168.076	49.724
20	10p 10w	9.978	51.75	149.030	54.81
25	12.5p12.5	8.89	47.66	134.738	59.57

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HARDNESS TEST RESULT

Table A4: Hardness Test for Pawpaw peel + Water Melon rind Filler + LDPE

FILLER LOADING (%)	CODE	BHN
10	5p5w	29.98
15	7.5p7.5w	34.67
20	10p10w	39.23
25	12.5p12.5w	42.98

Table A5: Hardness Test for Water Melon Filler + LDPE + LLDPE

FILLER LOADING (%)	CODE	BHN
5	5w	18.29
7.5	7.5w	18.75
10	10w	19.39
12.5	12.5w	19.96

Table A6: Hardness Test for Pawpaw Peel Filler + LDPE + LLDPE

FILLER	CODE	BHN
LOADING		
(%)		
5	5p	18.89
7.5	7.5p	19.23
10	10p	19.80
12.5	12.5p	20.48

IMPACT ENERGY TEST RESULT

Table A7: Impact Energy Test for Pawpaw peel + Water Melon rind Filler + LDPE

FILLER	CODE	IMPACT
%	LOADING	ENERGY (J/m²)
10	5p5w	6.98
15	7.5p7.5w	7.67
20	10p10w	9.23
25	12.5p12.5w	10.98

Table A8: Impact Energy Test for Water Melon rind Filler + LDPE + LLDPE

FILLER	CODE	IMPACT
LOADING		ENERGY (J/m²)
(%)		
5	5w	3.45
7.5	7.5w	3.97
10	10w	4.45
12.5	12.5w	4.98

Table A9: Impact Energy Test for Pawpaw Peel Filler + LDPE + LLDPE

FILLER LOADING (%)	CODE	IMPACT ENERGY (J/m²)
5	5p	3.84
7.5	7.5p	4.12
10	10p	4.97
12.5	12.5p	5.02