STUDIES OF PHYSICAL AND MECHANICAL PROPERTIES OF UNSATURATED POLYESTER RESIN HYBRID COMPOSITES REINFORCED WITH JUTE FIBRE AND MAIZE COB PARTICLES

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AHMADU BELLO UNIVERSITY, ZARIA

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JANUARY, 2016

DECLARATION

I declare that the work in this dissertation entitled "Studies of Physical and Mechanical Properties of Unsaturated Polyester Resin Hybrid Composites Reinforced With Jute Fibre and Maize Cob Particles" has been carried out by me in the Department of Textile Science And Technology. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other university.

BABA ALI,JAMILA _____ _____

Name of student Signature Date

CERTIFICATION

This dissertation entitled "STUDIES OF PHYSICAL AND MECHANICAL PROPERTIES OF UNSATURATED POLYESTER RESIN HYBRID COMPOSITES REINFORCED WITH JUTE FIBRE AND MAIZE COB PARTICLES" by BABA ALI, JAMILA meets the regulations governing the award of the Master degree of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

In this study**,** Jute fibre/ Unsaturated Polyester Resin and Maize Cob / Unsaturated Polyester Resin Composites were prepared. Similarly, hybrid composites of Jute fibre (JF)/Maize Cob(MC) with Unsaturated Polyester Resin(UPR) were prepared using an open molding techniques at several percentage filler loadings, 10% Maize Cob and 10% Jute fibres were employed as the percentage for composites hybridization. The Physical and Mechanical properties of the composites were studied. The Scanning Electron Microscopy of the composites was also investigated. The study reveals that, as the percentage filler loading increases, the tensile strength, elongation, impact strength, hardness and flexural strength decreases due to clumping, voids and agglomerate formation which resulted in weak bonding or poor inter facial adhesion between the fillers and the matrix. However, the hybrid composite shows moderates improvement in the mechanical properties such as tensile strength of 32.86 Mpa and elongation of 19.60 % for 5%JF/5%MC which has the highest strength compared to its control samples which has tensile strength of 12.84Mpa and elongation at break of 12.80% for 10%JF/UPR and 21.55Mpa and 16.00% for 10% MC/UPR respectively. The hybrid composite also shows moderate value of impact strength, hardness and flexural strength with 0.48J/m, 37.65 shore A and 44.79Mpa respectively for filler loading of 5%JF/5%MC and 0.35 J/m,21.17 shore A and 41.47Mpa for varying fillers of 9%JF/1%MC hybrid composite sample. The improvements are likely attributed to the extent of good intermingling between the fillers and the matrix. The study also reveals that, density of the composites decreases with increase in filler loading the density drops from 1.66 to 0.80g/cm^3 for 100%UPR and 15% JF/UPR composites respectively and from 1.66 to 0.70g/cm^3 for 100% UPR and 20% MC/UPR composites respectively. The hybrid composite also shows decrease in density from 1.29 to 1.00g/cm^3 with varying percentage of filler loadings of 9%JF/1%MC and 7%JF/3%MC respectively. The composites shows increase in water uptake with increasing filler loading and increasing number of days up to when the samples reaches their saturation when no water absorption was observed. The results shows that the highest water absorption rate was observed at 15% filler loading of JF having maximum water absorption of 6.4% and 3% for 20% MC and a maximum of 2.3% for hybrid composites. SEM analysis shows good interfacial interaction between the fillers and the matrix, random filler dispersion within the matrix and formation of few noticeable voids which could be due to air trapped during the composites fabrication and cracks along filler matrix interface which has effect in the mechanical properties of the composites samples. The mechanical and physical properties of the composites indicate that it can be useful in application which required moderate strength. These composites could be considered as a potential source of utilizing agricultural waste materials and as sustainable resources for manufacturing of structural materials such as particle board, fibre board, stores and library shelf's, partitioning panels, ceiling boards thereby reducing the amount of agricultural wastes and eliminating the pollution caused by burning of such residue (Maize Cob) and in turns adding value to Jute fibre.

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SYMBOLS	MEANING
JF	Jute Fibre
MC	Maize Cob
UPR	Unsaturated Polyester Resin
SEM	Scanning Electron Microscope
MEKP	Methyl Ethyl Ketone Peroxide
CMC	Ceramic Matrix Composites
MMC	Metal Matrix Composites
PMC	Polymer Matrix Composites
PG	Polyethylene Glycol
MA	Maleic Acid
HDT	Heat Distortion Temperature
NPG	Neo-Pentyl Glycol
DEG	Di-Ethylene Glycol
EG	Ethylene Glycol
TG	Glass Transition Temperature
MPa	Mega Pascal

CHAPTER ONE

1.0 INTRODUCTION

Interest in the utilization of bio-fillers in thermosetting and thermoplastics has received increasing attention both by the academic sector and the industry. Natural fillers have many significantadvantages over synthetic fillers and fibres, such as their light-weight, low cost, ability to reduce abrasion of machinery and also non-toxicity(Nabi-saheband Jog,1999).In addition,use ofmaize cob and jutefibres as fillers have advantages over mineral fillers, as they are non-abrasive, require less energy for processing and ability to reduce the density of finished products. Hence, natural fibre composites have attracted much attention, and are becoming increasingly important for the production of a wide variety of cheap light-weight environment friendly composites(Bharath,*etal.*,2014).

Increasing concern about global warming and depleting petroleum reserves have made scientists to focus more on the use of natural fibres such as Jute, bagasse, coir, sisal, etc. Many research articles have been published to justify the utility and to establish advantageous features of such natural fibres.This has resulted in creation of more awareness about the use of natural fibres based materials mainly composites(Madhusudhana*et al.*,2014). In past decades there have been many efforts to develop composites to replace the petroleum and other non-decaying materials based products. The abundant availability of natural fibres gives attention on the development of natural fibre composites primarily to explore value-added application avenues. Reinforcement with natural fibre in composites has recently gained attention due to low cost, easy availability, low density, acceptable specific properties, ease of preparation, enhanced energy recovery, Co_2 neutrality, biodegradability and recyclable in nature (Vermal*et al.*,2013). The present research work is more interested in preparing a hybrid composites made of natural

fibres as they are abundantly available and cheaper compared to synthetic fibres which need to be processed and made-up of chemicals to gain the required property of composites. These natural fibres yield better mechanical strength when added to thermosets or thermoplastics. The mechanical properties of particulate filled polymer composites depend strongly on the particle size, particle-matrix interface adhesion and particle loading (Ishiaku *et al.*,2007). In the recent years, Polymer matrix composites are gaining more importance compared to monolithical materials as being more reliable and cheaply available. With the advancement of polymer matrix composites (PMC) their properties have been increased by one. The addition of one more fibre as hybrid composites boost the property of PMC. The single fibre composite lags polymeric composite materials in variety of uses such as automotive, sporting goods, marine, electrical, industrial, construction, household applications etc. Polymeric composites have high strength and stiffness, light weight and high corrosion resistance. (Madhusudhana *et al.*,2014)

Most of the composites available in the market today are produced with a high durability to ensure product longevity. Unfortunately, in order to make these products, companies have traditionally used non-biodegradable fibres, made from non-renewable resources. The most important disadvantage of such composite materials is the problem of disposal after end use. This draw the attention of researchers'to the use of natural,sustainable,biodegradable and renewable resources. In modern production environment, there is a great demand for every material to be recyclable or degradable. Natural fibres composites, are composite materials i.e., formed by a matrix (resin) and a reinforcement (fibre), in which the fibres are natural i.e., mainly formed by cellulose and therefore originating from plants. Some of these fibres can be hemp, Jute, flax, sisal, banana, kapok etc. Natural fibre composites(NFC) markets are significantly on the rise, mainly because of the environmental necessitiesand recyclability, unsaturated polyester

is an outstanding commercially important thermosetting material with wide range of applications in various fields because of its balanced chemical and mechanical properties(Navdeep *et al,2012*) .In this study, maize cob and Jute fibre/unsaturated polyester composites were prepared with Maize cob and Jute fibre as filler and Unsaturated Polyester Resin(UPR) as the matrix.

1.2 STATEMENT OF THE RESEARCH PROBLEM.

Composites of synthetic fillers and matrices are non-biodegradable and help in constituting environmental hazards.On the other hand natural fillers in synthetic matrices produce composites that are biodegradable.

In the quest to develop biodegradable composites which are environmental friendly, this research prepared and characterized composites of jute fibre and maize cob as well as hybrid composites of the two fillers with unsaturated polyester resin. It is intended to in addition to development of biodegradable composites, value will beadded to jute fibres and maize cob, especially the maize cob which hitherto has very little popularity in the composites world despites its large abundance that mostly end up as waste.Jute fibres on the other hand are equally grown abundantly and have been used in clothing and composites.

Both short fibres and particulates composites have their unique characteristics. It is hoped that by combing jute fibres and maize cob to produce hybrid composites, materials that have the advantages of short fibres as well as particulate properties will be produced in addition to being biodegrable and having low cost.

1.3 AIM AND OBJECTIVES OF THE RESEARCH

1.3.1 AIM

To prepare hybrid composites of Jute fibre/ Maize cob particles / Unsaturated Polyester Resin, and evaluate their physical and mechanical properties.

1.3.2 OBJECTIVES OF THE RESEARCH

i. To extract Jute fibre by water retting method.

ii. To use Maize cob and Jute fibre as bio fillers at different filler loadings in unsaturated polyester resin to obtain bio composites.

iii. To study the physical and mechanical properties,(such as density, tensile strength, impact strength, hardness, flexural strength, and water absorption).

iv. To study the effect of different filler loadings on the properties of hybrid composites of Maize cob in particulate form and Jute fibre in short length reinforced in unsaturated polyester resin.

1.4 JUSTIFICATION

Due to the drawbacks associated with using synthetic fibres in composites, this study intends to explore the use of hybrid reinforcement of Jute fibre/Maize cob as a way of improving their properties to make them amenable for use in hybrid composites. The success of this hybrid will reduce the cost of composites as Jute fibre and Maize cob are readily and abundantly available at little or no cost in the country and also reduce environmental waste problem.

1.5 SCOPE OF THE STUDY

The scope are as stated below:

1. Only short lengths of Jute fibres (0.5-1cm), is used.
2. Particulates sizeof Maize cob (300μ) employed.

3.Unsaturated Polyester Resinhas been used as a matrix

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 FIBRE

Fibre is a unit of matter that is characterized by high ratio of length to thickness. Fibres can be generally classified into natural, man-made and mineral fibres.

2.1.1 NATURAL FIBRES

Natural fibres include those produced by plants, animals and geological processes. They are biodegradable over time. They can be classified according to their origin.

i. Vegetable fibres are generally based on arrangements often with lignin. Example includes cotton, hemp, Jute, flax, ramie, sisal and pineapple fibre etc. Plant fibres are employed in the manufacture of paper and textile (cloth), and dietary fibre is an important component of human nutrition.

ii. Wood fibres, distinguished from vegetable fibres, they are from tree sources. Forms include ground wood and bleached or unbleached craft sulfite pulps. Craft sulfite pulp, refers to a type of Pulping process used to remove the lignin bonding the original wood structure, thus, freeing the fibre for use in paper and engineered wood products such as fireboard.

iii. Animal fibres consist largely of particularly proteins, Instances are spider, silk, sinew, catgut, wool and hair such as cashmere, mohair and angora, from animals such as sheep skin, rabbit, mink, fox, beaver, etc.

iv. Mineral fibres comprises of asbestos.Asbestos is the only naturally occurring long natural fibre.Short, fibre like mineral includes wollastnite, attapulgite, and hallovsite (Mohanty *et*

al.,2005).

2.1.2 MAN-MADE FIBRES

Synthetic or man-made fibres generally come from synthetic materials such as petrochemicals. But some types of synthetic fibres are manufactured from natural cellulose including rayon, modal, and the more recently developed lyocell. Cellulose-based fibres are of two types: regenerated or pure cellulose such as from cuprammonium process and modified or derivatised cellulose acetate (Danladi and Shuaib,2014).

2.1.3 MINERAL FIBRES

These include:

i. Glass fibres made from specific glass, and optical fibres, made from purified natural quartz, are also man-made fibres that come from natural raw materials.

ii. Metallic fibres can be drawn from ductile metals such as copper, gold or silver and extruded or deposited from more brittle ones such as nickel, aluminum or iron(Danladi and Shuaib,2014).

2.2 JUTE FIBRE

Jute is a natural fibre with golden and silky shine appearance and hence called “The golden fibre”. It is 100% bio degradable and recyclable and thus environmental friendly. It is one of the cheapest, longest and strongest of vegetable procured from the bast or skin of the plant stem and considered as future fibres. Jute is the second most important vegetable fibre after cotton, in terms of usage, global consumption, production and availability.

Jute is a lignocelluloses fibre (i.e. partially a textile fibre and partially wood) composed primarily of the plant materials cellulose (major component of plant fibre) and lignin (major component of wood fibre).Jute is along soft shinny vegetable fibre with a length of about l-4mm, diameter of 17-20mm.It can be extracted from the bast of Jute stem or plant by water, chemical,

enzymes, mechanical, dew retting process etc. it has high tensile strength, low extensibility better breath ability of fabrics. Therefore Jute is very suitable in agricultural commodity bulk packaging.Jute fibre is use to make best quality industrial yarn, fabrics, net and sacks that has been used in raw materials for packaging textiles, non-textiles contracture, and agricultural sectors. Bulking of yam results in reduced breaking tenacity and an increase breaking extensibility when blended as a ternary blend.Jute fibres have the advantage of good insulating and antistatic properties, as well as having low thermal conductivity and moderate moisture regain. Other advantages of Jute include acoustic insulating properties and manufacture with no skin irritation. Jute has the ability to be blended with other fibres both synthetic and natural fibres and accepts cellulosic dye classes such as natural, basic, vat, sulphur, reactive and pigment dyes. Some noted disadvantages include poor drapability and crease resistance, brittleness (Ghimire and Thakur, 2003).Jute has a decreased strength when wet and also become a subject to microbial attack in humid climate. The best varieties of Jute are *corchorus olitorious* (golden shine) and*corchorus capsularis* (whitish shine).Raw Jute and Jute goods are interpreted as burlap in some part of the world(North America)(Mitra *et al.,* 1998).

2.2.1 JUTE CULTIVATION

Jute cultivation is a wide procedure in which temperature is a unique option to maintain 24-34 ^{0}c and almost 80% of humidity is required to measure a unit in successful cultivation, at least 2” to 3” rainfall is also mandatory for cultivation (for sowing season). Farmers grow Jute by Scattering its seed on the cultivated soil and when they grow-up about 15-20cm long they get thinned away.

2.2.2 HARVESTING.

Harvesting the plants at the correct time is most important and requires long experience .With Jute the correct time is judged to be when the plant are in their small pod stage. Harvesting

before flowering generally results in lower yields and weaker fibre, and if the seeds are allowed to mature, the fibre becomes harsh and coarse and difficult to extract from the plant. Jute is harvested anytime between 120-l50days when the flowers have been shed, early harvesting is good for healthy fibres. The plant from 8-12 feet are harvested with a sickle and cut close to the ground level. In flooded land, plant are uprooted, the harvested plant are left in the field for 3days for the leaves to shed. The cut stems are then tied into bundles for retting which is carried out immediately after harvesting (Ghimire and Thakur, 2003).

2.2.3 RETTING

Retting and extraction processes have a profound effect on the quality of fibre produced and on the cost of fibre production. It affects the efficiency of manufacturing, the quality of the end products and their competitiveness in the market. Ultimately, it determines the level of earnings for industry and returns for growers. Given the severe levels of competition in fibre markets, Jute producers are keenly aware of the need to improve retting and extraction processes, decrease their reliance on water, become less labour-intensive, lower costs and, above all, enhance the quality of the fibre produced. Retting is a process by which the fibres are separated from the leaves, bark and woody core due to the removal of pectins, gums, lignin and other substances by retting bacteria present in water. It is also the submerging of plant leaf stems such as sisal, Jute, hemp, flax, pina leaf in water, and soaking them for a period of time to loosen the fibres from other components of the stem. Another type of retting can also be done by letting bacterial action attack the pectin and lignin, freeing the cellulose fibres. The leaves or stems are then removed washed and subject to mechanical processing to remove the soft tissue and then dried so that all that remains are the fibres (Tahir*et al.*, 2011).The method and duration of retting differs from place to place depending upon the temperature of retting water and stage at which the crop has

been harvested. This is also variable according to different species of fibre crops. Growing season of the crop and time of harvest is also controlling factor for retting and quality of fibre. If the retting temperature is high, it will take less time for completion of retting. This implies that the crops harvested during March to July when the temperature of water is high will naturally take less time for retting but the crops harvested during September to January will take much time due to lower temperature.

It is generally found that plants harvested at early stage of growth will take less time for retting and yield good quality fibre but the fibre harvested at later stage would yield fibre of inferior quality. Retting should be done in clear stagnant or flowing water. Retting in muddy water affects the colour and luster of fibre. Proper retting is necessary for the production of quality fibre. It is found that most parameters like color, luster, and strength are directly influenced by the retting condition.

