SYNTHESIS AND CHARACTERIZATION STUDIES OF STARCH BASED BIOPLASTICS USING BIOWASTE

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ABSTRACT

Excessive use of plastics has caused severe impacts to the environment and it doesn’t degrade easily causing various kinds of pollution. Recently bioplastics have been suggested as a potential alternative. It is biodegradable and is made wholly or partly from renewable biomass. The present study focuses on the production of bioplastic from waste materials which further reduces its making cost. Three different bioplastic samples were made from peels of tapioca, banana and potato. In the first stage starch powder is obtained by drying and grinding of leaves. It is followed by production of bioplastic and then its characterization is done to study the properties of bioplastics produced. Moisture content and Water solubility was highest for samples having high glycerol content. Water absorption was observed to decrease with filler added. BBP was fairly soluble in alcohol than the other two. All the three samples were soluble in acid and not in base. Since it is made from natural sources like starch and water, all the three samples were highly degraded and banana shows the highest degradability rate. Burning of these bioplastics doesn’t release harmful gases into the environment and was fully degraded in hot water.

LIST OF ABBREVIATIONS

TBB - Tapioca based bioplastic

PBB - Potato based bioplastic

BBP - Banana based bioplastic

PPS - Potato peel starch

TPS - Tapioca peel starch

BPS - Banana peel starch

ESP - Egg shell powder

ASTM - American society of testing material

INDEX

CHAPTER 1

INTRODUCTION

Plastic is one of supporting material that is usually used in human's daily activity. Plastic is used broadly because of light, flexible, transparent, and infrangible plastic properties. Such several plastic properties are the reason why plastic is broadly used particularly as food packaging material. Plastic consumption as package could achieve two third of total amount of plastic consumption in general. (Marsh and Bugusu,2007)

Excessive use of plastics has caused severe impacts to the environment, and it is estimated that about 34 million tons of plastics are produced per year by humans. Out of that only 7% is recycled and the remaining 93% is dumped into the landfills . oceans and seas. In 2015, more than 300 million tons of plastic was used in the world . (Mekonnen *et al*., 2013)

Instead of strengthens owned by plastic, of course plastic also has weakness on basic property of plastic material. Plastic usage as packaging material faces various environmental problems, i. e. it could not be recycled, and it could not degraded naturally by microbe in land, so that plastic waste stacking that causes contamination and degradation on environment occurs. Besides that, plastic used currently is synthetic polymer from crude oil material whose amount is limited, and it could not be renewable. Based on the fact, it is necessary the plastic material alternative that is obtained from material that is easily gained, available in nature in large amount, and cheap, but it could produce product with the same strength. (Darni and Utami, 2009)

The widespread use of petroleum-based plastics has raised environmental concerns and instigated efforts towards developing alternatives. The most commonly used plastic materials such as polyethylene, polyvinylchloride (PVC), polystyrene and polypropylene are synthesized from petrochemicals and are often referred to as traditional plastics (Nawrath *et al*., 1995)

Traditional plastics can release toxic byproducts into the environment. For example, PVC plastics are used to make food containers and contain plasticizers called phthalates that canleach out into food (Meeker et al., 2009). Phthalates, bisphenol A or polybrominateddiphenyl ethers, as well as other chemicals found in plastics, may be harmful to humans by altering endocrine function or interfering with other biological mechanisms (Heudorf *et al*.,2007).

Another major concern with traditional plastic usage is green house gas emissions; 2-3 kg CO2 emissions are estimated to be produced per kg of resin used .Traditional plastics not only use fossil fuels as feedstock but also as an energy source for their manufacture.(Yu and Chen, 2008).

Unavoidable concern is plastic disposal; traditional plastics are designed to be stable in different conditions and to persist in the environment for many years. The ubiquitous use of plastics has contributed to about 12% of the 227 metric tons of municipal waste produced annually in the United States. About 30% of plastic is recovered from the waste stream by recycling, but that still allows plastics to accumulate in the environment at a rate of more than 18.2 metric tons per year (Mooney, 2009).

Toxicity, depleting petroleum resources as well as waste accumulation has made it imperative to rethink synthetic polymers. Biopolymer-based plastics (bioplastics) can mitigate many of these problems.(Zhao *et al.*,2008)

Bioplastics are biodegradable plastics which are made from biomass. Based on the definition, biodegradable plastic is capable to break down or decomposed through actions by bacteria or other living organisms. There are two types of bioplastics, which are plastics that made from renewable raw materials such as poly-3hydroxybutyrate (PHB) and polyhydroxyvalerate (PHV) and plastics that contain additives to enhance biodegradation. (Penjumbras *et al*., 2015)

Bioplastics are made wholly or in part from renewable biomass sources such as sugarcane and corn, or from microbe such as yeast. Some bioplastics are biodegradable or even compostable, under the right conditions. Bioplastics made from renewable resources can be naturally recycled by biological processes, thus protecting the environment. Therefore, bioplastics are sustainable, largely biodegradable, and biocompatible. Bioplastics can reduce carbon dioxide emissions by 30–70% compared with conventional plastics (Fang and Fowler, 2003)

The advantage of plastic material from material available in nature could reduce or replace basic material of conventional plastic so that it is easily degraded by decomposing microorganism that is called by biodegradable plastic (bioplastic). The advantage of this bioplastic could surely reduce plastic waste that the longer, the more. This bioplastic is designed to facilitate degradation process toward microorganism enzymatic such as bacteria and fungi (Avella *et al*.,2009)

Cassava is a large abundant source of starch. Cassava peel can be used as bioplastic matrix for its high starch content. Utilization of organic waste such as cassava peel for production of starch based bioplastic can help reducing the environmental damages that are caused by conventional plastics. (Gross and Kalra, 2002)

The main components of starch granules are amylose (20% to 25%), amylopectin (70% to 85%), and other materials such as protein and fat (5% to 10%). Amylose is a straight-chain glucose polymer that binds to α-1,4, while amylopectin is a branched glucose chain consisting of short-chain α-1,4 which binds to β-1,6. Amylose is easier to form entanglement when starch is heated, compared to amylopectin . (Van Soest *et al*., 1997)

The tensile properties of the bioplastics would rise when the amylose content was increased. Therefore, the production of bioplastic using high amylose content will be beneficial. Starch modification to convert amylopectin to amylose was conducted as one way to make optimal use of starch. (Ceseracciu *et al* .,2015)

So the motivation for bioplastics is sustainability. The principle for sustainability is simply explained: Whatever man needs for survival and well-being directly and indirectly comes from our natural environment. Sustainable action is one that maintains conditions under which humans and nature coexist harmoniously and where social, economic, and environmental requirements of present and future generations are met. (Halley and Averous ,2014)

AIM AND OBJECTIVES OF THE STUDY

AIM

Production of bioplastic from vegetable waste and its characterisation

OBJECTIVE

- Extraction of starch from raw materials
- Production of bioplastic
- Characterization of bioplastic

CHAPTER-2

REVIEW OF LITERATURE

Cassava peel (*Manihot utilissima*) is waste of agricultural result that is much potential as raw material of bioplastic making. Bioplastic making from cassava peel aims to characterize the resulted bioplastic (mechanical and physical properties, SEM analysis, and FTIR analysis and time test of bioplastic degradation). The bioplastic preparation takes place by mixing starch of cassava peel and chitosan (20, 30, 40 and 50% w/w), glycerol 30% w/w as plasticizer, and liquid smoke (0, 1 and 2 mL) as antimicrobial agent. The research result shows the highest value of tensile strength is 96.04 MPa, the highest elongation at break is 52.27%, and the value of water-resistant test is 22.68%. (Myllarinen *et al*., 2002)

Microalgae are abundant in our ecosystems and can be collected, processed, and utilized to make biopolymers easily. Microalgae have no harmful effects but have a faster growth rate and the capacity to cultivate in wastewater. The polysaccharides in the algae can be used to produce biodegradable plastic (Mose *et al*., 2011)

Bioplastic was formulated by using agriculture waste from cassava peel. Three different concentration of glycerol were set up at 20%, 30% and 40% with constant amount of $CaCO_3$ (filler) were used for the optimization. The characterization of the bioplastic was carried out using FTIR analysis. Each sample shows similarities in spectra, indicating similar chemical composition of functional group present. (Maulida *et al*., 2016)

The influence of microcrystalline cellulose derived from sugar palm fibers and glycerol on the mechanical properties of bioplastics from avocado seed starch was studied. Sugar palm fibers underwent alkali treatment, bleaching, and hydrolysis with HCl to produce microcrystalline cellulose. Bioplastic was successfully fabricated through solution casting technique. (Mahawan *et al*.,2015)

A study on the influence of zinc oxide Nano filler on the mechanical properties of bioplastic cassava starch films were studied. Bioplastic cassava starch film-based zinc oxide reinforced composite bio polymeric films were prepared by casting technique. The content of zinc oxide in the bioplastic films was varied. The result showed that the Tensile strength (TS)

was improved significantly with the additional of zinc oxide but the elongation at break (EB %) of the composites was decreased. (Ulloa *et al*., 2012)

A study was conducted to produce and characterize bioplastics prepared from myofibrillar proteins found in gilded catfish (*Brachyplatystoma rousseauxii*) waste, through response surface methodology. The design process evaluated five variables; the concentrations of protein and plasticizer were significant, and thus subsequently subjected to rotatable central composite design to define the best mechanical, physical and barrier properties. The results of the design process were that bioplastic was prepared with 0.79% protein and 40% plasticizer indicating the biopolymers extracted from fish can be used to produce bioplastics. (Szymanowski *et al*.,2005)

The characteristics and biodegradation performance of several starch-based biodegradable plastics added with fibers and nanoparticles are studied and natural fibers added claimed to increase the strength of bioplastics and accelerate the degradation process in the soil. (Gómez-Heincke et al.,2017).

A study was conducted on hydric and biodegradability properties of cassava starch-based bioplastics reinforced with crude kaolin or treated kaolinitic clay at 700 °C called metakaolin using water adsorption and microbiological tests. The biodegradability of the clay reinforced bioplastics was significantly improved due to the bacterial proliferation. The thermal treatment of kaolinitic clay further improved the hydric and biodegradability properties of starch-based bioplastics. (Willett *et al*.,1994).

Starch bioplastics were tested for their biodegradability and mechanical properties like hardness and impact strength. It also attempts to characterize bioplastics through techniques like thermo gravimetric analysis and Fourier transform infrared spectroscopy analysis. (Ashok *et al* ., 2018)

Bioplastics composite material made of Polylactic Acid (PLA) incorporated with tapioca starch (TS) to investigate the effect of Tapioca Starch as the filler towards the mechanical properties of this bioplastic. This study was conducted to develop material for food packaging usage limitation of usage and application below the 160^{o} of temperature application. The addition of Tapioca Starch in this composite system gives better results in tensile modulus and decreased in the value of crashed impact. (Albertsson and Karlsson,1995)

A study was conducted to use of agricultural waste for the production of bioplastic. The project seek to reduce the environmental pollution by the use waste of cassava, to produce bioplastic to replace the existing products cuurently that are not environment friendly. It was confirmed that treatment of Cassava peel starch with acetic acid and plasticizers formed plastic resin (PFA). Tensile strength, Strain, Energy and Extension ranged from 1.30-2.87MPa, 0.086-0.093, 0.1-0.278J and 5.83-7.06mm respectively. The result of the biodegradability test indicates degradability rate ranged from approximately 14% (day 3) to 86% (day 12) (Machovic and Janecek, 2006)

A study centers on green-production of a variety of bioplastic samples from (1) banana peel starch (BPP) and (2) a composite of banana peel starch, cornstarch and rice starch (COM) with varying amounts of potato peel powder and wood dust powder as fillers, respectively. Two different plasticizers – Glycerol and Sorbitol – have been utilized separately and in a 1:1 combination. A total of 12 samples of each of two types of bioplastics were made using multiple amounts and combinations of the fillers and plasticizers, to test the differences in the physical and chemical characteristics (moisture content, absorption of water, solubility in water, solubility in alcohol, biodegradation in soil, tensile strength, Young's modulus and FT-IR) of the produced samples due to their different compositions. The differences in the properties of the bioplastic samples produced make them suitable for usage in many different applications. All 24 of the samples produced were synthesized using natural and environmentally safe raw material and showed biodegradation, thus proving to be a good alternative to the conventional plastics. (Shulga *et al*., 2007)

Proteins secreted by Ophiostoma ulmi, were investigated for their application in bioplastic product. Proteins were isolated from fungal cultures by anion exchange chromatography and used to treat starch. Subsequently, plastic films were generated by solution casting, with glycerol as plasticizer. Tensile strength of the films was found to increase significantly compared to the control. Proteins secreted by O. ulmi were therefore implicated in improving properties of starch-based plastics. (Bernier *et al*., 2004).

A study was done to analyse the effect of glycerol on microbial degradation. This experimental research investigated the use of cassava flour mixed with glycerol plasticizer at various concentrations (0, 2, 2.5, 3%) in the synthesis of bioplastics. The aspects studied were biodegradability, moisture absorption (using ASTM D 570), shelf life, and morphological properties (using a camera equipped with a macro lens) and SEM. This study revealed that complete degradation could be achieved on the 9th day. The addition of a large concentration of glycerol would accelerate the microbial degradation process, increase moisture, and extend the shelf life of bioplastics in a dry place . (Suryanto *et al*., 2016)

An investigation was done into the effects of fructose and glycerol as plasticizers in cassava bioplastic production.. The objectives of the research were to produce cassava-based bioplastics to investigate the use of fructose and glycerol as plasticizers in the production of the cassava-based bioplastics and to conduct physical and chemical quality tests on the bioplastics to determine which plasticizer is best for industrial use. A Randomized Complete Block Design (RCBD) was used in the experiments. The parameters measured were film thickness, density, moisture content, solubility in water, water absorption, swelling index, and biodegradability test. Overall, fructose as a plasticizer is recommended over glycerol and over fructose and glycerol. (H. Obueh and Odesiri-Eruteyan,2016).