Retting is the main challenge faced during the processing of bast plant for the production of long fibre. The traditional method for separating the long bast fibre is by water or dew retting. Both retting method requires 13-28days to degrade the pectin material, hemicelluloses and lignin. Even though the fibre produced from water rating can be of high quality the long duration and polluted water have made the method less attractive. A number of other alternative methods such as mechanical, chemical and enzyme have been discovered to eliminate the disadvantages of water retting. The action of retting methods involves water, microorganism, chemical, enzymes, and takes between 2-8days to completion. If the fibre is over retted it will produced very weak fibreunder retting causes severe defects like presence of leaves roots, cuttings. This also affects highly the colour and luster of fibre(Goodman *et al*,2002). The quality of fibre and progress of retting depend on several factors like pH and temperature of retting water, effect of

fertilization of crop, maturity of plant, volume and nature of retting water. The method of extraction differs from place to place in different areas. If the degree of retting is insufficient, the fibre cannot easily be stripped from the woody core and may be contaminated with cortical cells and if the retting proceeds too far, the fibre cells themselves may be attacked and weakened by microorganisms.(Tahir*etal.*,2011)

below are the various method of retting;

2.2.4 WATER RETTING

This is done by submerging bundles of stalks in water. The water penetrating into the central portion swells the inner cells bursting the outer most layers, thus increasing absorption of both moisture and decay producing bacteria. Retting time must be carefully observed, under retting makes separation difficult and over retting weakens the fibre. In bundle retting, a gentle process producing excellent fibre, the stalks are removed from the water before retting is completed, dried for several months then retted again in water (Tahir *et al*,2011).

Water retting can be sub-divide into two (2).

2.2.5 Natural Water Retting:

This employs stagnate or slow moving water such as ponds, bogs and slow streams and rivers. The stalk bundles are weighed down, usually with stones or wood for 13-28days depending on water temperature and mineral content.

2.2.6 Tank Water Retting

This employs vats usually requires about 4-6days and is feasible in any season. In the first 6-8hours, called the leaching period, much of the dirt and colouring matter are removed by the water, which is usually changed to assure clean fibre. Waste retted water which requires treatment to reduce harmful toxic elements before it is released, can be used as a liquid

fertilizers. Generally water retting take a period of about 13-28days for retting to be completed; extensive stench and pollution arise from anaerobic bacterial. Fermentation of the plant with putrid odour, and it requires water treatment maintenance. Thus, other methods have been devised to reduce these effects (Tahir*et al.,* 2011).

2.2.7 MECHANICAL RETING

Dried Jute bundles are steeped in water for 24hours and the fibres are separated from the biopolymer such as pectin, cellulose and hemicelluloses that hold the bast cells to the rest of the steam by hammering the bast with hammer mill, decorticator or batton followed by stripping and thorough rinsing. This method is used to produce massive quantity of fibres in short time but the fibres are of low quality.

2.2.8 CHEMICAL RETTING

Chemicals such as sodium hydroxide, sodium benzanate and hydrogen peroxide are used to attack the non-fibrous tissues in bast plant. Dried Jute bundles are soaked in 1 .6M NaOH (pH 14) solution for 48hours and then neutralized with 1% vol acetic acid. Fibres are then washed with deionized water until the pH value is 7. This method is costly and affects the surface morphology (structure) of the fibre (Tahir *etal.*,2011).

2.2.9 ENZYMATIC RETTING

Microbial retting is not a new process. This traditional method is mainly achieved by the pectin enzymes produces by bacterial during retting, the bacterial multiply and produce extracellular pectinases, which releases the best fibre from the surrounding curted by dissolving the pectin. Nowadays, with the advancement of biotechnology tools, enzymes such as xylases, pectinasescan be commercially produced, thus making enzymes retting a more popular choice for the production of long fibres.

Enzymes such as pectinases, xylases, biolase are used to attack the pectin material in the bast. The process is carried out under controlled conditions based on the type of enzymes. The Jute bundles is soaked in the enzymes for 2-4days, the enzymatic reactions cause a partial degradation of the components separating the cellulosic fibres from non-fibrous tissues such as pectin's, the hemicellulose, celluloses. This process is faster and cleaner (Tahir,*et al.2011*).

2.2.10 STRIPPING (FIBRE EXTRACTION)

Stripping is the process of removing the fibres from the stalk after the completion of retting fibres are removed from the stalk by any of the following methods

i. Single plants are removed and there fibres are taken off.

ii. Taken off a handful of stalks, breaking it in to and fro motion in water.

iii. Washing the stalks first by standing in waist deep waters and then stripping afterwards.

When there is plenty of water, bundles of stalks are laid in the pond ditches or slow moving water and left for 5-l5days under water. The bunch of stem is held in one hand and the root tapped lightly with a mallet. After loosens the rest of fibres, fibres are extracted and washed.

2.2.11 WASHING AND DRYING

Extracted fibres are washed in clean water. The dark colour of fibres can be removed by dipping them in tamarind water for 15-20 minutes and again washed in clean water. After squeezingExcess water the fibres are hanged on bamboo railing for sun drying for 2-3days.

2.2.12 CHEMICAL COMPOSITIONSOF JUTE.

Jute retted fibre have three principle chemical constituents namely: X-celluloses, hemicelluloses and lignin. The range of composition has been given as; Lignin 12-14%, X-cellulose 58-63% and hemicelluloses 21-24%; Jute also contain minor constituents such as fats and waxed,0.4-0.8%;

then organic matter 0.6-1.2, nitrogenous matter, *0.3-1.5%;* and traces of pigment in total they are about 2%(Tahir*et al.*,2011).

2.2.14 USES OF JUTE

Jute is the second most important vegetable fibre after the cotton, not only for cultivation, but also for various uses.

i. Jute is used chiefly to make cloth for wrapping bales of raw cotton, and to make sacks and coarse cloth.

ii. The fibres are also woven into curtains, chair coverings, carpets, area rugs, hessian cloth,and backing for linoleum.

iii. White Jute is being replaced by synthetic materials in many of these uses, some uses take advantage of Jute's biodegradable nature, where synthetics would be unsuitable.

iv. Jute butts, the coarse ends of the plants, are used to make inexpensive cloth.

v. Traditionally Jute was used in traditional textile machines as textiles fibres having cellulose(vegetable fibre content) and lignin (wood fibre content). But the major breakthrough came when the automobile, pulp and paper, and the furniture and bedding industries starts to use Jute and its allied fibres with their non-woven and composite technology to manufacture nonwovens, technical textiles, and composites.

vi. Hessain, lighter than sacking, is used for bags, wrappers, wall- coverings, upholstery, and home furnishings.

vii. Diversified Jute products are becoming more and more valuable to the consumer today. Among these are espadrilles, floor coverings, home textiles, high performance technical textiles,Geotextiles, composites, and more.

viii. Jute is also used in the making of ghillie suits which are used as camouflage and resemble grasses or brush.

Thus, Jute is the most environment-friendly fibre starting from the seed to expired fibre, as the expired fibres can be recycled more than once (Goodman *et al.*, 2002).Another diversified Jute product is Geotextiles, which made this agricultural commodity more popular in the agricultural sector. It is a lightly woven fabric made from natural fibres that are used for soil erosion, seed protection, weed control, and many other agricultural and land spacing uses. The Geotextiles can be used more than a year and the bio-degradable Jute Geotextile left to rot on the ground keeps the ground cool and is able to make the land more fertile(Anon,2009).

2.3 MAIZE

Indian corn or maize, *Zea Mays*, is America's main contribution to the important group of cereals. Maize have originated in a wild state in the lowlands of southern Mexico and central America from which it spread to the Andes where it cultivation goes back to prehistoric time. The ancestor was probably teostinte a primitive ancestor that bore a single row of kernels in a husk. Selection in southern Mexico resulted in a cob with several rows of kernels. Later development produced the longer cob or ear familiar as the maize found in the tombs of the Incas in Peru represent several different varieties sod that the plant must have grown for many centuries. Prominent role in the civilization of the Mayas and Aztecs. The Amerindians in New Mexico grew it as early as 2000BC. By the time Columbus maize was growing all the way from the Great Lakes and Lo wet St. Lawrence valley to Chile and Argentina(Winkel,2001).

2.3.1 CULTIVATION

Because it is cold-intolerant, in the temperate zones maize must be planted in the spring. Its root system is generally shallow, so the plant is dependent on soil moisture. As a C4 plant (a plant

that uses C4 carbon fixation), maize is a considerably more water-efficient crop than C3 plants (plants that use C3 carbon fixation) like the small grains, alfalfa and soybeans. Maize is most sensitive to drought at the time of silk emergence, when the flowers are ready for pollination. In the United States, a good harvest was traditionally predicted if the maize were "knee-high by the fourth of July", although modern hybrids generally exceed this growth rate. Maize used for silage is harvested while the plant is green and the fruit immature. Sweet corn is harvested in the "milk stage", after pollination but before starch has formed, between late summer and early to mid-autumn. Field maize is left in the field very late in the autumn to thoroughly dry the grain.

In fact, sometimes not be harvested until winter or even early spring. The importance of sufficient soil moisture is shown in many parts of Africa, where periodic drought regularly causes maize crop failure and consequent famine. Although it is grown mainly in wet, hot climates, it has been said to thrive in cold, hot, dry or wet conditions, meaning that it is an extremely versatile crop. Many of the maize varieties grown in the United States and Canada are hybrids. Often the varieties have been genetically modified to tolerate glyphosate or to provide protection against natural pests. Glyphosate is an herbicide which kills all plants except those with genetic tolerance. This genetic tolerance is very rarely found in nature. (Winkel,2001).

In mid-western United States, low-till or no-till farming techniques are usually used. In lo w-till, fields are covered once, maybe twice, with a tillage implement either ahead of crop planting or after the previous harvest. The fields are planted and fertilized. Weeds are controlled through the use of herbicides, and no cultivation tillage is done during the growing season. This technique reduces moisture evaporation from the soil, and thus provides more moisture for the crop (Karl,2010).

2.3.2 HERVESTING OF MAIZE

Before World War II, most maize in North America was harvested by hand. This involves a large numbers of workers and associated social events (husking or shucking bees). Some one- and two-row mechanical pickers were in use, but the maize combine harvesters was not adopted until after the War. By hand or mechanical picker, the entire maize ear is harvested, which then requires a separate operation of a maize Sheller to remove the kernels from the ear. Whole ears of maize were often stored in corn cribs, and these whole ears are a sufficient form for some livestock feeding use. Few modern farms store maize in this manner. Most harvest the grain from the field and store it in bins. The combine harvester with a corn head (with points and snap rolls instead of a reel) does not cut the stalk; it simply pulls the stalk down. The stalk continues downward and is crumpled into a mangled pile on the ground. The ear of maize is too large to pass between slots in a plate as the

snap rolls pull the stalk away, leaving only the ear and husk to enter the machinery. The combine separates out the husk and the cob, keeping only the kernels (Winter and Roney,2009).

2.3.3 STORAGE OF MAIZE

For storing grain in bins, the moisture of the grain must be sufficiently low to avoid spoiling. If the moisture content of the harvested grain is too high, grain dryers are used to reduce the moisture content by blowing heated air through the grain. This can require large amounts of energy in the form of combustible gases (propane or natural gas) and electricity to power the blowers (Karl, 2013).

2.3.4 CHARACTERISTICS OF MAIZE

The largest of all cereals, maize is a tall annual grass that can attain a height of 1-3 ft. The join ted stem is solid and contains a considerable amount of sugar when mature. The leaves are large

and narrow with wavy margins. There is an extensive fibrous root system with aerial prop roots at the base of the stem, which bears the staminate flowers and the cob or ear with pistil late followers. The ear is produced lower down on the stalk and thus is protected by the leaves. The ovaries, that become the mature grains, are produced in rows on the cob. A husk composed of leafy bracks surrounds the cob. The grains have a hull (6%), protein or aleurone layer (8-14%), endosperm (70%) and embryo (11%). Two kinds of endosperm are usually present; a hard, yellow endosperm and a soft white starchy endosperm (Karl, 2013).

2.3.5 MAIZE COB

Maize cob is an integral part of the maize which is the central core of an ear of maize. It is the part of the ear on which the kernels grow. The innermost part of the cob is white and has a consistency similar to formed plastic. Maize cobs are easily biodegradable (Roth and Cole,2014). The use of maize cob in the area of composites has seldom been reported. However, Danladi and Patrick(2013)have reported on its use in particle board production using Ureaformaldehyde resin.

2.4UNSATURATED POLYESTER RESIN

Unsaturated Polyester Resin (UPR) is used for a wide variety of industrial and consumer applications . In fact, more than 0.8 billion kg was consumed in the United States in 1999. This consumption can be split into two major categories of applications; reinforced and non-reinforced. In reinforced applications, resin and reinforcement, such as fibre glass, are used together to produce a composite with improved physical properties. Typical reinforced applications are boats, cars, shower stalls, building panels, and corrosion-resistant tanks and pipes. Non-fibre reinforced applications generally have a mineral “filler” incorporated into the composite for property modification. Some typical non-fibre reinforced applications are sinks, bowling balls, and coatings. Polyester resin composites are costly and the physical properties can

be tailoredtospecificapplications (Hansmann,2003).Another advantage of polyester resin composites is that they can be cured in a variety of ways without altering the physical properties of the finished part consequently, polyester resin composites compete favorably in custom markets. Unsaturated Polyester Resinis a thermoset, capable of being cured from a liquid or solid state when subjected to the right conditions. Unsaturated polyester differs from saturated polyester such as Terylene which cannot be cured in this way. It is usual, however, to refer to Unsaturated Polyester Resin as 'Polyester Resins' (Bharath,2012). Unsaturated polyester resins are very versatile as the processing into a composite products can be done using several techniques; hand lay-up and spray lay-up lamination. Casting, compression molding, pultrusion, resin transfer moulding (RTM), vacuum infusion and filament winding. In chemistry the reaction of a base with an acid produces a salt. Similarly, in organic chemistry the reaction of an alcohol with an organic acid produces an ester and water. By using special alcohols, such as glycol, in a reaction with di-basic acids, a polyester and water will be produced. This reaction, together with the addition of compounds such as unsaturated di-basic acids and cross-,inking monomers, forms the basic process of polyester manufacture as a resultthere is a whole range of polyester made from different acids, glycols and monomers, all having varying properties(Hansmann,2003).

Unsaturated polyester resins are further classified into the following categories:

• Ortho-phthalic polyesters — resins made from ortho-phthalic anhydride are generally cheaper than the other two classes of unsaturated polyester resins. They are usually used to manufacture general purpose composite laminates where only moderate structural properties are required.

• Iso-phthalic polyesters — resins made from Iso-phthalic acid. These resins are much more

structurally competent than the ortho-phthalic resins. They also have superior corrosion resistance and are used for more demanding applications.

• Tere-phthalic polyesters — Tere-phthalate resins are made from tere-phthalic acid. These resins are currently made in small volumes and are considered a specialty resin. Although they tend to have better thermal and chemical resistance than iso-phthalic resins they are difficult to manufacture. Propylene glycol is the predominant alcohol used in producing the various types of unsaturated polyester resins. Other alcohols like neo-pentyl glycol (NPG), di-ethylene glycol (DEG) and ethylene glycol (EG) are also used in the production of unsaturated polyester resins. Each of these alcohols contributes to the final polymer characteristics, which includes heat distortion temperature (HDT), physical strength, water uptake and weather resistance(Bharath,2012). Isophthalic resins tend to show higher tensile and flexural properties than orthophthalic resins. This may be because isophthalics usually form more linear, higher-molecular-weight polymers than orthophthalic (Hansmann,2003).