Plasticized hydroxypropyl cassava thermoplastic starch (TPS) with glycerol was blended with polybutylene adipate terephthalate (PBAT) via blown-film extrusion. Effects of PBAT/TPS ratios (60/40 and 50/50) and degrees of substitution (DS) for hydroxypropyl groups in TPS on film properties were investigated. All PBAT/TPS blend films were determined for morphology, thermal stability, thermomechanical, mechanical and barrier properties. Higher DS increased film clarity and glossy surface, improved compatibility between PBAT and TPS, reduced crystallinity and enhanced exposure of hydroxyl groups and hydrogen-bonding of the films. Blending caused phase separation with dispersed starch granules in continuous PBAT matrices, giving high surface roughness. Increased TPS and DS facilitated formation of co-continuous structures and miscibility, improving elongation by approximately 210%. Different DS modified microstructure and hydrophilicity of PBAT/TPS films which consequently reduced water vapor permeability by 34%. Modified DS in hydroxypropyl starch efficiently improved clarity, mechanical and barrier properties of bioplastic packaging. (Ebnesajjad,2012).

The objective of the present work was to evaluate the impact of the cassava starch (CS) substitution by gelatinized starch (GS), a residue generated in the sieving step of starch processing, verifying possible changes in the final material characteristics. The raw materials characterization includes determination of amylose and moisture contents, centesimal composition, particle size distribution, and thermal analysis. After casting solution and drying processes, the samples were evaluated regarding the visual macroscopic and microscopic aspects showing continuous and homogeneous structure. The results were related to the physicochemical and mechanical properties. The GS addition promoted a decrease in the tensile strength (3.3 ± 0.1 MPa to 1.2 ± 0.3 MPa) and elastic modulus (52 ± 13 MPa to 10 ± 3 MPa) values, while the elongation percentage (160 ± 30% to 212 ± 14%) values seem to have not been so affected. It can be seen a high potential for the use of agro-industrial residues containing starch in bioplastic production. (Chaplin.,2005).

Food waste is being generated from all stages of the food supply chain including post-production, handling/storage, manufacturing, wholesale/retail, and consumption stages (Ravindran and Jaiswal,2016)

The Food and Agriculture Organization (FAO) of the United Nations reported that around 1.3 billion tons of food is lost or wasted every year globally. It is found that this amount corresponds to one-third of all food resources produced for human consumption. Note that sources of food waste include household, commercial, industrial, and agricultural residues, while the compositional matrix of food wastes varies broadly based on source and type. (Gouhua *et al*., 2006)

In Malaysia, it is estimated that 6.7 million tons of FW are generated annually in 2020. Approximately 567 to 726 million tons of FW (equivalent to up to 40 wt% of the total food production) are generated annually in the USA (US EPA. This quantity of FW is equivalent to USD 218 billion. (Gunders and Bloom, 2012)

If such waste was properly converted into value-added products, huge economic and energy losses can be saved. In France, the government has already implemented a policy for stimulating valorization of FW through recovery of energy (e.g., biogas) and value-added materials (e.g., bioplastic) with a punitive law amid a FW epidemic (El Kadi, 2010)

The average energy requirement of bioplastics production is obviously less than traditional petro polymer (57 MJ kg−1 compared to 77 MJ kg−1) to be beneficial toward global warming problem (Gironi et al., 2011). Therefore, due to similar functions of bioplastic and conventional polymer, bioplastic is an ideal alternative in the context of environmental sustainability. The European Union generates 90 million tons of FW annually. Among them, 38 wt% is originated from the food manufacturing sectors .Thus, the conversion of FW into value-added chemicals can be the desired end use of food waste for increasing global sustainability. (Pfaltzgraff *et al*.,2013).

The main constituent of bread waste is a starch-based material, Bioplastics derived from a succinic acid monomer are a viable option for producing bioplastics from bread waste (on the basis of the general alternation yield of 0.55 g succinic acid g−1 bread). The properties and structure of starch can be altered through hydrothermal treatment without thermal degradation of the original morphology (Hoover, 2010)

Cassava peel waste is one of the raw materials used in making environmentally friendly bioplastic as it is available in large amounts and does not compete with humans and animals for food as explained by (Teodoro *et al*., 2005)

Bioplastics are unstable and do not have the same tensile strength as synthetic plastic hence the adoption of the technology has been slow, however, plasticizers give the cassava bioplastic the tensile strength that is lacking (Li and Huneault, 2011)

Cassava (Manihot esculenta), or manioc, mandioca, and yuca, is a woody perennial in the family (Euphorbiaceae) is a staple crop in the tropics important for food security as state. According to Waisundara, the plant can be grown throughout the year and is known0 to exist under severe climates and soils that are not fertile (Combrzyński *et al* .,2012)

Bioplastics are a promising alternative as they decompose by biotic factors and also constitute a source of organic compounds for microorganism though their biodegradability in different environments is highly affected by their chemical and physical structure as described in many reports(Median *et al* .,2017)

The cassava starch-based bioplastics that were produced were similar, in terms of flexibility and elasticity, to the potato starch-based bioplastics done by (Samyang *et al* .,2016)

The properties of cassava starch-based bioplastics are similar to those of bioplastics whose starch content has been derived from other sources. The results also show that the effect of fructose, glycerol and fructose and glycerol blend as plasticizers have similar properties on cassava starch-based bioplastics to bioplastics with different starch sources.(Rahmatiah Al Faruqy *et al*., 2016)

The production of starch based bioplastics from cassava peel reeinforced with microcrystalline cellulose using sorbitol as plasticizer was investigated. Physical properties of bioplastics were determined by density, water uptake, tensile strength and Fourier Transform Infrared Spectroscopy. (Barker *et al*.,2007)

Starch as biodegradable polymer becomes reasonable material for the production of bioplastics beacause of its low cost . Therefore, production of bioplastics is the breakthrough innovation to solve the environmental issues by using renewable and degradable natural resources and to provide more cost effective bioplastics. (Rosida *et al*., 2018)

Raw materials for bioplastics originate from natural constituents such as polysaccharides (e.g. starch, cellulose, chitin and lignin), proteins (e.g. gelatine, casein and wheat gluten) and lipids (e.g. plant oils and animals fats) (Song *et al*., 2009)

In Indonesia, development of starch based bioplastics has a big potential, because starch can be easily obtained by majority of Indonesia's plant. Cassava processing results in organic waste such as cassava peel that can be used as bioplastic matrix for its high starch content. However, bioplastic based on starch still has many disadvantages like poor mechanical properties and high moisture adsorption, therefore an alternative is used to improve its properties. (Wittaya, 2009)