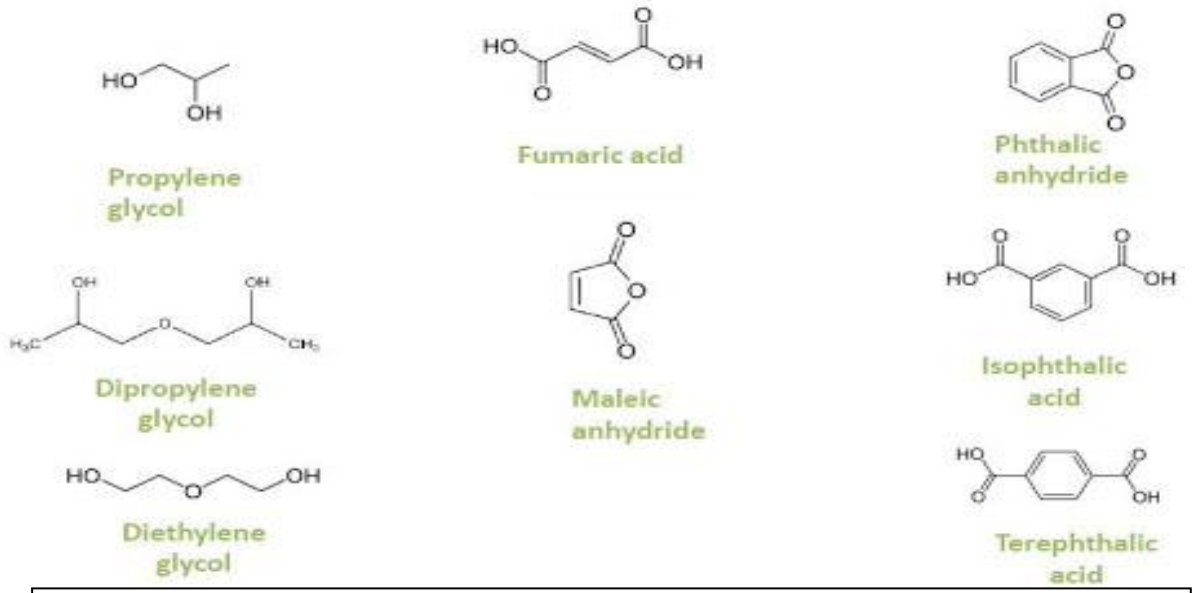


Fig2.1: Shows some monomers of unsaturated polyester (David and Gurit, 2015)

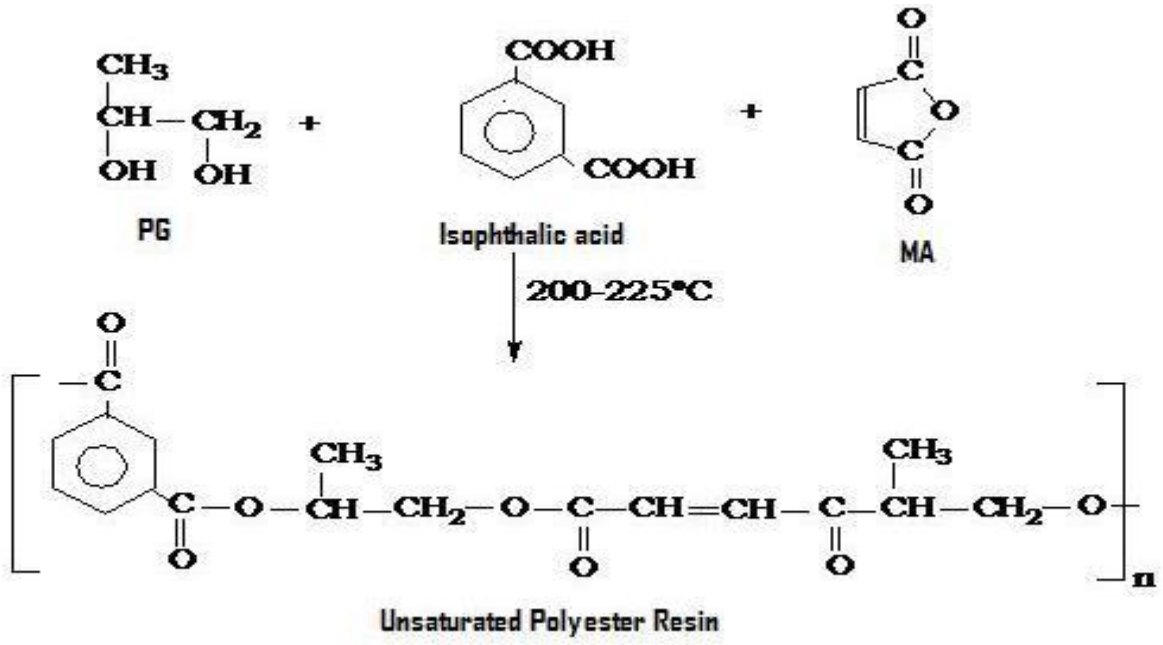


Figure 2.2:Chemical Synthesis of unsaturated Polyesterresin.(David and Gurit.2015)

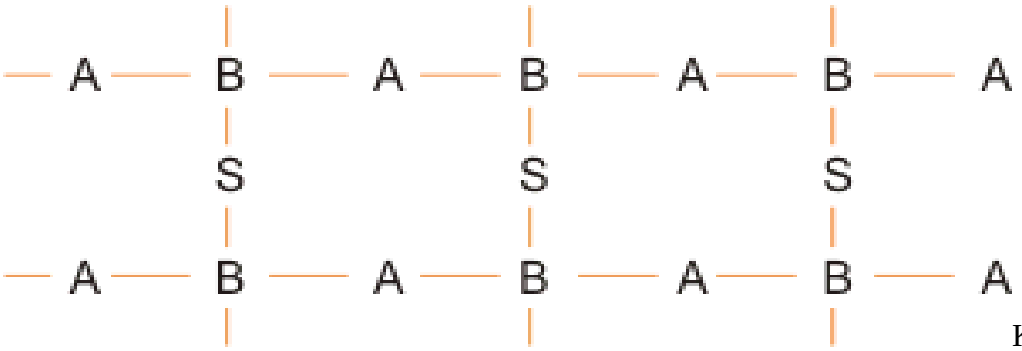
Most polyester resins are viscous, pale coloured liquids consisting of a solution of polyester in a monomer which is usually styrene. The addition of styrene in amounts of up to *50%* helps to make the resin easier to handle by reducing its viscosity. The styrene also performs the vital function of enabling the resin to cure from a liquid to a solid by 'cross -linking' the molecular chains of the polyester, without the evolution of any by-products (Dholakiya, 2012). These resins can therefore be moulded without the use of pressure and are called 'contact' or 'low pressure' resins. Polyester resins have a limited storage life as they will set or 'gel' on their own over a long period of time. Often small quantities of inhibitor are added during the resin manufacture to slow this gelling actionDavid and Gurit (2015)

For use in moulding, a polyester resin requires the addition of several ancillary products, such as catalyst, accelerator and additives.

Manufacturer may supply the resin in its basic form or with any of the ancillary products. already included. Resins can be formulated to the moulder's requirement ready for the addition

of the catalyst prior to moulding. As has been mentioned, given time an Unsaturated Polyester Resinwill set by itself. This rate of polymerization is slow for practical purposes and therefore catalysts and accelerators are used for polymerization of the resin within a practical time period. Catalysts are added to resin system shortly before use to initiate the polymerization reaction. The catalyst does not take part in the chemical reaction but simply activates the process. An accelerator added to the catalyzed resin to enable the reaction to proceed at workshop temperature and/or at a greater rate. Since accelerators have little influence on the resin in the catalyst they are sometimes added to the resin by the polyester manufacturer to create a 'pre-accelerated resinDavid and Gurit (2015)

With the addition of styrene 'S', and in the presence of catalyst, the styrene cross-linked the polymer chains at each of the reactive sites to form a highly complex three dimensional network.



Key: S=Styrene

Figure2.3:Schematic Representation of Unsaturated Polyester Resin(cured)(David andGurit,2015)

The Polyester Resin is then said to be 'cured'. It is now a chemically (and usually) hard solid. The cross-linking or curing process is called 'polymerization'. It is a non-reversible chemical reaction. The 'side-by-side' nature of this cross-linking of the molecular chains tends to mean that polyester laminates suffers from brittleness when shock loadings are applied. Great care is needed in the preparation of the resin mix prior to moulding. The resin and any additives must be carefully stirred to disperse all the components evenly before the catalyst is

added. This stirring must be thorough and careful as any air introduced into the resin mix affects the quality of the final moulding. This is especially so when laminating with layers of reinforcing materials as air bubbles can be formed within the resultant laminate which can weaken the structure. It is also important to add the accelerator and catalyst in carefully measured amounts to control the polymerization reaction to give the best material properties. Too much catalyst will cause too rapid a gelation time, whereas too little catalyst will result in under-cure. Colouring of the resin mix can be carried out with pigments. The choice of a suitable pigment material, even though only added at about 3% resin weight, must be carefully considered as it's easy to affect the curing reaction and degrade the final laminate by use of unsuitable pigments.

Filler materials are used extensively with Polyester Resins for a variety of reasons including:

-To reduce the cost of the moulding

-To facilitate the moulding

-To impart specific properties to the mould

Fillers are often added in quantities up to *50%* of the resin weight such addition levels will affect the flexural and tensile strength of the laminate. The use of fillers can be beneficial in the laminating or casting of thick components where otherwise considerable exothermic heating can occur. Addition of certain fillers can also contribute to increasing the fire-resistance of the laminate (David and Gurit2015).

2.4.1 Gelation, curing and post-curing

On addition of the catalyst or hardener,a resin will startto become more viscous until it reaches a state when it is no longer a liquid and has lost its ability to flow. This is the 'gel point'. The resin will continue to harden after it has gelled, until, at some time later, it has obtained its ful1 hardness and properties. This reaction itself is accompanied by the generation of exothermic

heat, which in turn, speeds the reaction. The whole process is known as the ‘curing’ of the resin the speed of cure is controlled by the amount of accelerator in a polyester or vinyl ester resin and by varying the type, not the quantity, of hardener in an epoxy resin. Generally polyester resins produce a more severe exotherm and a faster development of initial mechanical properties than epoxies of a similar working time. With both resintypes, however, it is possible to accelerate the cure by the application of heat, so that the higher the temperature the faster the final hardening will occur. This can be most useful when the cure would otherwise take several hours or even days at room temperature. A quick rule of thumb for the accelerating effect of heat on a resin is that 10^0C increases in temperature will roughly double the reaction rate. Therefore if a resin gels in a laminate in 25minutes at 20°C it will gel in about 12 minutes at 30°C, providing no extra exotherm occurs. Curing at elevate temperatures has the added advantage that it actually increases the end mechanical properties of the material, and many resin system (Sharifah,*etal.*,2005).

2.5 COMPOSITE MATERIALS

Composite material is a material composed of two or more distinct phases (matrix phase and reinforcing phase) and having bulk properties significantly different from those of any of the constituents. Also, Composites are engineering materials made from two or more constituent materials that remain separate and distinct on microscope level while forming a single component. There are two categories of constituent materials: matrix and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement material by maintaining their relative position. The reinforcement impacts their special mechanical properties to enhance the matrix properties. A synergism produces materials properties unavailable from the individual constituent materials, while the wide

variety of matrix strengthening materials allows the designer of the product or structure to choose an optimum combination. Engineered composite materials must be forced to shape(Sudipt and Ananda,, *2008*). The matrix material can be introduced to the reinforcement before or after the reinforcement material is placed into the mold cavity or onto mold surface. The matrix material experiences a melding event, after which the part shape is essentially set. Depending on the nature of the matrix material, this melding event can occur in various ways such as chemical polymerization or solidification from the melted state.High performance composites consist of high modulus, high strength filaments bonded together by a much softer matrix to form structure material marked by high modulus and high strength. Composites differ from ordinary materials in several aspects. Properties are variable depending primarily on fibres and matrix properties, volume content of these constituents, and the orientation and geometry of fibres. All are controllable and selected by a fabricator to fulfill structural requirement for a given application. Ordinary materials are isotropic and have more nearly fixed properties, whereas the composites are anisotropic, having properties dependent on the axis of testing.

However, Favorable properties of composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance etc (Ananda, and Sudipt, 2008).

2.5.1MATRIX

This is the continuous phase of material, and its role is primarily that of a glue or binder. A resin is a type of matrix, which must have the proper viscosity for easy process ability-namely; it must have the proper viscosity and evolve minimum amount of volatile product during cure.

Most useful matrix materials are cross-linked polymers of the thermosetting type. The main matrix materials for advance composites are usually thermosets, e.g. epoxy, polyester, phenolic, vinyl ester, and polyamide. Some thermoplastics are also in use; these thermoplastic polyester, polyethylene, polysulphanone and polyetherketone (peek) (Sudipt and Ananda, 2008).

2.5.2REINFORCEMENT

These are discrete inclusions used to improve the structural characteristics of materials. They can be continuous in form (fibre, filament or tape) or discontinuous in form (whiskers, flake or particulates). Reinforcements reduce cost, improve formality and electrical properties, increase the ratios of strength to density and stiffness todensity; increase resistance to corrosion, fatigue creep, stress rupture, and reduced the coefficient of thermal expansion. Reinforcements allow the matrix to be tailored to the material. Fillers are considered to be cheap extenders and diluents used to reduce the cost of a composites (Joel,2007).

2.5.3 CHARACTERISTICS0FCOMPOSITE MATERIALS

These composites are artificially made materials (thus, excluding natural material such as wood), they consist of at least two different species with a well-defined interface. The properties of composites are influenced by the volume percentage of ingredients. These materials have at least one property not possessed by the individual constituents. The performance of these composites material depends on the properties of matrix and reinforcement, size and distribution of constituents, shape of constituents, nature of interface between constituents(Navdeep,*et al., 2012*).

2.5.4CLASSIFICATION OF COMPOSITES

Composite materials are classified:

2.5.4.1 ON THE BASIS OF MATRIX:

2.5.4.1.1 Metal Matrix Composites (MMC)

Metal Matrix Composites are composed of a metallic matrix (aluminium, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead,tungsten, molybdenum) phase.Metallic Reinforcement may be tungsten, beryllium etc. MMCs are used for Space Shuttle, commercial airliners, electronic substrates, bicycles, automobiles, golf clubs and a variety of other applications. From a material point of view, when compared to polymer matrix composites, the advantages of MMCs lie in their retention of strength and stiffness at elevated temperature, good abrasion and creep resistance properties. Most MMCs are still in the development stage or the early stages of production and are not so widely established as polymer matrix composites(Sudipt and Ananda,2008)

2.5.4.1.2Ceramic Matrix Composites (CMC)

Ceramic Matrix Composites are composed of a ceramic matrix and imbedded fibres of other ceramic materials (dispersed phase).

2.5.4.1.3Polymer Matrix Composites (PMC)

This type of matrix often determines the maximum service temperature, since it normally softens, melts or degrades at a much lower temperature than the fibres reinforcement (Navdeep *et al*,2012).The most widely utilized and expensive polymer resins are the polyester and vinyl esters namely; thermoplastics resins (poly propylene, poly phenylene, siphone, polymide etc.) and thermo set resins (polyesters, phenolic, melamine, silicones, polyurethanes, etc.). The role of polymer matrix in a fibre reinforced composites is to transfer stress between the fibres, to

provide a barrier against an adverse environment and to protect the surface of the fibre from mechanical abrasion. The matrix plays a major role in the tensile load carrying capacity of a composites structure (Ziegler,*et al*, 1999). The binding agent or matrix in the composites is of critical importance. Polymer resins have been broadly divided into two categories: Thermosetting and Thermoplastic resinSudipt and Ananda (2008)

2.5.4.1.3.1 Thermosets

Thermoset is a hard and stiff cross-linked material that does not soften or become moldable when heated (Sinha,2000). Thermosets are stiff and do not stretch the way elastomers and thermoplastic do. Examples of thermoset polymers are: polyester resin, epoxy resin, polyamides, phenolic, vinyl esters etc.

Unsaturated polyester resins are extremely versatile in properties and applications and have been a popular thermoset used as the polymer matrix in composites (Sharifah, 2005). They are widely produced industrially as they possess many advantages, which include room temperature cure capability, good mechanical properties and transparency among others. The reinforcement of polyesters with cellulosic fibres has been widely reported Roe and Ansell, (1985).Polyester-Jute (Mohanty*et al.*, 2005), Polyester-sisal (Satyanarayana *et al*., 1982), are some of the promising systems Mwaikambo and Bisanda, (1999). Etc.

2.5.3.3.2 Thermoplastics

Thermoplastics are polymers that required heat to make them process able (Sharifah,*et al*,2005). After cooling, such materials retain their shape,in addition, these thermoplastics polymers may be reheated and reformed, often without significant changes in their properties. Examples of thermoplastics are as follows: polyethylene, polypropylene, polystyrenes etc.

2.5.3.4 On The Basis of Filler Material:

i. Particulate Composites

ii. Fibrous CompositesAnanda, *and* Sudipt (2008)

2.6 NATURAL FIBRE REINFORCED COMPOSITES

The interest in natural fibre-reinforced polymer composite materials are rapidly growing both in terms of their industrial applications and research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, Jute, sisal, Maize cob, pineapple, ramie, bamboo, banana (Dhakal *et a.*, 2007) etc, as well as wood, used from time immemorial as a source of lignocelluloses fibres, are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibres used for the manufacturing of composites. The natural fibre-containing composite are more environmentally friendly, and are used in transportation (automobiles, railways coaches, aerospace). Military applications, building and construction industries (ceiling fanpaneling, partition boards), packaging, consumer products, etc (Mallick, 1993).Jute fibre is one of the most common agro fibres used as a reinforcing component for thermoplastics and thermosetting matrices Karmaka and Youngquist(1996).

2.7 HYBRID COMPOSITES

The incorporation of several different types of fibres into a single matrix has led to the development of hybrid bio composites. The behavior of hybrid composites is a weighed sum of the individual components in which there is a more favorable balance between the inherent advantages and disadvantages. Also, using a hybrid composite that contains two or more types of fibres, the advantages of one type of fibre could complement with what are lacking in the

other. As a consequence, a balance in cost and performance can be achieved through proper material design Liao and Thwe(2003). The properties of a hybrid composite mainly depend upon the fibre content, length of individual fibres, orientation, extent of intermingling of fibres, fibre to matrix bonding and arrangement of both the fibres. The strength of the hybrid composite is also dependent on the failure strain of individual fibres. Maximum hybrid results are obtained when the fibres are highly strain compatible (George *et al.*,2002). The properties of the hybrid system consisting of two components can be predicted by the rule of mixtures.