Utilization of organic waste such as cassava peel for production of starch based bioplastic can help reducing the environmental damages that are caused by conventional plastics. Higher value bioplastics can be obtained by improving their properties with the most abundant and biodegradable reinforcing filler like cellulose. (Reddy *et al*.,2013)

Microcrystalline cellulose used as reinforcement filler for starch based edible films was analyzed . The results showed higher strength and elongation and lower water vapour transmission rate (WVTR) of bioplastics. Microcrystalline cellulose Avicel PH 101 is used as reinforcing filler because it offers higher density of hydroxyl groups on its surface that is available for hydrogen bonding . (Sarasa *et al*., 2009)

Non-reinforced bioplastics (BP) and those containing 5 wt.% crude kaolin (BPKB) or metakaolin (BPMKB) were manufactured using the casting/evaporation method. Results obtained showed a decrease in the solubility and in the water diffusion and permeability of clay-reinforced bioplastics with respect to the ones without reinforcement. (Karana, 2012)

Lignocellulosic fibers and lignin have showed great success in making the bioplastics. There are strong inter-molecular interactions in lignocellulosic fibers and lignin which render recalcitrance for interaction with other biopolymers. Most of lignocellulosic fibers and lignin have low added-value . If they are used as fillers or alternatives for biopolymers, the microparticles have a more promising future in bioplastics. (Duval and Lawoko,2014)

A case study of cassava starch-based material, and a comparative analysis between petroleum-based and cassava starch-based packaging was done. The results clearly indicate that compostable packaging of cassava starch has far better societal and environmental outcomes than petroleum-based packaging. The transition from the linear (take-make-use-dispose) to the circular (grow-make-use-restore) pattern creates new opportunities for innovation beyond technology, as it inevitably redefines the significance of waste, products, services, markets, natural capital, and growth. (Rosa *et al*., 2009)

A study was conducted to explore bioplastics produced from cassava peels as food industry waste and seaweed carrageenan (Eucheuma cottonii).The cassava peel waste and carrageenan have the potential to be made into bioplastics because they contain one type of polysaccharide that can make films based on the principle of gelatinization. The development of bioplastics from cassava peel waste and seaweed carrageenan potentially being able to solve two problems indirectly, such as reducing plastic waste which has many negative impacts as well as being able to utilize cassava peel waste from the industry and maximize the potential of seaweed which is abundant in Indonesia, to promoting the environmental sustainability. (Ching *et al*., 2016)

Bioplastics are made by heating a solution of modified cassava starch at 75 °C for 1 hour. After starch solution was gelatinized, glycerol (5% based on starch weight) was added, and then PVA solution (25, 50, 100% based on starch weight) was inserted gradually. While stirring was continued, citric acid (5% based on starch weight) was added into the solution. The bioplastic solution was then poured into a 20 × 20 cm acrylic sheet and cooled at room temperature for 3 days, so that the bioplastic sheet was ready for mechanical strength test. The results suggested that the addition of 25% polyvinyl alcohol (PVA) into bioplastic made from modified cassava starch produced bioplastic with higher tensile strength compare to that without PVA addition. On the other hand, the addition of 100% PVA could slightly increase bioplastic elongation. The decomposition temperature of bioplastic made from modified cassava starch with 50% PVA was higher than that of the bioplastic without PVA addition, indicated that bioplastic with 50% PVA was more thermally stable.(Choo *et al*., 2016)

A study was conducted on sonication treatment on the morphology and mechanical properties of bioplastic filler nanoclay with different nanoclay concentration. The bioplastic was prepared using blending method among bioplastic, glycerol, and nanoclay with assistance of sonication treatment of 30 mins. Structural characterization of bioplastic was examined using scanning electron microscopy (SEM), mechanical properties using durumeter Shore A, tensile strength and the physical properties using density. SEM evidence on a bioplastic basis. Hardness of bioplastic with addition of nanoclay 5.0% (b/b) and sonication treatment produce bioplastic with maximum hardness properties increased to 76.24 Shore A, tensile strength of 13.5 and Young’s modulus of 47, as well as the added density of 1.238 g/cm^3. Nanoclay 7.5% (b/b) upwards will experience decreased hardness and experience agglomerate and debonding.(Yoshida *et al*.,1987)

A research was conducted to find out the thermal decomposition and the activation energy of cassava starch based bioplastic. The methods were synthesis bioplastic with cassava starch as main component and glycerol as plasticizer. The thermogravimetry analysis was conducted to obtain the decomposition process mechanism of bioplastic and the heating value of bioplastic was measured using the adiabatic bomb calorimetric. Data analysis was conducted using a fitting model approach with an acikalin method to determine the activation energy. The result of the thermogravimetricanalysis showed that bioplastic is gradually decomposed to the moisture, volatilematter, fixed carbon, and ash in four stages mechanism. Totally decomposition of bioplastic was 530°C, then all of bioplastic was become the ash. The activation energy in the early and primary thermal decomposition stages are 1.27 kJ/mol and 22.62 kJ/mol, respectively and heating valueof bioplastic is 15.16 MJ/kg. (Reddy *et al*., 2013)

The study was conducted on jackfruit seed starch plasticized with glycerol were developed and characterized. The starch and glycerol concentrations ranged from 2 to 6% w/w and 20 to 60 g/100 g starch, respectively. Bioplastics were obtained by the casting method and characterized in terms of color, mechanical properties, solubility, water vapor permeability (*WVP*), morphology and free energy of the hydrophobic interaction. The results replaced that jackfruit starch can be used to develop films, with low opacity, moderate *WVP* and relatively high mechanical stability, by using glycerol in the gelatinized starch dispersions. (Mukprasirt and Sajjaanantakul,2004)

The effect of modification in the bioplastics developed from native and hydrothermal modified green plantain banana (*Musa paradisiaca* L.) starch by heat moisture treatment (HMT) was studied. The physical modification by HMT led to changes in the mechanical properties and water vapor permeability of the bioplastics. Less values of pasting viscosities and retrogradation promoted increase in mechanical properties. Mechanical properties of bioplastic obtained using modified starch under the conditions of 25% moisture, 100 ºC and 23.92 h (PM04) were improved with respect to native starch bioplastic, reaching an elastic modulus of 12.38 MPa, a tensile strength of 27.09 MPa, an elongation of 6.0%, a puncture resistance of 251.8 N and deformation of 2.8 mm. However, water vapor permeability decreased to 7.1×10^{-14} g.cm/(cm^2·s.Pa) and the solubility has not changed significantly. (Basiak *et al*., 2017)

Cassava starch is widely used as the main ingredient in the making of bioplastics. This study aims to obtain the optimal value of adding calcium carbonate as a reinforcer to bioplastics made using cassava starch with glycerol plasticizer. Bioplastics were made by blending and cast printing methods. The stage of making bioplastics begins with the extraction of cassava into cassava starch as a base for making bioplastics. Then, calcium carbonate was added. Addition of calcium carbonate was done with variations (0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0%). Characteristics of mechanical properties were studied namely tensile and elongation tests. The tensile test show that the best tensile strength was obtained at 0.4% calcium carbonate (22.88 ± 1.46 MPa). While the addition of 0.5 to 1.0% decreased the tensile strength. The best elongation value was obtained by the addition of 0.8% calcium carbonate (27.57 ± 0.14 %) (Reddy *et al*.,2013)