PH = P1 V1 + P2 V2 Liao and Thwe(2003)

Where

PH is the property to be investigated, P1 the corresponding property of the first system and P2 the corresponding property of the second system. V1 and V2 are the relative hybrid volume fractions of the first and second system andV1 + V2 = 1

A positive or negative hybrid effect is defined as a positive or negative deviation of a certain mechanical property from the rule of hybrid mixture. The term hybrid effect has been used to describe the phenomenon of an apparent synergistic improvement in the properties of a composite containing two or more types of fibres. The selection of the components that make up the hybrid composite is determined by the purpose of hybridization, requirements imposed on the material or the construction being designed. The problem of selecting the type of compatible fibres and the level of their properties is of prime importance when designing and producing hybrid composites. The successful use of hybrid composites is determined by the chemical, mechanical and physical stability of the fibre / matrix system. (Thwe and Liao,2003)

2.7.1TYPES OF HYBRID COMPOSITES

i. Interply or towby-tow, in which tows of the two or more constituent types of fibres are mixed in a regular or random manner;

ii. Sandwich hybrids, also known as core-shell, in which one material is sandwiched between two layers of another;

iii. Interply or laminated, where alternate layers of the two (or more) materials are stacked in a regular manner;

iv. Intimately mixed hybrids, where the constituent fibres are made to mix as randomly as possible so that no over-concentration of any one type is present in the material; other kinds, such as those reinforced with ribs, Pultruded wires, thin veils of fibre or combinations of the above.

Researchers have looked into tensile strength of ramie-cotton hybrid fibre reinforced polyester composites (Carvalho *et al.,* 2004).They observed that tensile behavior was dominated by volume fraction of ramie fibres aligned in the test direction. The fabric and diameter of the thread did not play any role in tensile characteristics. Cotton fabric was found to have minor reinforcement effect due to weak cotton/polyester interface. Similar studies were performed by Mwaikambo and Bisanda(1999), on kapok- cotton fibre reinforced polyester composites.

2.9 OPEN MOLDING

A process using one sided mould which shapes only one surface of the panel The opposite surface is determined by the amount of material placed upon the lower mould. Reinforcement material can be placed manually or robotically. They include continuous fibre forms fashioned into textile constructions and chopped fibre. The matrix is generally a resin, and can be applied with a pressure roller, a spray device or manually. This process is generally done at ambient

temperature and atmospheric pressure. Two variations of open molding are hand layup and spray up (Joel, 2007)

2.9.1 HAND LAY-UP METHOD

Hand lay-up techniques is the simplest and oldest open moulding method of the composites fabrication processes. It is a low volume, labor intensive method suited especially for large composites, such as boat hull, Glass or other reinforcing mat or woven fabric or roving is positioned manually in the open mould and resin is poured, brushed or sprayed over and into the glass piles. Entrapped air are removed manually with squeegees or rollers.Room temperature curing thermosets resins e.g, polyester and epoxy resins are the most commonly used matrix resin. Curing is initiated by a catalyst in the resin system which hardens the fibre reinforced resin composites. A pigmented gel is first applied to the mould surface for easy removal (Joel ,2007).

2.10 TESTING OF COMPOSITES

Evaluation of physical, mechanical and other characteristics of objects made from plastics is a function, which the plastic engineers are frequently required to perform. The purpose may be control of quality in production, acceptance testing against specifications, establishment of data for engineering and design or other end of substantial economic importance.

2.10.1 MECHANICAL TESTS

The test of physical properties using mechanical testing of plastics is among the most important tests. These tests determine the strength, stability, hardness and bending properties of materials. The literature from materials suppliers and manufactures requirement for incoming inspection of materials often quotes the qualities of plastics in terms of tensile strength, modulus, elongation, impact strength, hardness and flexural strength. These qualities outline

the plastic's characteristics under tension and its resistance to any change in shape. The five most important mechanical tests are tensile (ASTM D638), Izod impact (ASTM D256), Rockwell Hardness (ASTM D785), Durometer Hardness (ASTM D2240) and flexural strength (ASTMD790)The tests specimen are molded, normally in a master unit die (MUD mould), and therefore are affected by the molding and operating conditions inherent in their preparation. The test data is then gathered from test specimens that undergo steady deterioration. The molded product will ordinarily also be subjected to stress, cold flow, creep, chemical attack, aging, and changes in environment not reproducible under testing procedures(SitiRabiatull andHardinnawirda,2012)

2.10.1.1Tensile Properties

Tensile test measures the maximum stress that a material can withstand while being stretched or pulled. The properties derived from the tensile test are the most important indications of strength of a material. The force necessary to pull a specimen apart, as well as how the material stretches before breaking indicates how tough or brittle the material may be. Plastic materials produce stress-strain diagrams that offer clear indications of the various points of yielding as the load is increased. However, there are seven important references that can be derived from a stress strain diagram Netravali and Luo(1999)

i. Stress: This is the amount of force applied to the test specimen, or the ratio between the forces applied and cross-section of the specimen. By relating stress to strain, how much the material changes in length, provides information on the rigidity of the material.

ii.Strain: the change in length, in relation to the applied force. Strain is recorded along the bottom of the stress-strain diagram.

iii.Elastic Limit: this is best understood as that point of load at which the material under stress

can recover its approximate original dimensions. It marks the highest tensile force applied prior to permanently deforming the material. Tensile force that is released prior to reaching the elastic limit will stretch the material, but do not damage it. The elastic limit, on the stress-strain diagram, is the end of the straight line on the first portion of the graph. Below the elastic limit the applied load (stress) is proportional to its change in length (strain). If the specimen load does not exceed the elastic limit then the specimen will return to its original length. Plastic materials are not true elastic materials, for they do not act like a spring when a load is applied below their elastic limit. Plastics, however, always undergo deformation (permanent strain) when a load is applied. The plastic products are designed so that the applied force does not exceed 75% of the materials elastic limit.

iv.Modulus Of Elasticity: it is as also called tensile modulus or Young's modulus, it is the ratio of the stress to the strain, below the elastic limit. It is a measure of a material's stiffness. The modulus is calculated by dividing the strain into the stress. This value is recorded as the E value. Materials with high E are rigid stiff materials while materials with low E values are rubber like. Plastics that react with rubbers have high elongated (change in length) to low stress (force applied) and their E value range in the two hundreds.

v.Elongation:An increase in the length of the specimen of a given load (stress) is termed elongation. It is a measure of the materials ductility and can be related to toughness in plastics materials.

vi.Yield Point: this is the first point beyond the elastic limit where the plastic material begins to lose its ability to resist the force applied to it and begins to stretch. The molecular structure can no longer resist the applied force and begins to breakdown.

vii.Yield Strength: this is the stress at which the materials undergoing a load exhibits

deformation behavior found at the yield point. Unless otherwise specimen, it is reported as the same yield point. However, often the yield strength is reported as a percentage offset from the yield point. In this case, the yield strength is the stress at 0.2% or 0.5% offset toward the break point of the material (Netravali and Luo 1999)

viii.Ultimate Strength:This is the maximum force(stress),that a material can withstand. It is the same or higher that the ‘’yield point’’ for plastic material(Agarwal *et al.,* 2010)

2.10.1.2 IMPACT STRENGTH

This is the measure of the work done to break a test piece. It is the ability of a material to withstand shock loading or the work done in fracturing under shock loading. In practical terms, where the fabricated objects are to encounter dynamic force such as shock, impact strength may be more important than tensile strength Cantwell and Villanueva (2004). There are several types of impact testing machines.

2.10.1.3HARDNESS

This is described as the process of surface deformation of a material due to indentation. This test is employed using 2 types of durometer hardness machine i.e. type A and type D, usually for measuring the indentation the hardness a material that is ranging from soft rubber to hard rubber and plasticSitiRabiatull and Hardinnawirda (2012)

2.10.1.4 FLEXURAL STRENGTH

The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress. The transverse blending test is mostly employed, in which a sample having either a circular or rectangular cross-section is bent until fracture or yielding, Using a three-point or four-point flexural test techniques. Flexural strength is calculated in (Mpa) (Hodgkinson,2000).

2.10.2 PHYSICAL TESTS:

2.10.2.1 Density

This is the amount of substance in a specific area; it is also the mass in grams per unit volume of a substance.(g/cm^3)

2.10.2.2. WATER ABSORPTION

The percentage water absorption of the composites is determined according to ASTM standard. The samples are weighed and immersed in distilled water for 48hrs and thereafter re-weighed. The percentage water absorption was calculated using the formulae below:

$$percentage\ water\ absorption = \frac{final\ weight - initial\ weight}{initial\ weight} \times 100$$

Water absorption leads to reduction in the fibre matrix interface and decrease in mechanical properties. All inorganic polymeric materials will absorb moisture to some extent resulting in swelling and dissolving which can result in loss of mechanical properties of composites material (Amuthakkannan*et al.*,2014)

2.11 SCANNING ELECTRON MICROSCOPY (SEM)

Scanning Electron Microscope is a type of microscope that produces image of a sample by scanning it with a focused beam of electron. The electron interacts with the atoms in the sample, producing various signals that can be detected and that contain information about the samples surface Topography, sub-surface information and compositional difference. SEM is used to determine the size, distribution and orientation of fibres or particles, it identifies and characterize any defects (voids, debond, fibre pullout and fibre bonding). It also gives information on the degree of bonding between the matrix and reinforcement or between

layers.To prepare samples for SEM, insulating samples are coated with thin layer of Gold, Aluminum or Carbon by evaporation or sputtering.Samples can be viewed with different Kilo Voltage and micrographs can be obtainedat different magnifications(Webinar,2011).

CHAPTER THREE

3.0 MATERIALS AND METHODS.

This research was conducted using the following materials

3.1 Materials

i. Maize cob(300µ)

ii. Unsaturated Polyester Resin(Olasco Chemical Company, Zaria, Nigeria)

iii. JuteFibre(5-10mm)

iv. Accelerator (cobalt)(Olasco Chemical Company, Zaria, Nigeria)

v. Catalyst(Methyl-Ethyl-Ketone-Peroxide)(Olasco Chemical Company Zaria,Nigeria)

3.2 Equipment:

i. Tensometer type "W"(Made in UK by Monsanto)

ii. Analytical Balance (Sartorius. Model: ED2245)

iii. Stop Watch

iv. 200x100x40 (mm) glass Mould

v. IndentecUniversal Hardness Testing Machine (Model: 8187.5) LKV "B".

vi.A Retting Bath.

vii. Universal Material Testing Machine.(Cat Nr.Model:261)

viii. Retsch Sieve Shaker Machine (Endocatt. Model: 7416)

ix.Charpy Impact Testing Machine" 15 Joules Capacity"(Cat Nr.Model:412)

x. SEM. Phenon Pro-X by Phenon-World Eindhoven Neither Land.

3.3 Preparation of Maize cob powder

Maize cobs were obtained from maize farmers in Samaru Village of Sabon Gari Local Government area, Kaduna State. It was first pounded with mortar and pestle and later ground with grinding machine into powdered form. The Maize cob powder was sieved to about300µparticulate size.

3.4 Extraction of Jute Fibres

Jute bark was obtained from farmers in Samaru Village of Sabon Gari Local Government Area, Kaduna state. The bark was bundled in ribbon form and immersed in a water retting bath, little pressure was applied to the retting bath to ensure the bark are fully submerged in the retting water. It was allowed to remain submerged for 21days during which the lignin, pectin, hemicelluloses and cellulose binding the fibres must have soften and loosen. The retted ribbon was removed and slightly beaten to loosen the fibres and then thoroughly washed with clean water, stripped with hand to remove the remaining unwanted substances and allowed to dry. After drying the Jute fibres were chopped into a short length of about (5-10mm), before it used for composites preparation.

3.5 Unsaturated Polyester Resin

Unsaturated Polyester Resinwas obtained from by Olasco Chemical Company in Sabon Gari Local Government, Kaduna state. Alongside the required promoters accelerator (cobalt) and catalyst (methyl ethyl ketone peroxide).

3.6 Composites preparation

3.6.1. Jute Fibre/ Unsaturated Polyester Resincomposites

The required amount of unsaturated polyester resin, accelerator(Cobalt) and catalyst(MEKP)2% to the resin volume were weighed out and thoroughly mixed. The corresponding amount of Jute fibres were weighed out as shown in Table 3.1 and added to the UPR it was thoroughly mixed to ensure even distribution of fibres. The prepared Jute fibre/ UPR mixture was then poured in to a mould of 200x100x40(mm) dimension in which foil paper has been laid to allow for ease of removal of the composites. The formed composites according to the fibre volume were removed and allowed to cure under laboratory conditions before subjecting them to the physical, mechanical tests and SEM.

3.6.2.Maize cob/Unsaturated Polyester Resincomposites

Composites of Maize cob and Unsaturated Polyester Resinwere prepared by weighing out the required volume of UPR, accelerator and catalyst.The corresponding amount ofMaize cob as shown in Table 3.2 below.The composites are formed as in (3.6.1) above.

3.6.3. Preparation of Hybrid Composites(Jutefibres/Maize cob/Unsaturated polyester)

From the results of the preliminary testson the composites prepared above, it was observed that at 10% Jute fibre and 10% Maize cob content, the fillers were fully integrated in the matrix structure. Similarly, the 10% filler content showed promising results of tensile properties, hence,10% filler content was chosen as the percentage hybridization content. The amount of fillers (Jute fibres/Maize cob) were varied in the Unsaturated Polyester Resinmatrix as shown in Table 3.3 below and the composites were prepared as in (3.6.1) above.

Table3.1: Jute Fibre/Unsaturated Polyester Resincomposites formulation

S/N	% of JF(g)	% UPR	Mass of JF(g)	Mass of UPR(g)	Total mass (g)
1	0(control)	100	0	90.40	90.40
2	5	95	4.52	85.88	90.40
3	10	90	9.04	81.36	90.40
4	15	85	13.56	76.84	90.40
5	20	80	18.08	72.32	90.40

Table3.2: Maize cob/Unsaturated Polyester ResinComposites Formulation

S/N	% of MC(g)	% UPR	Mass of MC(g)	Mass of UPR(g)	Total mass (g)
1	0(control)	100	0	90.40	90.40
2	5	95	4.52	85.88	90.40
3	10	90	9.04	81.36	90.40
4	15	85	13.56	76.84	90.40
5	20	80	18.08	72.32	90.40

Table3.3: Jute Fibre, Maize cob/Unsaturated Polyester Hybrid composites Formulation

S/N	% of JF	% of MC	% of UPR	Mass of UPR(g)	Total mass(g)
1	10	0	90	81.36	90.40
2	9	1	90	81.36	90.40
3	7	3	90	81.36	90.40
4	5	5	90	81.36	90.40
5	3	7	90	81.36	90.40
6	0	10	90	81.36	90.40

3.7 CHARACTERIZATION OF THE COMPOSITES

The characterizations were carried out according to ASTM standards for testing materials.

3.7.1 MECHANICAL TESTS:

After the fabrication of the composites, the samples were conditioned for 24hrs, and later subjected to the following tests.

3.7.1.1 Tensile Strength Test

The test samples in dumb-bell shape of the required standard dimensions according to ASTMD638 were cut and clamped between the upper and lower jawsof the type ”W’Monsanto tensometer and the machine was loaded Manually. The sample was stretched gradually with

the application of force, till it reached its breaking point. Reading of maximum load and elongation at break were taken accordingly. The test was repeated five times for each of the composites samples and the average values recorded accordingly.

3.7.1.2 Impact Strength

Using the Cat Nr.412 Charpy Impact Testing Machine 15 joules capacity.The tests were conducted according to ASTM D-256.Composites samples were cut into length not less than 10cm with uniform width, the composite sample was placed on the machine and held tightly with the aid of knots, while the ends are observed to be of equal length, the hammer of 15 joules energy capacity was raised and then released to hit the sample, which led to breaking thecomposite sample. The work done in breaking the test sample was recorded. The test was repeated five times for all the composite samples and the average values recorded accordingly.

3.7.1.3 Hardness Test

The “Indentec Universal Hardness Testing Machine Model 8187.5 LKV “B” Rockwell HRF indentor (1/16” steel ball) with minor load 10kg and major load 60k was used in measuring the hardness using the shore scale according to ASTM D2240. It consists of an indenter, a graduated circular tube and a flat surface which the sample /material to be tested are mounted or laid on. The sample was placed on the flat surface and the indenter was forced on the surface of the specimen, the load was maintained at maximum time of 10 to 15seconds, and the test was repeated five times and the averages of each tests result were recorded accordingly.

3.7.1.4 Flexural Strength

Flexural strength also known as modulus of rapture, bend strength or fracture strength is a material property, known as the stress in a material just before it yields in a flexure test

(Hodgkinson, 2000). The three point bending test was conducted according to ASTM D790 with Cat Nr.261 Universal Material Testing Machine-100KN. At least three rectangular beam samples were tested at a support span length of 70mm, the width and thickness were measured correctly using vanier caliper. The samples were centre loaded in 3-point bending as a simply supported beam,using 3mm diameter supports and loading bar. The deformation in mm and load in KN were recorded and the tests was repeated five times the average values recorded accordingly. The flexural strengths were calculated using the following equation:

Flexural Strength=$3PL/2bd^2$ (MPa)

3.7.2 PHYSICAL TESTS:

3.7.2.1 Water Absorption

Water absorption was conducted according to ASTM 2842. Twelve (12) samples were cut to a specific size (2X2 cm) and weighed using weighing balance correct to two (2) decimal places. The weighed samples were placed in a stainless steel container and enough water was added so that they were completely immersed. The composites samples were left in the water for 24hrs, thereafter, the samples were removed from the water clean with cloth to eliminate surface moisture, re-weighed.Same procedure was repeated for 30days reweighing after every 48hrs and the percentage water absorption was calculated using the equation below.

$$percentagewaterabsorption = \frac{finalweight - initialweight}{initialweight} X\,100 \quad (1)$$

3.7.2.2 Density:

Densities of the composites were determined according ASTM D792-13. It is the mass in grams per unit volume in cm^3 of a substance. A measuring cylinder (250ml) was rinsed thoroughly, a measured quantity of distilled water (60ml) was poured into the cylinder, composites samples were cut to about (1x1cm) and immersed into the cylinder containing the distilled water, and the displacement of water volume was observed, and the density of the composite were determined using the weight of the composite samples over the volume of water displaced in the cylinder.

$$\rho = \frac{m}{v} \qquad (2)$$

Where ρ= Density

m= Mass

v= Volume

The unit of density is grams per centimetre cube (g/cm^3)

3.7.3 SCANNING ELECTRON MICRSOCOPY

Phenon Pro-X Manufactured By Phenon-World Scanning electron microscopy(SEM)was used.Polymer composites are non-conductive to make them conductive a sputter machine used 5nm gold to coat the surface of the sample. The coated samples were placed on a sample holder and inserted into the machine column where the samples were viewed through a navigation camera, proper adjustment were made to view the samples clearly before the machine was transferred to electronic mode. The viewing voltage will be set using 10KV,the magnifications were increased then the sample morphology was stored in the electronic mode. The machine was

switched from electronic mode to navigation camera before ejecting the samples from the machine. Microstructures were obtained at magnifications of 1000X.