The production of bioplastic from jackfruit seed starch reinforced with microcrystalline cellulose (MCC) cocoa pod husk using glycerol as plasticizer was investigated to determine the most optimum mass and volume of MCC and glycerol in producing bioplastics. The degree of crystallinity of MCC, were determined by XRD, functional group by FT-IR and morphological analysis by SEM. Analysis of bioplastic mechanical properties includes tensile strength and elongation at break based on ASTM D882 standard. Bioplastics were produced by casting method from jackfruit seed starch and reinforced with MCC from cocoa pod husk at starch mass to MCC ratio of 6:4, 7:3, 8:2, and 9:1, using glycerol as plasticizer at 20%, 25%, 30% (wt/v of glycerol to starch). From the result, the isolated MCC from cocoa pod husk were in a form of rod-like shape of length 5-10 µm with diameter 11.635 nm and 74% crystallinity. The highest tensile strength of bioplastics was obtained at starch to MCC mass ratio of 8:2, addition of 20% glycerol with measured tensile strength of 0.637 MPa and elongation at break of 7.04%. (Kaewphan and Gheewala, 2013)

A research is to conduct starch extraction from cassava peels and glycerol extraction from waste cooking oil. It has been achieve during the extraction of 100g cassava peel will yield 3% of starch, while 800ml waste cooking oil yield of 5% only. The best formulation of the bioplastic obtained by controlling the ratio of carrageenan and starch at 2% and 5%. Based on the observation of degradation test,when the temperature was at 100ºc the bioplastic degrade within 1.18 minutes and at 20ºc was within 7.33 minutes. For the steam test, only at 100ºc the bioplastic start to degrade within 25minutes but for other temperature the plastic remains same.

As a conclusion cassava starch can be utilized as bioplastic film, because it can dissolve when contact with water and steam. Moreover, glycerine from waste cooking oil can be used as plasticizer.(Thompson *et al*., 2009)

A study was aimed at producing biodegradable plastic film using starch extracted from Manihot esculenta. Different mass of starch was used to produce bioplastic film using methanoic acid, ethanoic acid and propanoic acid in the presence of water and glycerol as plasticizers. The result of the study showed that the starch yield of 52.26%, moisture content of 19.74%, pH of 6.7 and amylose content of 20.67%. The result also revealed that the masses of the bioplastic films produced increased with increase in mass of starch and increased with carbon content of the organic acids. The tensile strength of the bioplastic films were found to be significantly higher ($p < 0.05$) when compared to the nylon. But the shear/tear resistance and percentage elongation of the nylon was found to be higher ($p < 0.05$) when compared to the bioplastic films produced. It was also revealed that the bioplastic film could be degraded by Pseudomonas aeruginosa and that the propanoic acid derived bioplastic could degrade faster than the others. (Dufresne and Vignon, (1998).

Bioplastics were synthesized from wastes of parsley and spinach stems, rice hulls, and cocoa pod husks by digesting in trifluoroacetic acid (TFA), casting, and evaporation. In this way, amorphous cellulose-based plastics are formed. Moreover, many other natural elements present in these plants are carried over into the bioplastics rendering them with many exceptional thermo-physical properties. (Cai *et al* .,2020)

CHAPTER 3

MATERIALS AND METHODS

4.1. MATERIALS

Vegetable waste such as tapioca peels, potato peels, banana peels were collected from Traditional markets. Eggshell waste materials were obtained from chicken farm and roadside foodshops.

4.1.1 STARCH EXTRACTION

4.1.1.1 Starch extraction from Tapioca peel

Tapioca peel was obtained from traditional market. The tubers were properly peeled and washed. The peels were further separated from inner pulp (parenchyma) and outer layer (cortex) with a clean knife. The tapioca peels were washed again with clean water and then it is shredded into small pieces. The shredded pieces were dried in oven at 80°C until it is completely dried. Once dried, they are grinded into fine powder (starch) using a blender. Starch extraction from tapioca peels were shown in plate (no.1)

4.1.1.2 Starch extraction from Potato peel

Potato peels were obtained from market. The potato was washed thoroughly and using a clean knife the peels or skin of the potato were removed. The collected peels were again subjected to thorough washing and it was then subjected to drying. The peels were dried in oven at 80°C until its completely dried, Once dried they are blended into fine powder to obtain the starch. Starch extraction from potato peel were shown in the plate (no.2)

4.1.1.3 Starch extraction from Banana peel

Banana peels obtained were washed thoroughly. The excess water is drained and cut into small pieces. The small cut pieces were dried in oven at 70°C and once its completely dried, they are grinded to fine powder (starch). Starch extraction from banana peel were shown in plate (no.3)

4.1.2 Preparation of Eggshell Powder

Waste eggshells were obtained from chicken farm and shops. They were washed in water to remove impurities from raw materials and then dried in an oven at 50°C for 5 hours. The dried eggshells were crushed and grinded into fine powder. Finally, the eggshell powder dried in an oven at 50°C until constant weight was achieved. The final samples were placed in a sealed bag and stored. Plate (no.4) shows egg shell powder preparation.

4.2 PRODUCTION OF BIOPLASTIC

4.2.1 Bioplastic from tapioca peel starch (TPS)

Acetic acid, glycerol and distilled water were the main ingredients. A total of 5 samples of tapioca peel starch (TPS1- TPS5) were produced varying the amount of the main ingredients glycerol (plasticizer)and vinegar to produce a variety of different samples which is given in the plate (no.5). The composition of which is given in the table 1.

In order to synthesize the bioplastic samples, following steps were used.

1. 10gm of tapioca starch was weighed and transferred to a beaker.
2. 5ml of glycerol (plasticizer) as well as the required amount of vinegar were added to the same beaker and stirred thoroughly.
3. The mixture was heated at 70°C for 10-15 minutes while continuously being stirred until it is gelatinized.
4. Then the gelatinized mixture was spread evenly into a plate and it was oven dried at 70°C for 24 hours.
5. Once set, the bioplastic was cooled to ambient temperature before peeled off.

Sample No.	Starch(g)	Vinegar(ml)	Glycerol(ml)
1	10	5	5
2	10	6	4
3	10	4	6
4	10	8	2
5	10	2	8

Table 1: Composition of different Tapioca based bioplastic samples

4.2.2 Bioplastic from potato peel starch (PPS)

A total of 5 samples of potato peel starch (PPB) were produced varying the amount of the main ingredients such as plasticizer content (glycerin, vinegar and their 1;1 combination) and eggshell powder (ESP) filler content to produce a variety of different samples, the composition of which is given in the table 2.