CHAPTER FOUR

4.0: RESULTS AND DISCUSSION

From the results, it could be seen that 20% JF/UPR Composites have no values in the test conducted. This is because the composites could not form at that filler loading. This could be attributed to the saturation of the UPR matrix at 20% filler content, thus, the composites could not form. However, composites of 20% MC were able to form. This could be as a result of small particle size used for the composites formation.

4.1 Mechanical Tests:

4.1.1 Tensile Strength

Table4.1: Tensile Strengthof JF/ UPR and MC/ UPR Composites.

S/N	%JF or MC	% of UPR	Tensile strength of JF/UPR(Mpa)	Tensile strength of MC/UPR(Mpa)
1	0(control)	100	34.08	34.08
2	5	95	17.02	24.27
3	10	90	12.84	21.55
4	15	85	10.89	20.39
5	20	80	Nill	14.74

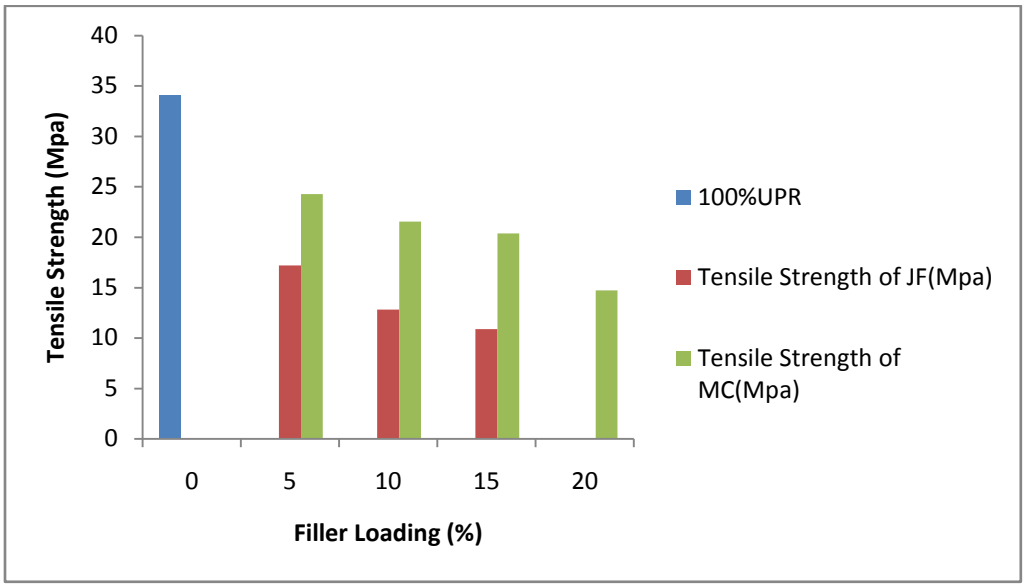


Figure 4.1Tensile Strength Versus Filler Loading for JF/UPR and MC/UPR Composites

Table4.2: Tensile Strengthof JF/MC/UPR Hybrid Composites

S/N	% of JF	% of MC	% of UPR	Tensile strength(MPa)
1	10	0	90	19.82
2	9	1	90	15.17
3	7	3	90	15.27
4	5	5	90	32.86
5	3	7	90	12.84
6	0	10	90	21.55

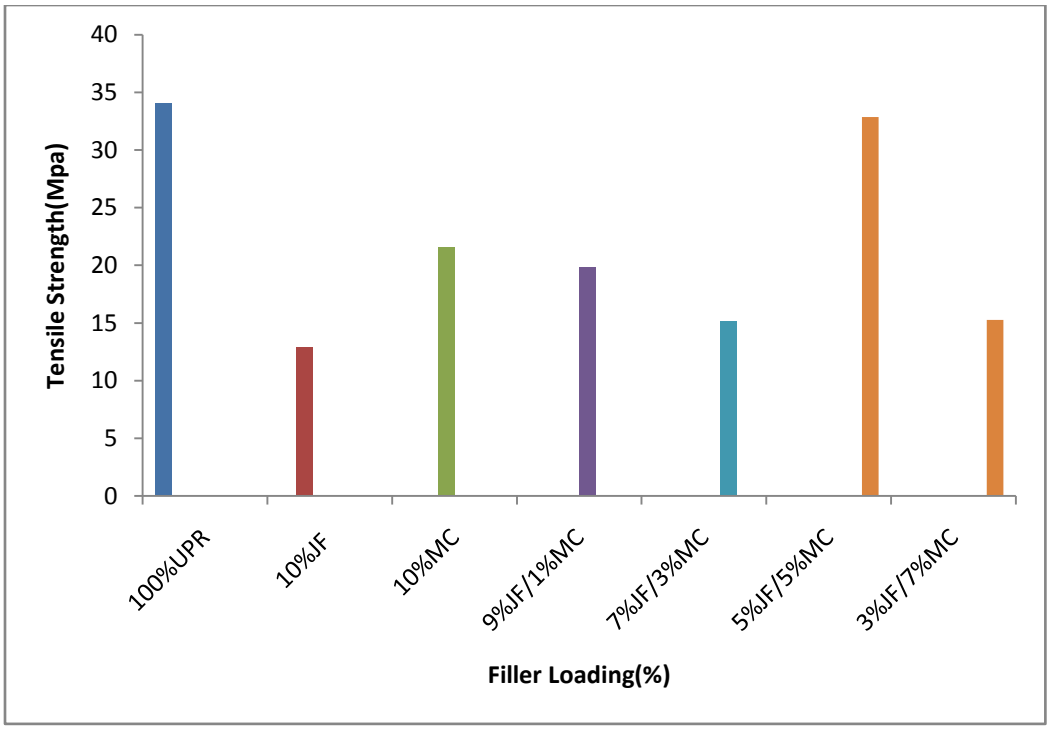


Figure4.2:Tensile Strength versus Filler loading of JF/MC/UPR Hybrid Composites.

The tensile strength of a material is the maximum load applied to the material in stretching it to rapture. Filler type plays an important role in the determination of mechanical properties of cellulose filled thermosets and thermoplastic composites. The most crucial factor affecting the mechanical properties of fibre-reinforced materials is the fibre/ matrix interfacial bonding, it is determined by several factors such as the nature of the fibre and polymer components, the processing method and fibre treatment (Ratnam *et al*,2008)

In this work,though there was a general decrease in the tensile strength of the composites with increase in both Jute fibre and Maize cob filler contents from 5% to 15% of JF and 5% to 20% of MC corresponding to 17.02 to 10.89Mpa and 24.27 to 14.74Mpa respectively as shown in tables 4.1 and figs 4.1 respectively. However, it is clear that the tensile strength of MC/UPR composites were higher than JF/UPR. This could be attributed to the fact that MC/UPR being

particulate composites which has better mechanical properties than short fibre composite because there is larger area for surface bonding in the case of particulate composites. Some studies on the mechanical properties of particulate-board from Maize cob and urea formaldehyde resin shows decrease in tensile strength with increase Maize cob as reported by (Danladi and Patrick, 2013). The decrease in strength observed in these composites could be attributed to agglomerate formation which could have resulted in the formation of stress Centre's in the composites which initiate failure on application of stress. Similar results have been reported by Shenoyand Melo(2007) From Table 4.2 and fig 4.2.it was observed that hybrid composites of JF/MC/UPR showed remarkable increase in tensile strength from 19.82Mpa and 20.39Mpa for JF/UPR and MC/UPR at 10% filler content respectively to 32.86Mpa for 5%JF/5%MC/90%UPR hybrid composites which reveals promising result which is close to that of 100% UPR which is 34.08Mpa. This behavior could be attributed to the extent of excellent inter mingling between the two fillers and good fibre-matrix interfacial adhesion.This implies that the hybrid composites with composition 5%JF/5%MC/90%UPR can produce composites of adequate strength value for useful applications such as book shelf's, pharmaceutical shelf's, shoe horns, particle board and partition wall.

4.1.2 Elongation at Break

Table4.3: Elongation of JF/UPR and MC/ UPR Composites.

S/N	% ofJF or MC	% of UPR	Elongation of JF/UPR composites (%)	Elongation of MC/UPR composites (%)
1	0(control)	100	20.30	20.30
2	5	95	17.32	18.10
3	10	90	12.80	16.00
4	15	85	11.50	13.90
5	20	80	Nill	13.30

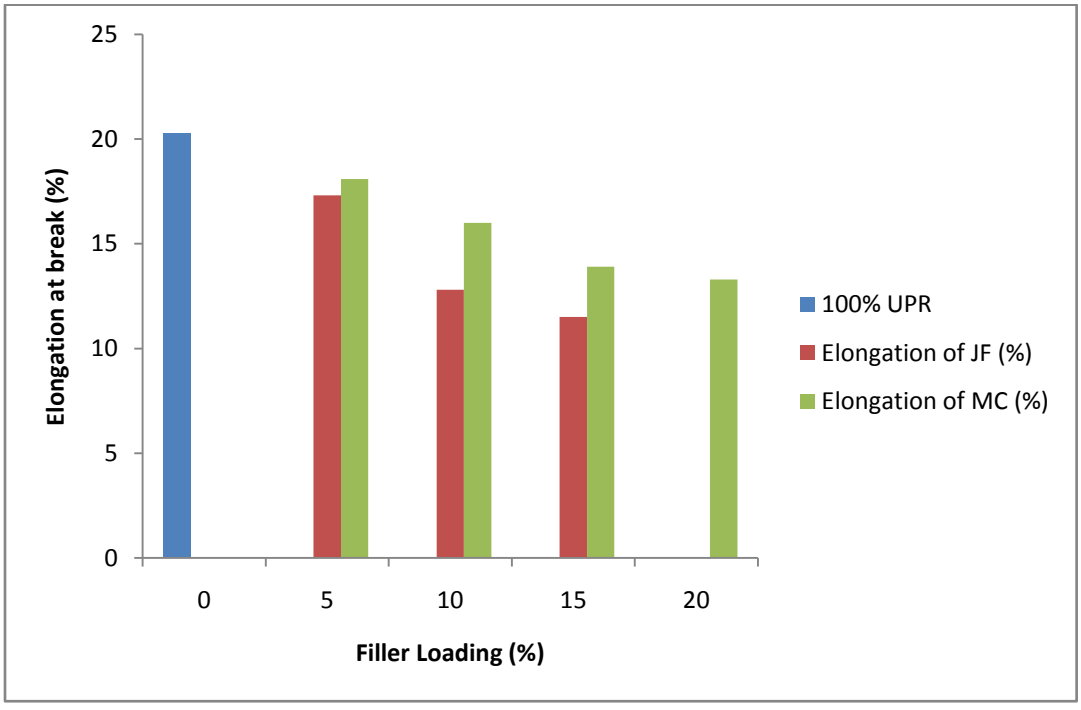


Figure 4.3 Elongation Versus Filler loading for JF/UPR and MC/UPR Composites.

Table4.4: Elongation of JF/MC/UPR Hybrid Composites.

S/N	% of JF	% of MC	% of UPR	Elongation (%)
1	10	0	90	12.80
2	9	1	90	18.53
3	7	3	90	19.20
4	5	5	90	19.60
5	3	7	90	17.08
6	0	10	90	16.00

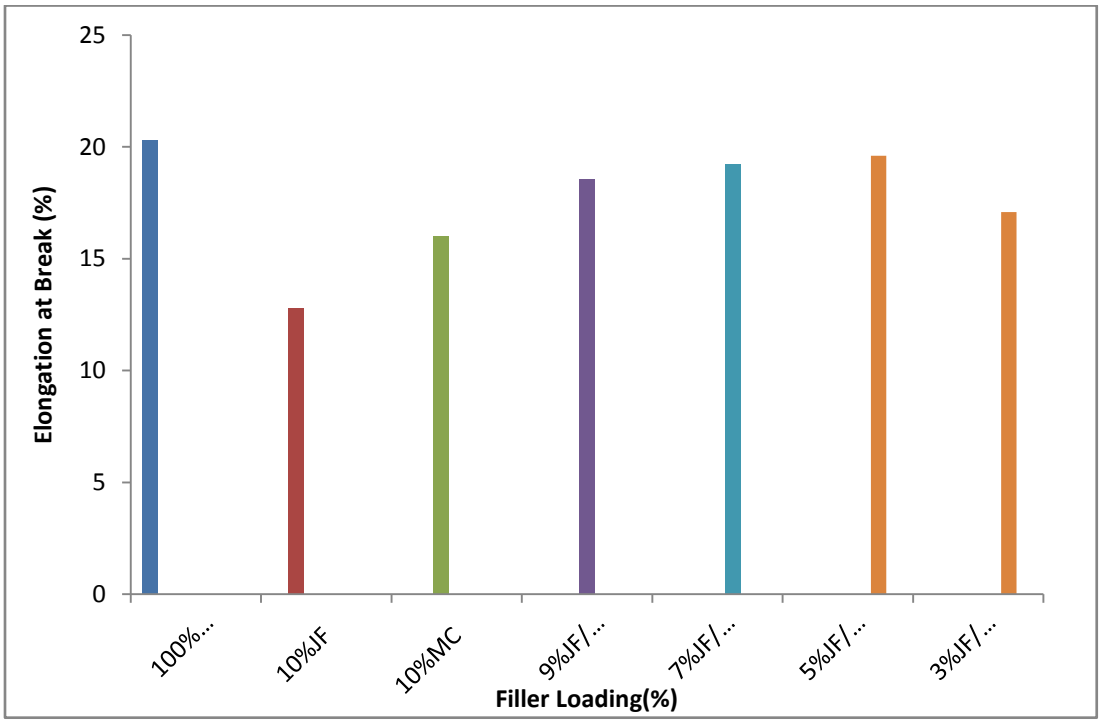


Fig4.4: Elongation Versus Filler loading for JF/MC/UPR Hybrid composites

Elongation at break or strain is expressed as the ratio of total deformation to the initial dimension of the material body in which forces are being applied (Shuhadah and Supri, 2009). Tables 4.3 and fig4.3 show the effect of filler loading on the elongation property of Unsaturated Polyester Resin composites.Fig4.3 show that the elongation at break of JF/UPR and MC/UPR composites decrease with increase in filler loading from 20.30 to 11.50 and 20.30 to 13.30as the filler content is varied from 0 to 15 and 0 to 20% respectively.The increase of filler loading in the Unsaturated Polyester Resinmatrix resulted in the stiffening and hardening of the composite which reduced its ductility, and led to lower elongation property. The reduction in the elongation at break with the increasing filler loading indicates the incapability of the filler to support the stress transfer from polymer matrix to the filler.Such a reduction in elongation at break of polymer composites with increase in filler content, irrespective of filler particle size and length has been reported by (Shuhadah and Supri, 2009).

Table 4.4 and fig 4.4 show elongation at break of hybrid composites, with varying filler loading the elongation at break shows slight increase from 17.08 for 3JF/7MC/90UPR up to a filler loading of 5%JF/5%MC/90%UPR which exhibited high ductility of 19.60 before it break compared to it control sample of 10% JF and 10%MC which has elongation values of 12.80(%) and 16.00(%) respectively. The ductility of the hybrid composites improved compared to the trend shown in fig 4.3 which demonstrates that the fillers had hardened the composites and reduces their ductility. These results could be attributed to less agglomerate formation in the hybrid composites and good filler- matrix bonding.

4.1.3 IMPACT STRENGTH TEST:

Table4.5: Impact Strength of JF/ UPR and MC/UPR Composites.

S/N	% of JF or MC	% of UPR	Impact strength of JF composites(J/m)	Impact Strength of MC composites(J/m)
1	0(control)	100	0.68	0.68
2	5	95	0.48	0.35
3	10	90	0.38	0.33
4	15	85	0.20	0.28
5	20	80	Nill	0.18

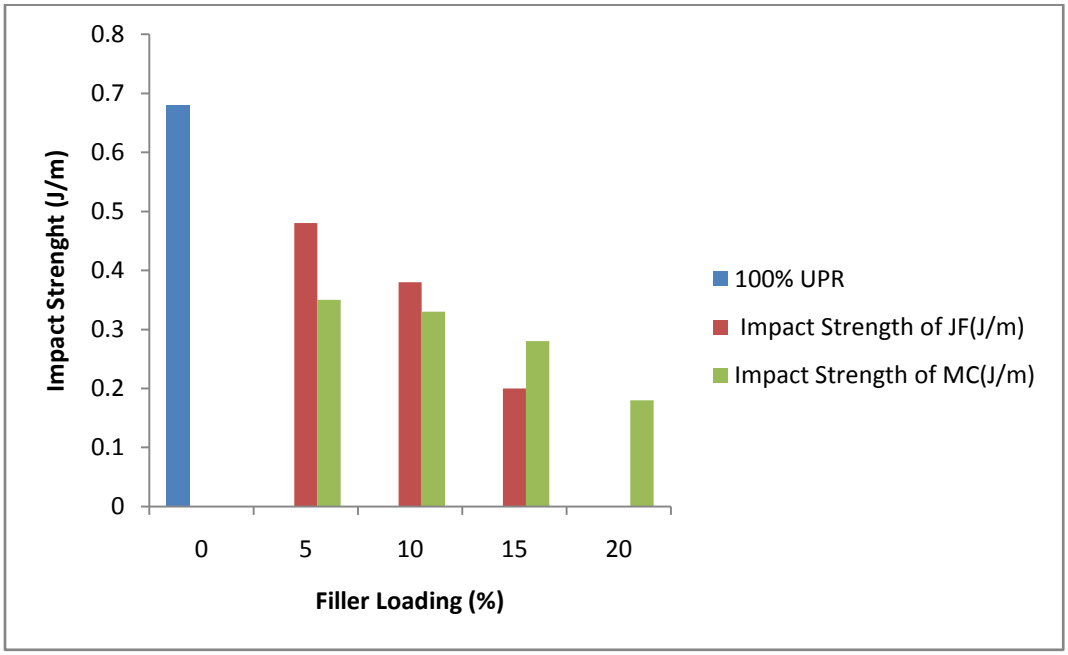


Fig4.5: Impact Strength Versus Filler loading for JF/UPR and MC/UPR composites.

Table4.6: Impact Strength of JF/MC/ UPR Hybrid Composites.

S/N	% of JF	% of MC	% of UPR	Impact strength(J/m)
1	10	0	90	0.38
2	9	1	90	0.35
3	7	3	90	0.28
4	5	5	90	0.48
5	3	7	90	0.28
6	0	10	90	0.33

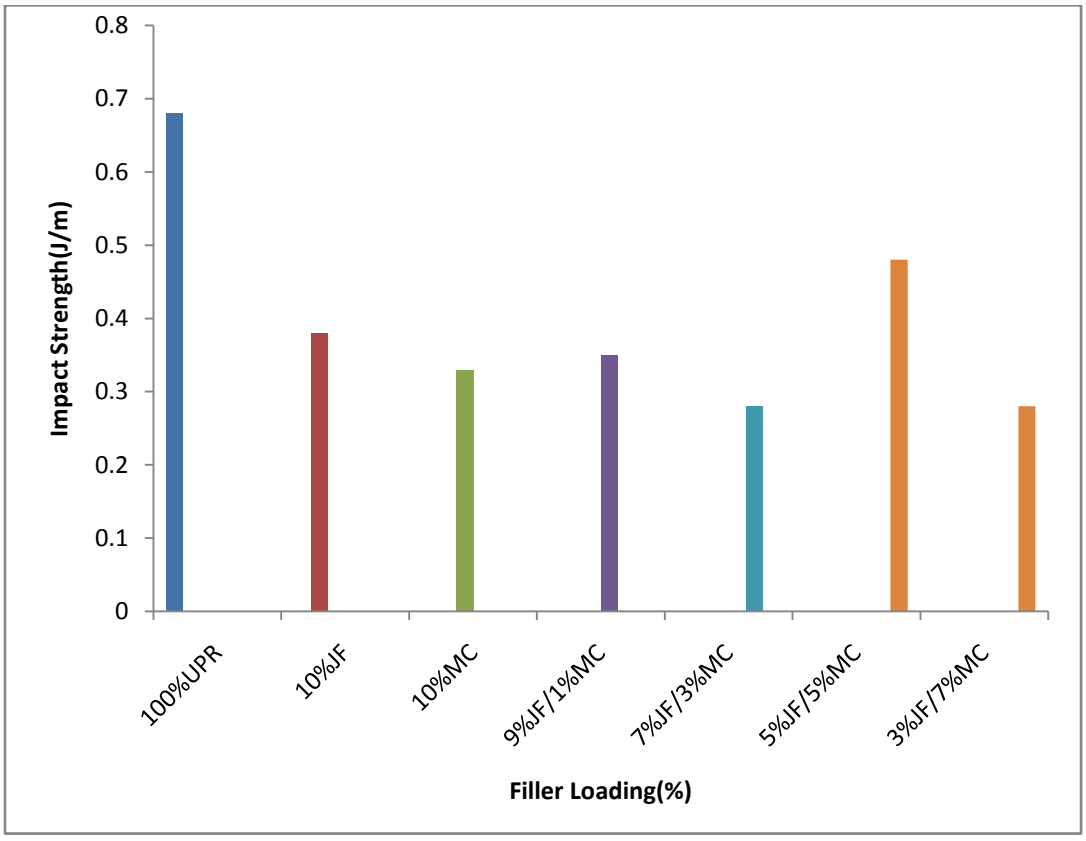


Fig4.6: Impact Strength Versus Filler loading of JF/MC/UPR Hybrid Composites.

Impact strength is the ability of the composites material to withstand shock loading or the ability of a material to absorb mechanical energy in the process of deformation and fracture under impact loading. Presence of longitudinal fibres at the loading points contributes to increase in the resistance and invariably better mechanical properties. This can only take place if the interfacial adhesion between the matrix and the filler will not result into a crack, lowering the impact strength of the composites. As filler loading increase there is a disturbance in the three dimensional network of the polymer matrix resulting into decrease in mobility of matrix molecules. Variation of impact strength with filler loading for both JF/UPR and MC/UPR is shown in table 4.5, and fig 4.5 respectively. The impact strength value decreases with increasing filler loading from 0.48 to 0.20(J/m) and 0.35 to 0.18(J/m) for JF/UPR 5% to 15% and MC/UPR 5% to 20% filler loading respectively. It has been reported that high fibre content increase the probability of fibre agglomeration which results in regions of stress concentration requiring less energy for crack propagation (Karmakar *et al*,2007).The decrease in impact strength can be attributed to saturation of the UPR by the fillers, thus, preventing proper bonding of the fillers to form a strong composites. From fig 4.6, it was observed that the hybrid composites with filler loading 5%JF/ 5%MC/ 90%UPR shows moderate impact strength values from 0.38(J/m), for 10% JF/UPR, 0.33(J/m) for 10% MC/UPR to 0.48(J/m) of JF/MC/UPR hybrid composites, this means that this hybrid composites can withstand medium energy impact without fracturing. The improvement in absorbing energy of the hybrid composites could be due to better interaction of the filler and matrix. A deviation was reported in similar work on production and properties of sweet potato flour/HDPE composites which shows decrease in impact strength with increase sweet potato powder as reported by (Danladi and Salihu, 2014).

However, it can be seen that despite the decrease in the impact resistance values, the composites of JF/UPR, MC /UPR and hybrid composites of JF/MC/UPR show fairly good results which can make them find useful applications like table tops, partition boards, ceiling boards etc.

4.1.4 HARDNESS TEST:

Table4.7: Hardness of JF/ UPR and MC/UPR composites.

S/N	% of JF or MC	% of UPR	Hardness of JF/UPRcomposite (shore A)	Hardness of MC/UPR composites(shore A)
1	0(control)	100	57.30	57.30
2	5	95	35.57	46.70
3	10	90	30.77	44.00
4	15	85	19.00	41.50
5	20	80	Nill	32.40

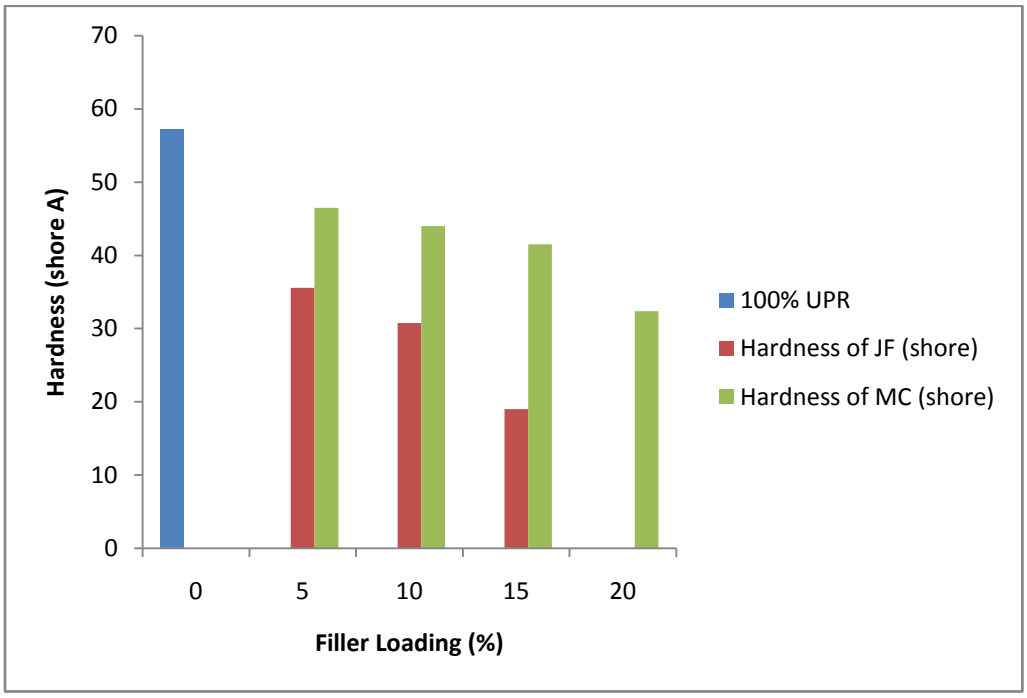


Fig4.7: Hardness Versus Filler loading for JF/UPR and MC/UPR composites.

Table4.8: Hardness of JF/MC/UPR Hybrid Composites.

S/N	% of JF	% of MC	% of UPR	Hardness(shore A)
1	10	0	90	30.77
2	9	1	90	21.17
3	7	3	90	23.25
4	5	5	90	37.65
5	3	7	90	23.17
6	0	10	90	44.00

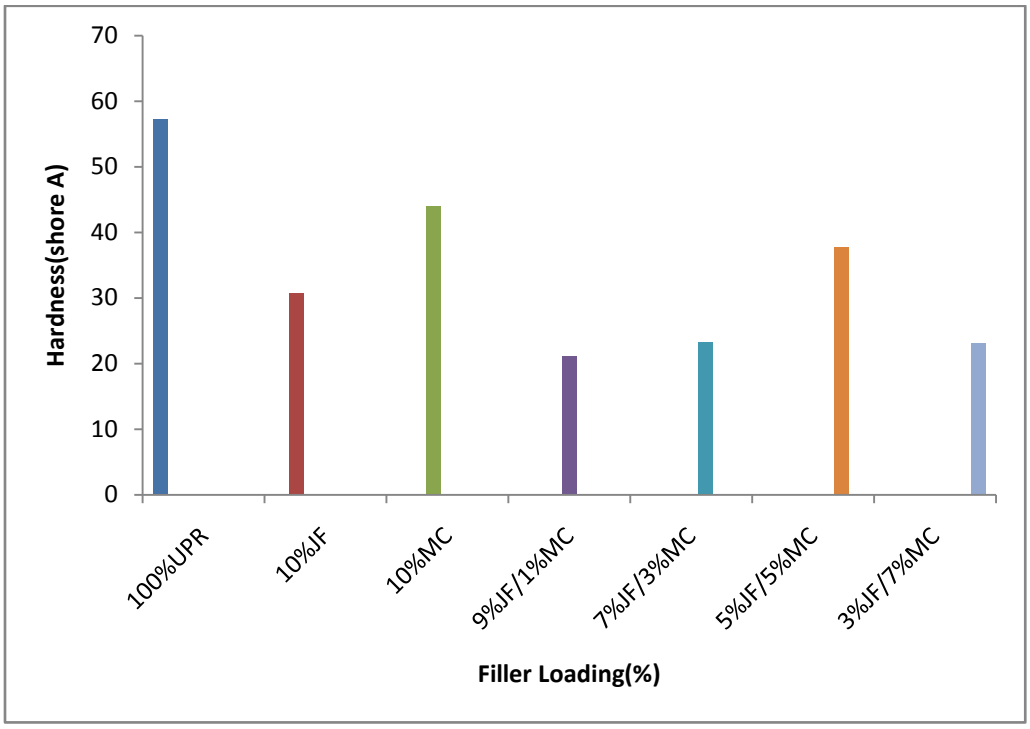


Fig4.8: HardnessVersus Filler loading of JF/MC/UPR Hybrid Composites

Hardness, is the measure of a materials resistance to surface indentation, it is also a function of the stress required to produce some specific type of surface deformation (Swamy *et al*,2011).Table 4.8 and fig 4.8 show the variation of hardness with percentage filler loading for JF/UPR, MC/UPR composites and JF/MC/UPR hybrid composites. It was observed that hardness value decreases with increase in filler loading from 35.57 to19.00 (shore) of 5% to 15% of JF filler loading this decrease in hardness could be attributed to weak interfacial bonding between JF filler and UPR matrix with increasing filler loading,thus, resulting in the decrease in composite hardness. The composites of MC/UPR show average value of hardness with increase in filler loading.The hardness decrease from 46.50 to 44.00(shore) for 5 and10% filler loading afterward the hardness decreases to 32.40(shore) at 20% MC filler loading. This filler increment reduces the ductility of the composites thereby increasing the composite stiffness. Generally, it

was observed that MC/UPR composite have slightly higher hardness values than the JF/UPR composites, this is attributed to the good dispersion of the MC filler into the UPR matrix with minimization of void and stronger surface bonding between the filler and the matrix. The hybrid composites also shows moderate improvement in the hardness from 30.77(shore) of 10% JF/UPR and 46.50 of 10% MC/UPR to 37.65(shore) of hybrid composites. There is a good reason for this phenomenon, MC being in particulate form; it contributed positively to the hardness of the hybrid composites by tailoring and improving the properties of the fibrous JF hence improving the hardness of the hybrid composites material. Similar results were reported by (Swamy *et al.*,2011).On the study of effect of particulates reinforcement on the mechanical properties of AI6061-WC and AI6061-Gr MMCS,which reported increase in hardness with increase in graphite content.

4.1.5 FLEXURAL TEST:

Table4.9: Flexural Strength of JF/ UPR and MC/UPR Composites.