Steps used for the synthesize of bioplastic samples are following

1. 10g of potato starch peel, 5ml of vinegar, 5ml of glycerol (plasticizer) and 60ml of water was taken in a beaker,
2. To this mixture add required amount of eggshell powder and stir thoroughly.
3. The mixture was then heated at 70°C for 10-15 minutes while continuously being stirred until it is gelatinized.

4. Then the gelatinized mixture was spread into the plate which was rubbed with oil and oven dried at 70°C for 24 hours.
5. Once properly dried, the bioplastics were cooled down properly before removing it from the foil.

Sample No.	Starch(g)	Vinegar(ml)	Glycerol(ml)
1	10	5	5
2	10	6	4
3	10	4	6
4	10	8	2
5	10	2	8

Table 2 : Composition of different Potato based bioplastic samples

4.2.3 Bioplastic from Banana peel starch (BPS)

A total of 5 samples were produced varying the amount of the main ingredient such as glycerol(plasticizer) and vinegar to produce a variety of different samples, the composition of which is given in the table 3.

1. 10gm of banana peel powder,5ml of vinegar,5ml of glycerol and 60ml of distilled water is taken in a beaker
2. To this mixture add appropriate amount of eggshell mixture and is stirred thoroughly.

3. The mixture was heated at 70°C for 10-15 minutes while continuously being stirred until it is gelatinized.
4. Then the gelatinized mixture was spread into oil coated plate using a clean spatula and oven dried at 70°C for 24 hours.
5. The bioplastic was cooled down before removing it from the soil.

Sample No.	Starch(g)	Vinegar(ml)	Glycerol(ml)
1	10	5	5
2	10	6	4
3	10	4	6
4	10	8	2
5	10	2	8

Table 3: Composition of different banana based bioplastic samples

4.3 BIOPLASTIC CHARACTERISTIC

4.3.1 Moisture Content

Bioplastic films were weighed to measure the initial weight (W1). The samples were dried in an oven at 60°C for 2 hours. The samples were weighed once more to measure the final weight (W2). The moisture content was then determined using the formula (Sanyang et al .,2016)

$$\text{Moisture Content (\%)} = \frac{W1-W2}{W1} X100$$

$W_{1=}$ Weight of wet sample

$W_{2=}$ Weight of dry sample

4.3.2 Water Absorption

Absorption of water of the bioplastic was found out from slightly modified ASTM D570-98 method. Bioplastic films were first dried in an oven at 60°C for 24 hours to allow measuring its dry weight (W1), followed by placing them in a beaker of 10ml distilled water at room temperature for 24 hours as shown in the figure. After 24 hours the bioplastic was obtained by filtering the water and then its weight was measured to find its final weight (W2). The absorption of water was found using the formula:

$$\text{Water Absorption (\%)} = \frac{W2-W1}{W1} X\ 100$$

W_1= Initial weight

W_2= Final weight

4.3.3 Solubility in water

Bioplastic films were first dried in an oven at 60°C for 24 hours to allow measuring its dry weight (W1), followed by placing them in a beaker of 10ml distilled water at room temperature for 24 hours as shown in fig. After 24 hours the bioplastic residues was obtained by filtering the water and then weighed to find the final weight (W2). The solubility was found using the formula (Sanyang *et al*., 2016)

$$\text{Solubility in Water (\%)} = \frac{W1-W2}{W1} X100$$

W_{1}= Weight before submersion

W_{2}= Weight after submersion

4.3.4 Solubility in alcohol

Bioplastic films were first dried in an oven at 60°C for 24 hours to allow measuring its dry weight (W1), followed by placing them in 3ml ethanol in test tubes with caps on at room temperature for 24 hours as shown in fig. After 24 hours the bioplastic residues was obtained by filtering and then weighed to find the final weight (W2). The solubility was found using the formula (Sanyang *et al* .,2016)

$$\text{Solubility in Alcohol (\%)} = \frac{W1-W2}{W1} X100$$

W_{1}= Weight before submersion

W_{2}= Weight after submersion

4.3.5 Chemical resistance

The bioplastic films were immersed in different solvents of 0.1N NaOH and 0.1N HCl solution for 24 hours. 0.1N NaOH was prepared by mixing 0.4g NaOH with 100ml distilled water whereas 0.1N HCl was prepared by mixing 0.83ml of HCl acid with 100ml of distilled water. The effects of strong acid and base on the samples were ascertained by measuring change in appearance (Mc Hugh *et al* ., 1994). Bioplastic films immersed in NaOH and HCl as shown in plate no.10

Biodegradable behavior of bioplastic was determined using soil burial degradation test, i.e., bioplastics were buried in the soil, so that it would be degraded completely. Degradation testing serves to determine the extent of damage to bioplastic. specimens The damage can be seen from the mass reduction of respective specimen in the ground. Bioplastic films were weighed to measure the initial weight (W1).then they were buried in soil at 5cm depth as shown in fig. the burial duration varied from 3 to 12 days. The soil was kept moist by sprinkling water for 12 days, after which the bioplastic residues was collected from the soil at burial duration and weighed to measure the final weight (W2). The biodegradability was measured from the following formula.

$$\text{Biodegradability test (\%)} = \frac{W1-W2}{W1} X100$$

W_1 = Weight before degradation

W_2 = Weight after degradation

4.3.6 Hot water solubility test

The Bioplastic films were first dried in an oven at 60°C for 24 hours to allow measuring its dry weight (W1), followed by placing them in a beaker containing 100ml distilled water and allowed to boil until it reaches a temperature of 80°C. After that the bioplastic residues was obtained by

filtering the water and then weighed to find the final weight (W2). The solubility was found using the formula,

$$\text{Hot water solubility (\%)} = \frac{W1-W2}{W1} X100$$

W_1 = Initial weight

W_2 = Final weight

4.3.7 Flame test

Bioplastic were weighed in order to obtain initial weight and then they were subjected to high flame for 30 seconds and was observed for any poisonous gases.

4.3.8 Density

Standard of ASTM D792-91 method of analysis was used to evaluate the film Density of bioplastic film obtained by weighing the film using a standard chemical digital weighing scale accurate to 0.1 g. The film volume was calculated by a water displacement method with a specified weight of the film, by multiplying the film area by the thickness. It was calculated using the formula

Density = Mass/Volume

Mass = W_2- W_1

W_1= Weight of the wet sample

W_2= Weight of the dry sample

CHAPTER 4

RESULTS AND DISCUSSIONS

5.1. Sample collection

Potato peel, Tapioca peel and Banana peel was collected from appropriate places.

5.2. Starch extraction

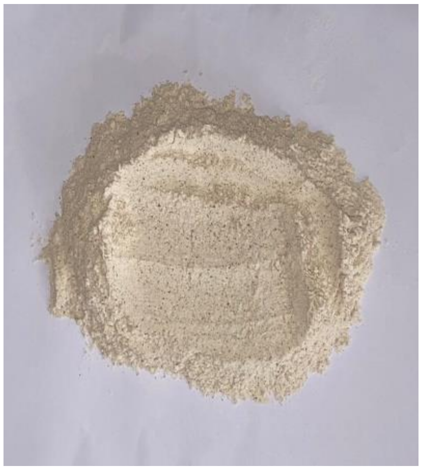
5.2.1. Starch extraction from tapioca peel

Starch powder was obtained from the peels of tapioca by washing , drying and grinding them into fine powder.

(a) Tapioca

(b) Tapioca peel

(c) Dried tapioca peel



(d) Tapioca starch

Plate 1: Starch extraction from tapioca peel

5.2.2.Starch extraction from potato peel

Starch powder was obtained from by grinding fresh cleaned and dried peels of potato.

(a) Potato

(b) Potato peel

(c) Dried potato peel

(d) Potato starch

Plate 2: Starch extraction from potato peel

5.2.3.Starch extraction from banana peel.

Banana peels were dried and grinded to obtain starch powder from banana.

(a) Banana peel

(b) Dried banana peel

(c) Banana starch

Plate 3: Starch extraction from banana peel

5.3. Production of eggshell powder

Egg shells were collected and dried into fine powder in order to use as a filler to improve the properties of bioplastics such as brittle hard etc.

(a) Egg shells (b) Eggshell powder

Plate 4: Eggshell powder preparation

5.4. Production of tapioca peel based bioplastic

Tapioca based bioplastic were synthesized from tapioca starch. 5 different samples were prepared using different amounts and combination using glycerol and vinegar. They have brown colour. The bioplastics prepared with low concentration of plasticizer is brittle, rigid and fragile. Many cracks were observed on the surface of bioplastic making it hard to peel and handle. While bioplastic with high plasticizer content was less brittle and rigid compared to the former. This observation could be attributed to the strong inter/intra molecular hydrogen bonds of starch which provide less mobility to the macromolecular chains, resulting in brittle and rigid films with surface cracks.(Tan *et al* .,2016). It was confirmed that treatment of tapioca peel starch with vinegar and plasticizers formed plastic resin PFA **(**Young *et al*.,1984).

Plate 5: Five samples of Tapioca based bioplastic

5.5. Production of potato peel based bioplastic

Potato based bioplastic were synthesized from potato starch. 5 different samples were prepared using different combination of glycerol and acetic acid. Potato based bioplastic were light brown in colour. Potato based bioplastic are less efficient in its role compared to tapioca peel based bioplastic. Glycerol and Acetic acid when added in almost equal ratio gives the best results.

Plate 6: Five samples of Potato based bioplastic

5.6. Production of banana peel based bioplastic

Banana peel based bioplastic were produced in 5 different combination ratios. Egg shell powder is added as a filler to improve its texture. A dark brown colour bioplastic was obtained. Some plastic resins get blended with fillers to reduce costs. Properly used mineral fillers, however, can improve a plastic's moldability and stability. They can also increase the plastic's heat-deflection temperature, reduce thermal expansion, and change other performance characteristics as well. (Kalambur S *et al* .,2006)

Plate 7: Five samples of Banana based bioplastic

5.6. Moisture content

The values for the moisture content of Tapioca peel based bioplastic, Potato peel based bioplastic and Banana peel based bioplastic were shown in Table 1, Table 2 and Table 3. It was noticed that the moisture content of the bioplastic films were increased when plasticizers were added. Bioplastic samples with glycerol had the highest values of moisture content. Thus glycerol comprises of hydroxyl group which has an affinity for water molecules that allowing them to make hydrogen bonds and enabling glycerol containing films to easily retain water within their matrix Glycerol has been added in casting solution to improve physical and chemical properties of bioplastic. The use of glycerol as plasticizers was affected the elasticity of the film and also increase in water vapor and oxygen permeability. (Cerqueira *et. al*, 2012).

Bioplastic sample No.	Initial weight (W1)	Final weight (W2)	Moisture content (%)
1	176g	118g	32.95%
2	176g	119.7g	32.98%
3	176.2g	118.3g	31.86%
4	174.9g	115g	34.32%
5	178g	121g	32.02%

Table 4: Moisture content of tapioca peel based bioplastic

Bioplastic sample No.	Initial weight (W1)	Final weight (W2)	Moisture content (%)
1	170g	121g	28.82%
2	171g	119g	30.40%
3	170.4g	119.3g	29.98%
4	170g	115g	32.35%
5	172.3g	121g	29.77%

Table 5: Moisture content of potato peel based bioplastic

Bioplastic sample No.	Initial weight (W1)	Final weight (W2)	Moisture content (%)
1	140g	118g	15.71%
2	140.5g	119.1g	15.23%
3	140.8g	118.6g	15.76%
4	139g	117.9g	15.17%
5	140.9g	120.2g	14.69%