S/N	% of JF or MC	% of UPR	Flexural Strength of JF/UPR composites (Mpa)	Flexural Strength of MC/UPR composites (Mpa)
1	0(control)	100	61.10	61.10
2	5	95	25.72	31.90
3	10	90	23.96	31.41
4	15	85	22.14	30.90
5	20	80	Nill	28.88

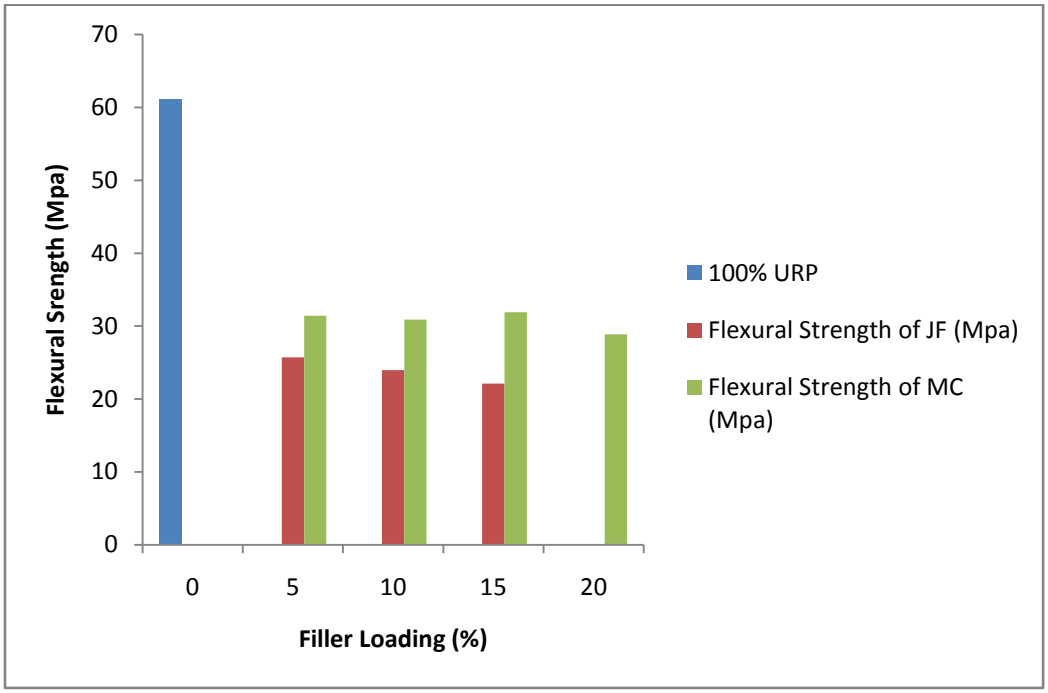


Fig4.9: Flexural Strength Versus Filler loading for JF/UPR and MC/UPR composites

Table4.10: Flexural Strength of JF/MC/UPR Hybrid Composites

S/N	% of JF	% of MC	% of UPR	Flexural Strength (MPa)
1	10	0	90	23.25
2	9	1	90	41.47
3	7	3	90	26.25
4	5	5	90	44.79
5	3	7	90	17.00
6	0	10	90	30.90

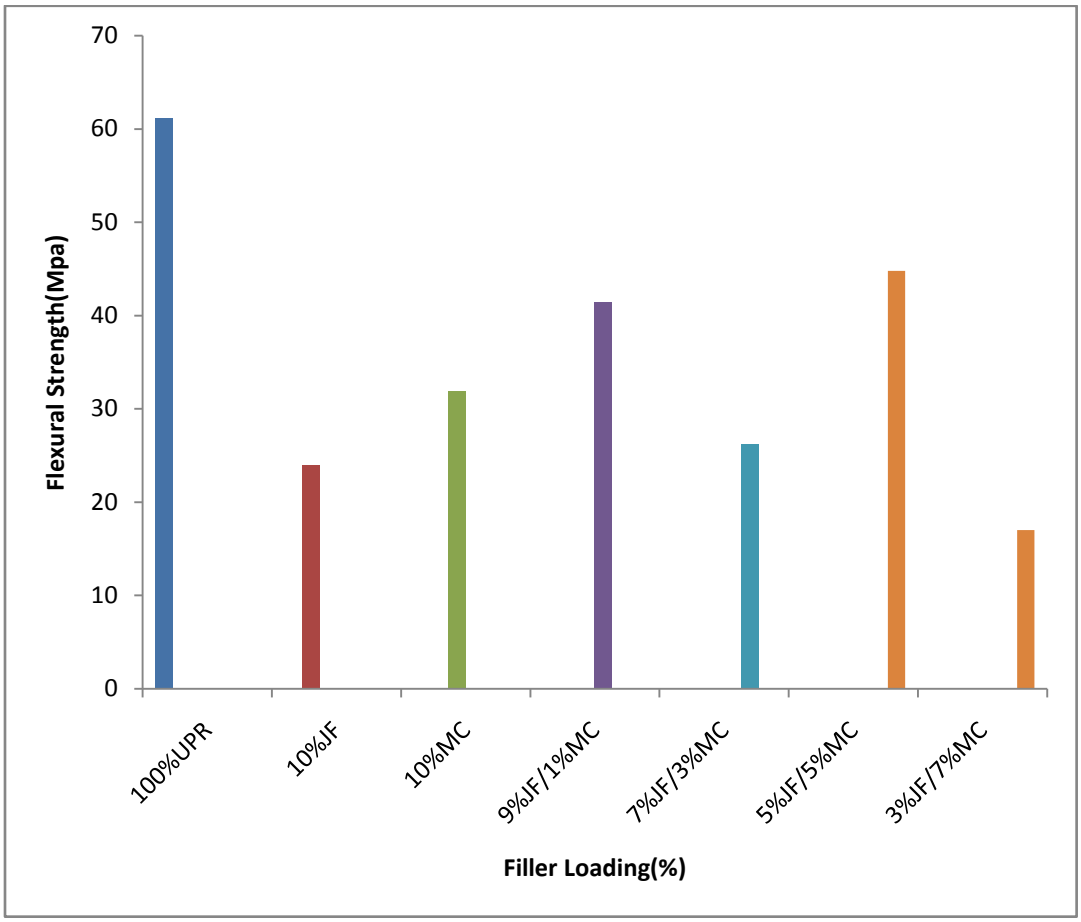


Fig4.10: Flexural strength Versus Filler loading of JF/MC/UPR Hybrid Composites

Flexural strength or bending strength is the stress in a material just before it yields. During introduction of fillers in to matrix, air may be trapped in the material. After curing micro voids may be formed in the composites along the individual fillers due to the fibre spacing in between the composite, which has adverse effect on the mechanical properties of the composites (Kabir, *et al.*, 2011).Formation of agglomerates result in creation of stress centres in the composites contributing to failure in mechanical properties of the composites (Shenoy and Melo, 2007).

From table 4.9 and fig 4.9, it was observed that the flexural strength of the composites decreases with increasing filler loading. Thus, this can be explained on the basis of agglomerate formation

at higher concentrations of the filler, which was also reflected in the tensile behavior of the composites. UPR with 0% filler have the highest bending resistance. The results also show that composites of Maize Cob/Unsaturated Polyester Resin has better flexural resistance of 31.41Mpa to 28.88Mpa compared to that of Jute Fibre/ Unsaturated Polyester Resin with flexural strength value of 25.72Mpa to 22.14Mpa. This is attributed to good interaction between the particulate Maize cob filler and the matrix which in turns improved the properties of the hybrid composites of 9%JF/1%MC/90 UPR and 5%JF/ 5%MC/90% UPR with 41.47Mpa and 44.79Mpa respectively which shows good bending resistance compared to its control sample of 10% JF(23.96Mpa) and 10% MC(31.90Mpa) percentage filler loading. This could be due to good intermolecular interaction between the matrix and the fillers. Similar results were obtained by (Mohammed, 2013) in his study on some Mechanical Properties of UPR filled with the seed shell of sunflower and water melon.

4.2 PHYSICAL TESTS:

4.2.1 Density

Table4.11: Density of JF/UPR and MC/UPR Composites.

S/N	% of JF or MC	% of UPR	Density of JF/UPR composites(g/cm^3)	Density of MC/UPR composites (g/cm^3)
1	0(control)	100	1.66	1.66
2	5	95	1.40	1.45
3	10	90	0.90	1.20
4	15	85	0.80	1.00
5	20	80	Nill	0.70

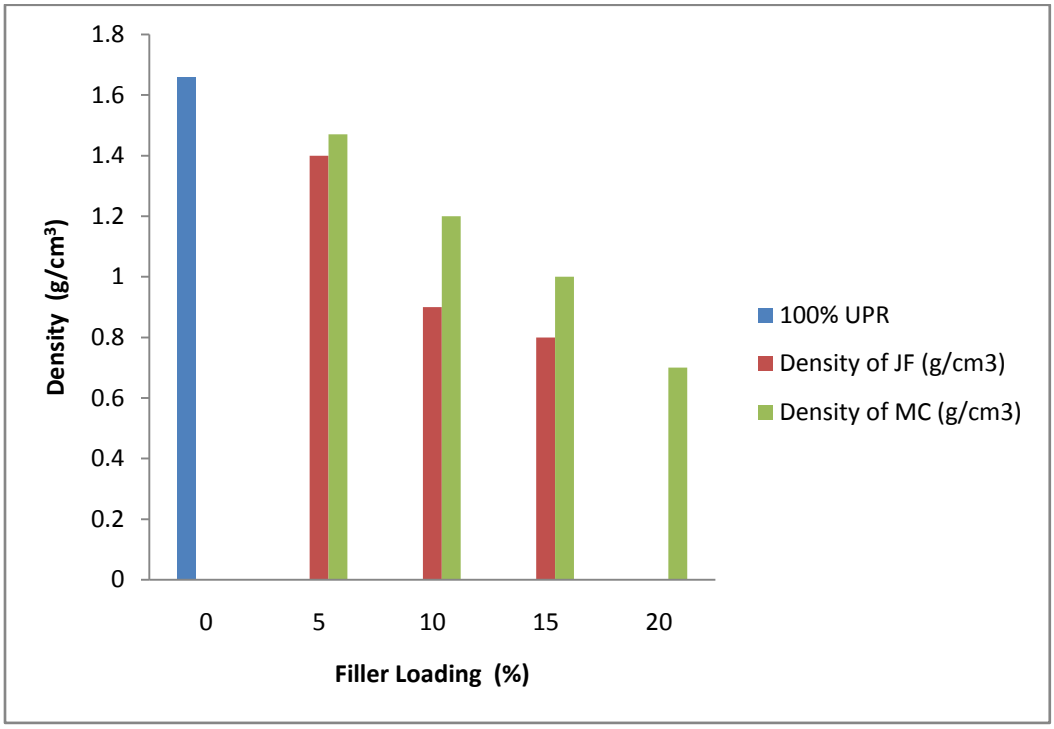


Fig4.11: Density Versus Filler loading for JF/UPR and MC/UPR composites.

Table4.12: Density of JF/MC/UPR Hybrid Composites.

S/N	% of JF	% of MC	% of UPR	DENSITY(g/cm$^{3)}$
1	10	0	90	0.90
2	9	1	90	1.29
3	7	3	90	1.00
4	5	5	90	1.13
5	3	7	90	1.25
6	0	10	90	1.20

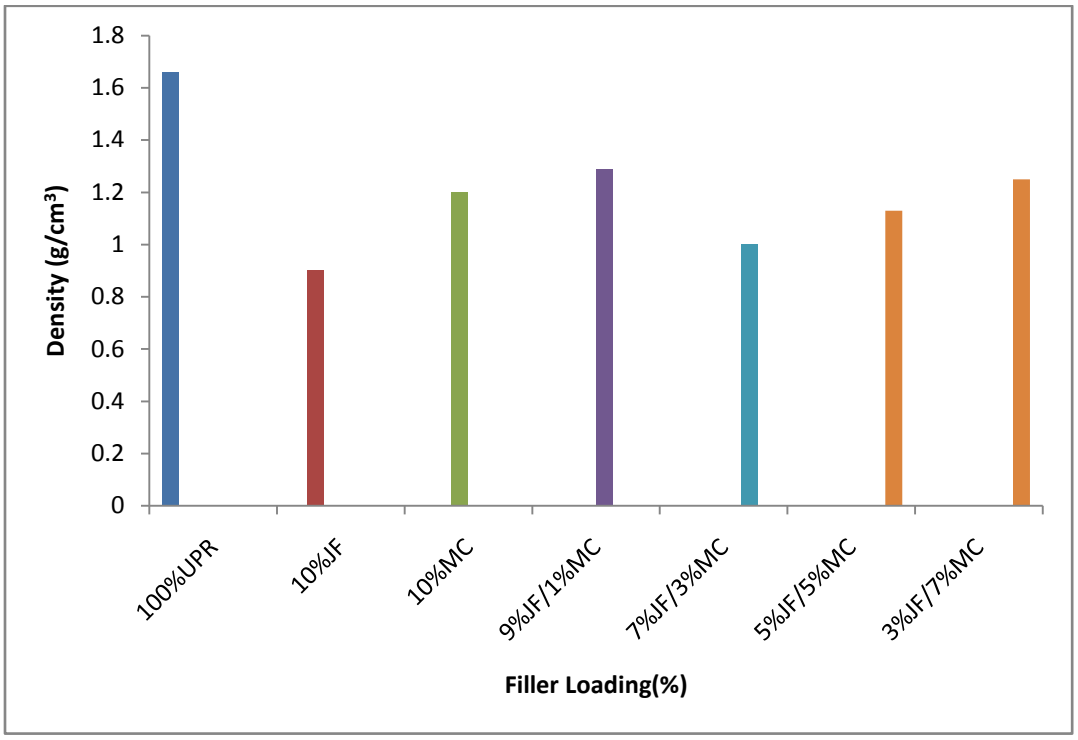


Fig4.12: DensityVersus Filler loading of JF/MC/UPR Hybrid Composites

The introduction of fillers in to matrix may cause air to be trapped in the material. After curing micro voids may be formed in the composites along the individual fillers due to the fibre spacing and between the composite, which has adverse effect on the general properties of composites hence, reduces the density of the material. However, natural fibres have the advantages of having lighter weight which explained why as the filler content increase the density of the composites decrease this is in line with the result obtained by (Danladi and Shuaib,2014). From Table 4.11 and fig 4.11 the values obtained show that there is a slight decrease in density of sample with 5% fillers content with 1.40(g/cm^3) and 1.45(g/cm^s) for JF/UPR and MC/UPR respectively from the control sample having density value of 1.66(g/cm^3), but as the fibre content increases there is a drastic decrease in the density of the composites. It should be noted that from the rule of mixture density of composites depends on dm *df +vm*vf (density of matrix by the density of the fibre

added by the volume of the matrix and that of the fibres sum up the density of the composites) (Sudipt and Ananda, 2012). However, since the weight of filler is less than that of the resin and volume is inversely proportional to density; then density will therefore decrease with increasing filler loading. The density of the hybrid composites also shows decrease with varying ratio of the fillers (JF and MC) ranging from 1.29 to 1.00(g/cm^3).These results of density implies that these composites can replace non-natural filler composites because of their light weight.

4.2.2 Water Absorption

Table4.13: Percentage(%)Water Absorption for JF/UPR and MC/UPR Composites.

No of days	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Samples	Water Absorption (%)															
100%UPR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5%JF	0	0.5	0.5	0.5	1	1	1.2	2	2	2	2	2	2.4	2.4	2.4	2.4
10%JF	0	1	1	1	1	1	1.3	2	2	2	2.4	2.6	2.8	3	3	3
15%JF	0	1.1	1.2	1.3	1.49	1.5	1.5	1.5	1.77	1.77	2.7	2.7	3.6	4.4	6.4	6.4
5%MC	0	0	0.05	0.05	0.1	0.1	0.1	0.3	0.3	0.5	0.5	0.5	1.1	1.1	1.1	1.1
10%MC	0	0.1	0.1	0.1	0.1	0.1	0.5	0.5	1.2	1.2	1.82	1.82	1.82	1.82	1.82	1.82
15%MC	0	0.5	0.5	0.5	0.6	0.6	0.6	1.04	1.04	1.04	1.15	2.28	2.28	2.28	2.28	2.28
20%MC	0	0.74	0.74	0.9	0.9	0.9	1.1	1.1	1.56	1.56	2.4	2.4	3.1	3.8	3.8	3.8

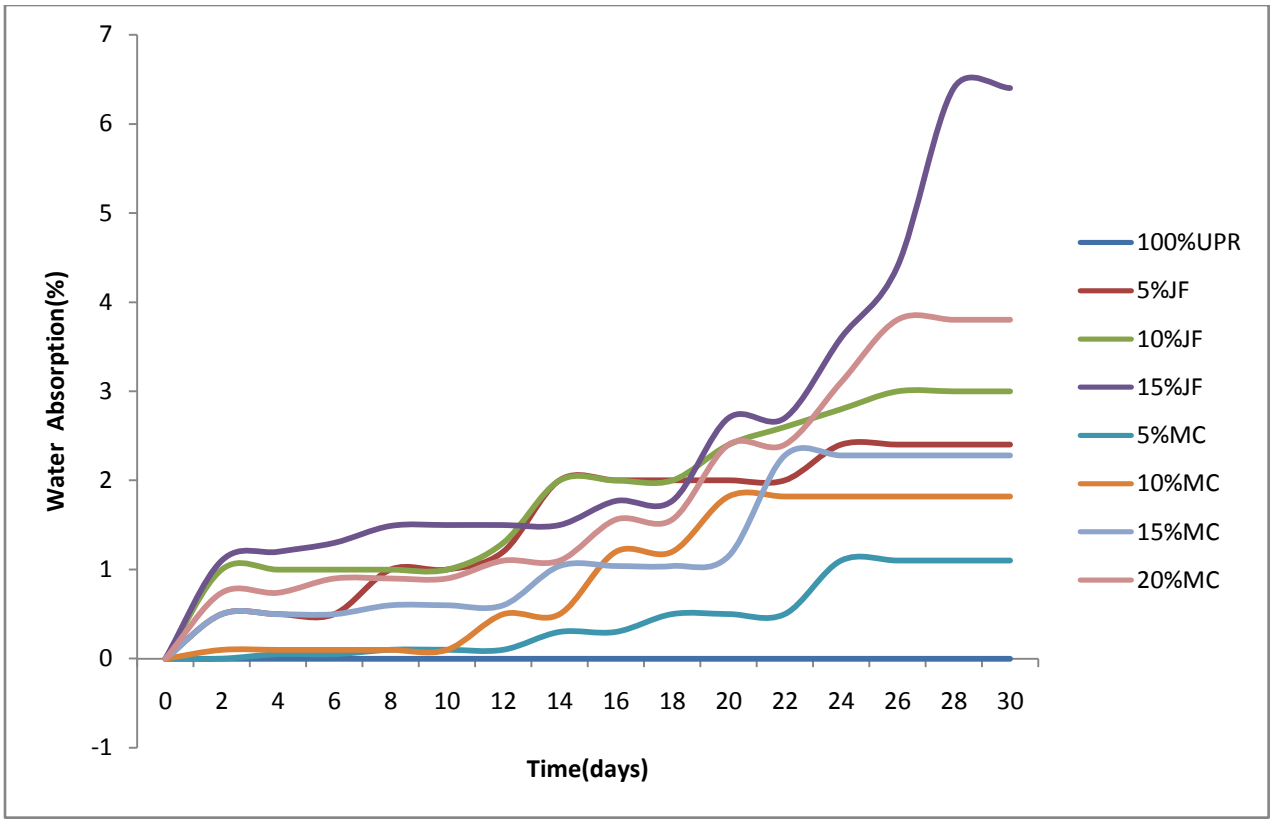


Fig4.13: Water Absorption versus number of days for JF/UPR and MC/UPR composites

Table4.14: Percentage water Absorption of JF/MC/UPR Hybrid Composites.

No of days	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Samples	Water Absorption (%)															
10%JF	0	1	1	1	1	1.3	1.3	1.6	1.6	2	2	2.4	2.6	2.8	3	3
10%MC	0	0.1	0.1	0.1	0.1	0.1	0.5	0.5	1.2	1.2	1.4	1.82	1.82	1.82	1.82	1.82
9%JF/1%MC	0	0.09	0.18	0.27	0.57	0.57	1.14	1.14	1.17	1.17	1.6	1.6	1.6	1.6	1.6	1.6
7%JF/3%MC	0	0.098	0.29	0.29	0.29	0.29	0.29	0.5	0.5	0.5	0.5	0.5	0.99	0.99	1.03	1.03
5%JF/5%MC	0	0.09	0.22	0.22	0.25	0.35	0.35	0.35	0.44	0.44	0.4	0.44	0.44	0.44	0.69	0.69
3%JF/7%MC	0	0.3	0.3	0.39	0.39	0.5	0.6	0.8	0.8	0.8	0.8	1.2	1.2	1.5	1.5	1.5

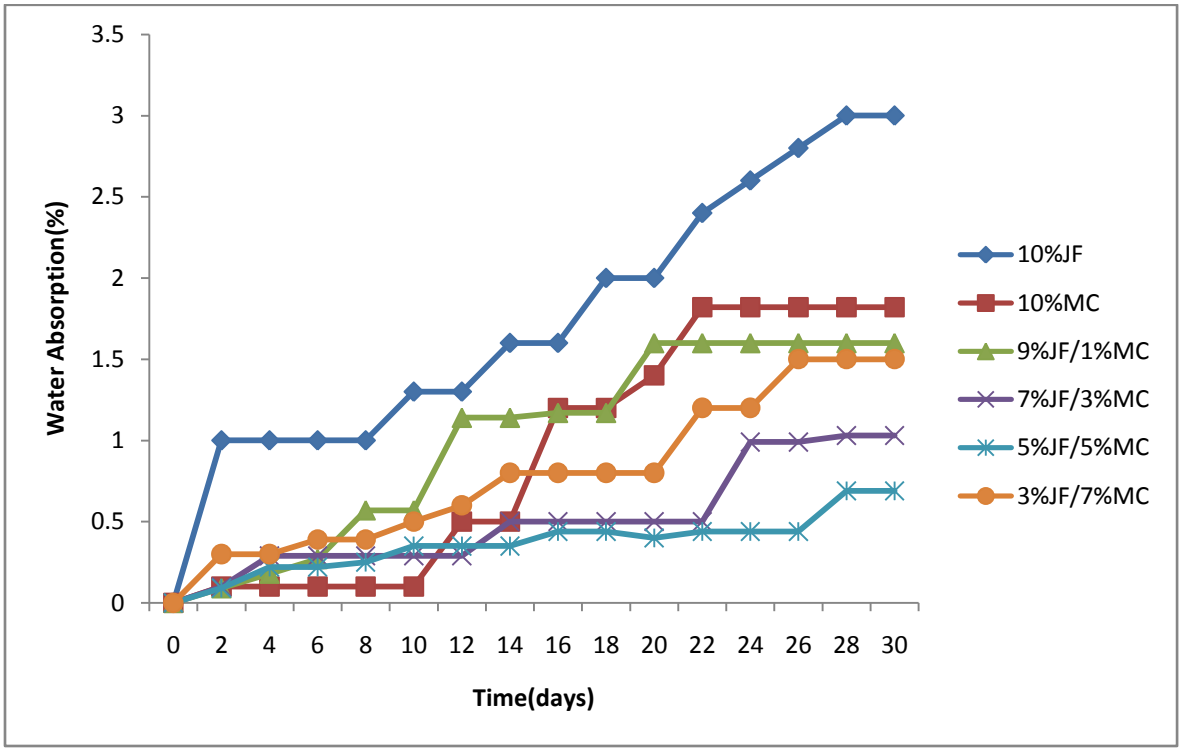


Fig4.14: Water Absorption versus number of days for JF/MC/UPR Hybrid composites

Table 4.13, and fig 4.13, show the percentage water uptake of JF/UPR and MC/UPR at different filler loading for 1 to 30 days . The general trend is that as the filler loading increases or the UPR content decreases, the sample exhibits higher water absorption. This may be due to the fact that, Jute fibres and Maize cob are hygroscopic in nature. It is a well-known fact that, natural fibres are generally hydrophilic in nature, whereas, polymer molecules are hydrophobic in character i.e they do not contain any polar group as such, the polymer does not easily bond to water molecules explaining its ability to stay dry(Kabir *et al.*,2011). However, as the UPR content decreases there is also increase in filler agglomeration resulting in a larger surface area of fillers exposed to water because the fillers are not fully surrounded by the matrix. This explained why the samples with higher filler loading absorbed more water as shown in Table 4.13 and fig 4.13. It was observed that Control sample with 0% filler content has zero percent wateruptake which is due to the hydrophobic nature of UPR polymer molecules as stated above.

However, sample with filler loading of 15%JF and20% MC showed higher water uptake with increasing number of days compared to samples with 5% filler loading. It was also observed that before the samples achieved their substantially saturated weight, illustrated by a plateau in weight increase, there seems to be loss of mass , which is particularly pronounce for specimen with higher fibre loading. As previously mentioned, the higher the fibre loading, the poorer the interfacial adhesion, possibly resulting in loose fibres.

Cellulosic fibres tend to absorbed more moisture as they are exposured longer in water thereby, gradually degrading the fibre in the composites by the action of microorganisms in the water creating voids in the structure which reduces the strength of the composites. It was further observed that the hybrid samples absorbed less water which shows that the fillers are fully embedded in the matrix and there is good interfacial adhesion between the fillers and the matrix. The high cellulose in the fillers contributed to more water penetration into the interface through micro-cracks induced up to 6.4% water uptake in 15% JF/UPR up to 3% for MC/UPR composite by swelling of fillers which also create stresses and finally leading to composites failure.

The hybrid composites absorbed highest water uptake of up 1.14%for sample with 9%JF/1%MC filler loading. Water uptake may affect the mechanical behavior of the composites. It has already been established that the water uptake affects the tensile behavior of the polymer matrix composites (Agarwal *et al.,* 2010).Because of the moderate water uptake exhibited by the composites this behavior limits their application to indoor usage.

4.3. SCANNING ELECTRON MICROSCOPY

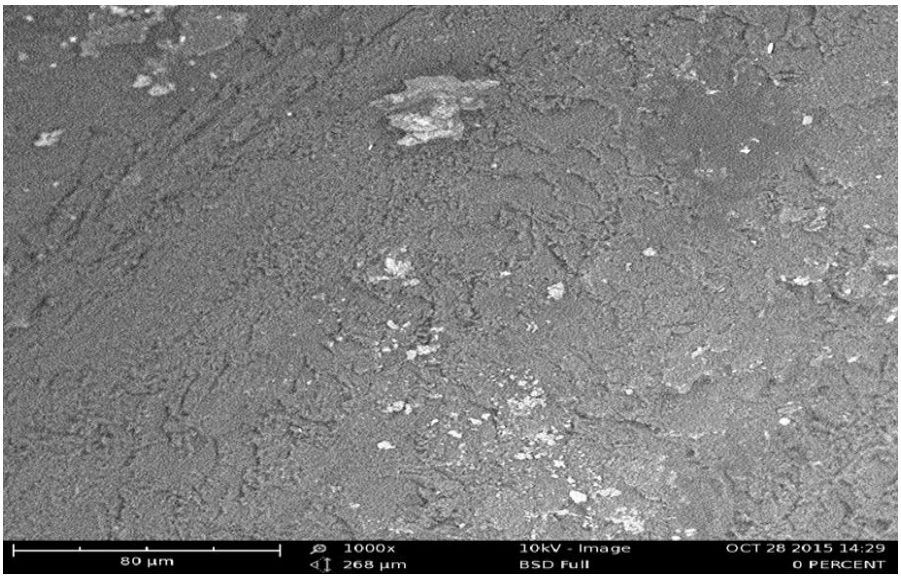


Plate 4.1: Micrograph of 100% Unsaturated Polyester Resinat 1000x:

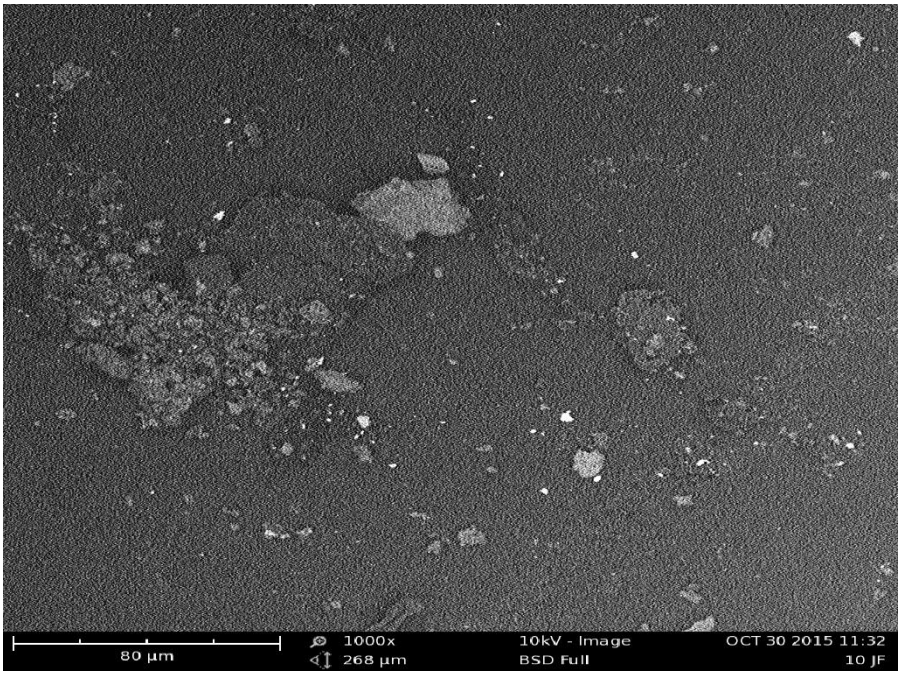


Plate 4.2: Micrograph of 10% Jute Fibre and 90% Unsaturated Polyester Resinat 1000x

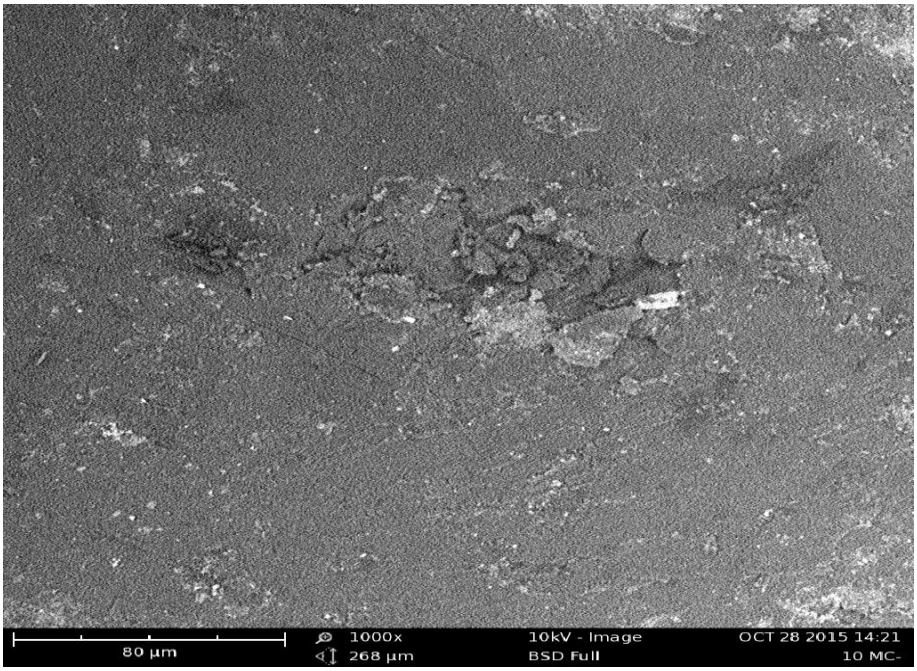


Plate 4.3: Micrograph of 10% Maize cob& 90% Unsaturated Polyester Resinat 1000x



Plate 4.4: Micrograph of 5% MC % 5% JF+ 90% Unsaturated Polyester Resinat 1000x

Plate4.1 shows micrograph of 100% UPR, plates 4.2 and 4.3 show 10:90 % (JF/UPR and MC/UPR) respectively while plate IV shows micrograph of 5JF/5MC % Morphological analysis using SEM clearly shows difference in the morphology of UPR and its composites.The micrograph of control sample UPR matrix in plate I reveal chain of lamellae and interlammeller structure with linear boundaries.

Plate 4.2 the SEM micrograph of JF/ UPR composites at 10% filler loading showed average interfacial interaction between the fillers and UPR and proper dispersion of the fillers in the matrix. However, there are few voids observed in the structure which could be due to air trap during the composites fabrication which is a peculiar demerit of hand lay-up method.Thus, as the filler loading increases there is an increase in interfacial area. This increase results in poor interfacial bonding and inefficient stress transfer between the filler and the matrix. The poor bonding resulted in decrease in the strength of the composites as shownby conventional lignocellulosic thermoplastic composite (Pracella *et al.,* 2006)This, however, confirms the results obtained in this research and other research work reported by Abdullahi(2014).

From SEM micrograph showed in plate 4.3, good MC particles dispersion and moderate filler (MC) matrix (UPR) interaction was depicted indicating moderate compatibility of MC and UPR in the composites. Also, few voids and cracks were observed along the particle matrix interface in the structure.

SEM micrograph in plate 4.4 indicates good compatibility between the two fillers and the matrix, good fillers dispersion within the structure and also, Good interfacial bonding between the fillers and the matrix was observed also few voids were seen. The good interaction between the fillers and the matrix observed in plate IV confirmed the efficient stress transfer between the fillers and

the matrix which resulted in the better stiffness and strength of the composite as observed in the results. Similar result were reported by Pracella *et al.*,(2006).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study shows the successful preparation of JF/UPR, MC/UPR and hybrid of JF/MC/UPR composites.Using hand lay-up techniques. Thus creates a better means of disposing Maize cob posing a challenge to our environment, and of course adding value to Jutefibre.The incorporation of fillers (Jute fibre and Maize cob) into Unsaturated Polyester Resinenhanced the stiffness and impact behavior of the composite systems.

Generally, the mechanical properties of the hybrid composites improved such as tensile strength with32.86Mpa at 5%JF/5%MC/90UPR, elongationat break from 18.53,19.20 up to 19.60% for 9%JF/1%MC/90UPR to 5%JF/5%MC/90UPR, impact strength with values of 0.48 and 0.35 J/m for 5%JF/5%MC/90UPR and 9%JF/1%MC/90UPR, hardness values of 37.65 shore A at 5%JF/5%MC/90UPRand flexural strength 44.79 and 41.47Mpa at 5%JF/5%MC/90UPR and 9%JF/1%MC/90UPR respectively. These results showimprovement with the addition of Maize cob to Jute fibre in hybrid composites offering better fibre-matrix interfacial adhesion and thus, increase in the mechanical properties. However, the results also show that density of the hybrid composites decreases considerably with varying percentage of filler loadings having least density of 1.00g/cm^3 at 7%JF/3%MC/90UPR.With 5% JF/ 5%MC and 90%UPR having the best properties which is comparable to that of 100% UPR which show good interaction and moderates interfacial bonding between the fillers and the matrix as seen in the SEM micrographs.The micrographs show noticeable few voids on the surfaces of the composite structures, good fibre dispersion and good interfacial interaction between the fillers and the matrix result in the moderateincrease in mechanical properties of the materials as shown in the

figures.The results obtained from water absorption behavior of the composites at different filler loadings did not differ from results obtained by other research work. Water uptake significantly influences the physical and mechanical properties of composites. The results obtained after 30days period showed increase in percentage of water absorption with increasing filler content and increase in number of days up to 6.4% for composites of 15%JF and 3% for composite of 20%MC whereas with 100% UPR shows 0% water uptake. Similar results were observed by (Melo *et al.*,2009) and (Calegari *et al*.,2007).The hybridcomposites show moderate water uptake with maximum of 1.14% for 9% MC / 1 % JF /90 % UPR composite.The Moisture absorption of the composites limits their application to indoor usage.The composites will be suitable for particle board, fibre board, office partition walls, library book shelf, grain storage containers, pharmacy shelf, hand bag rack, indoor wardrobe for light weight clothing and shoe horns.

5.2 RECOMMENDATIONS

To find better and greater method of utilizing Jute fibre and Maize cob, It is suggested that:

1. The potential of Jute fibres and Maize cob as reinforcement in other polymer matrix composites should be investigated.
2. The interaction of smaller particle sizes (i.e. nano level) of the Maize cob and continuous length in Jute fibres reinforcement with Unsaturated Polyester Resinshould be investigated.
3. Other composite moulding techniques instead of local hand mix should be used in the production of these composites.
4. Further characterization tests e.g. compressive test, FTIR etc. and microscopic examinations should be used to study the properties of the composites.

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