Table 6: Moisture content of banana peel based bioplastic

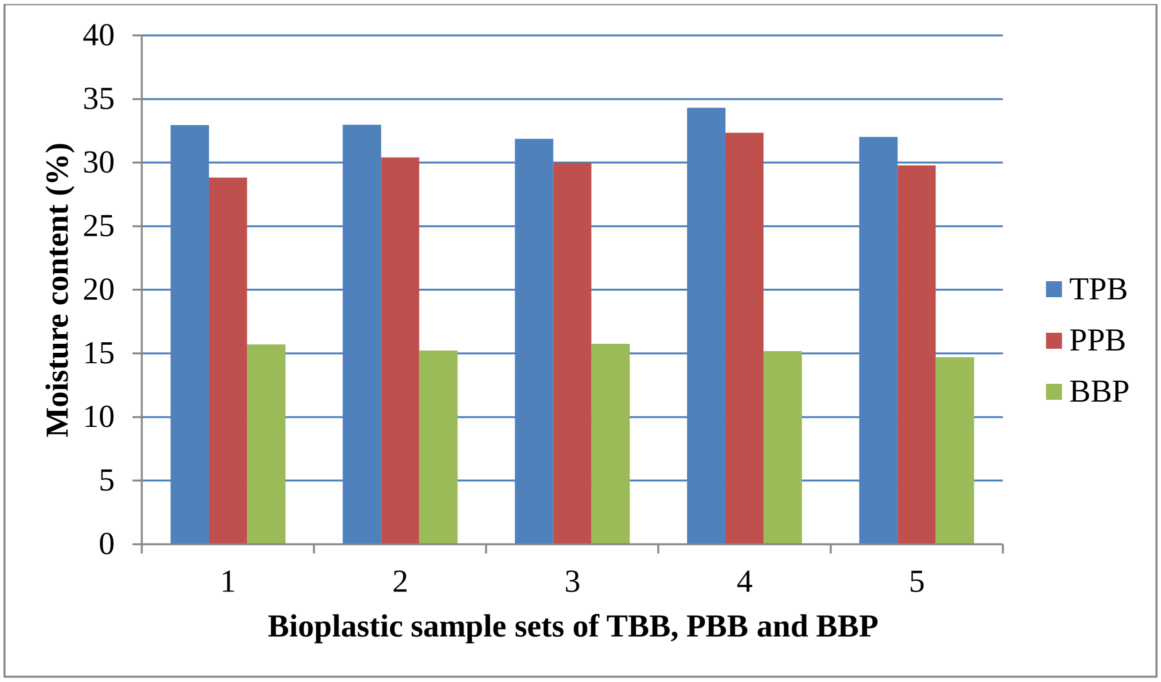


Fig 1: Rate of Moisture content of TBB,PBB and BBP

.7.Water absorption

When comparing all sample set of TBB, PBB and BBB bioplastic films, TBB shows more water absorption percentage compared to PBB and BBB. In all bioplastic samples water absorption was observed to decrease with increasing the amount of filler added because as filler percentage increases bioplastic becomes more flexible .Such results were also observed in research undertaken by (Mohan *et al*., 2016). The high amount of water absorbed is presumably because the nature of water and plasticizers are very polar so they tend to absorb more water. Water absorption capacity can also be linked to the chemical structure of materials that have a functional group (OH) that can absorb water**.** (Cao *et al*., 2009) . In a study by (Y.Darni *et al*., 2017) similar results were also noticed in which absorption of water was seen to increase when sorghum stalks filler was added into a sorghum starch based bioplastic. This can be attributed to sorghum stalks comprising of cellulose, and cellulose being hydrophilic. Because of higher water absorption, TBB may not use in the food services industry but can be used as packing materials. However, mechanical property, tensile strength, hydrostatic pressure, elastic property, and strength property should be identified in order to determine the industrial usage.

Bioplastic sample No.	Initial weight (W1)	Final weight (W2)	Water absorption (%)
1	5	8	60%
2	5	8	60%
3	5	6	20%
4	5	9	80%
5	5	6	20%

Table 7 : Water absorption of tapioca-based bioplastic

Bioplastic sample No.	Initial weight (W1)	Final weight (W2)	Water absorption (%)
1	5	5.6	12
2	5	6.3	26
3	5	6	20
4	5	7	40
5	5	6	20

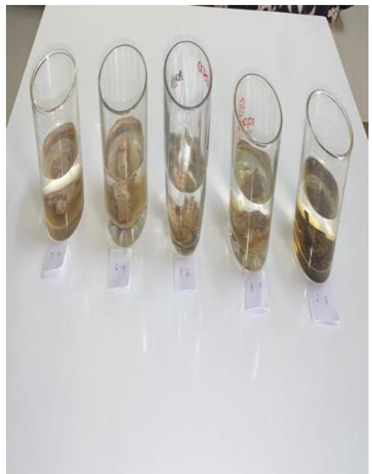
Table 8: Water absorption of potato based bioplastic

Bioplastic sample No.	Initial weight (W1)	Final weight (W2)	Water absorption (%)
1	5	6.9	38
2	5	6.6	32
3	5	7	40
4	5	8	60
5	5	6.1	22

Table 9: Water absorption of banana based bioplastic

TBB

PBB



BBP

Plate 8 : Bioplastic samples immersed in distilled water for water absorption test

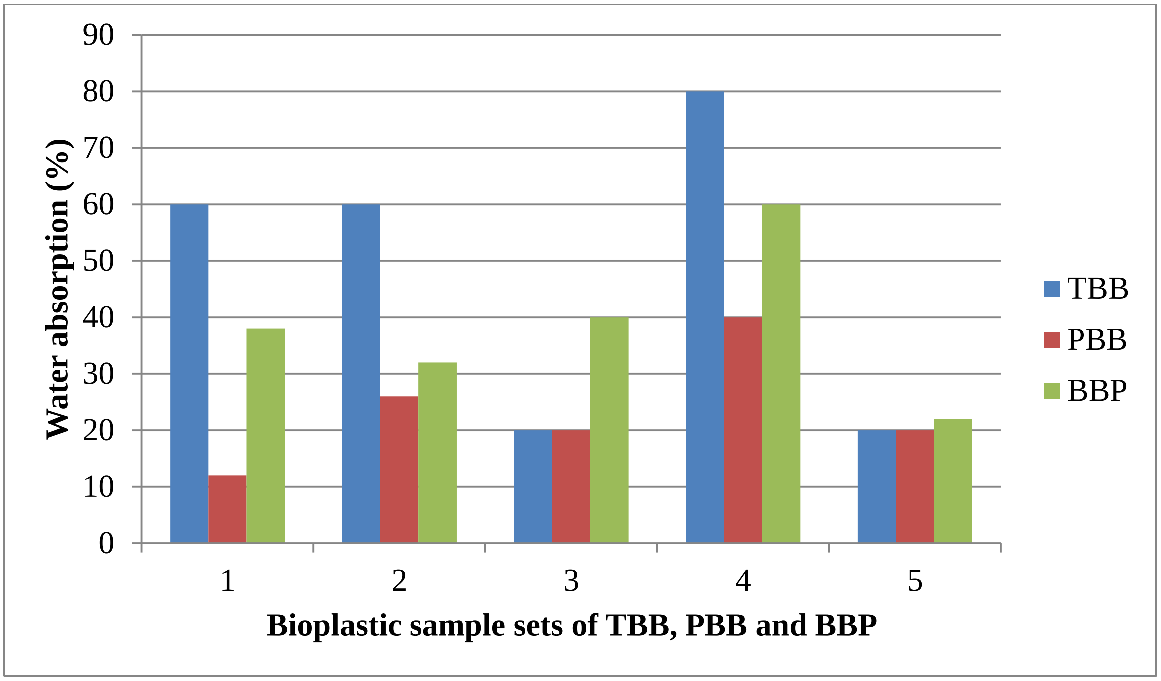


Fig 2: Rate of water absorption of TBB,PBB and BBP

5.8. Water solubility

Potato based bioplastic show better result when compared to other two. When comparing all the three samples, most soluble sample of bioplastic has high concentration of glycerol when compared to vinegar. The characteristics of bioplastics for water absorption and solubility of bioplastics are one of the important indicators to show the level of loss of bioplastic in contact with water or water vapor.. Based on solubility, the solubility value of glycerol is near complete, which can dissolve as a whole in water. (Siracusa *et al*.,2008)

Bioplastic Sample No.	Initial weight (W1)	Final weight (W2)	Water solubility (%)
1	10	5	50
2	10	5	50
3	10	6	40
4	10	4	60
5	10	7	30

Table 10: Water solubility of tapioca-based bioplastic

Bioplastic Sample No.	Initial weight (W1)	Final weight (W2)	Water solubility (%)
1	5	2	60
2	5	2	60
3	5	2	60
4	5	1	80
5	5	3	40

Table 11: Water solubility of potato based bioplastic

Bioplastic Sample No.	Initial weight (W1)	Final weight (W2)	Water solubility (%)
1	5	2	60
2	5	2.7	46
3	5	3	40
4	5	2	60
5	5	4	20

Table 12: Water solubility of banana based bioplastic

TBB PBB BBB

Plate 9: Bioplastic samples immersed in distilled water for water absorption test

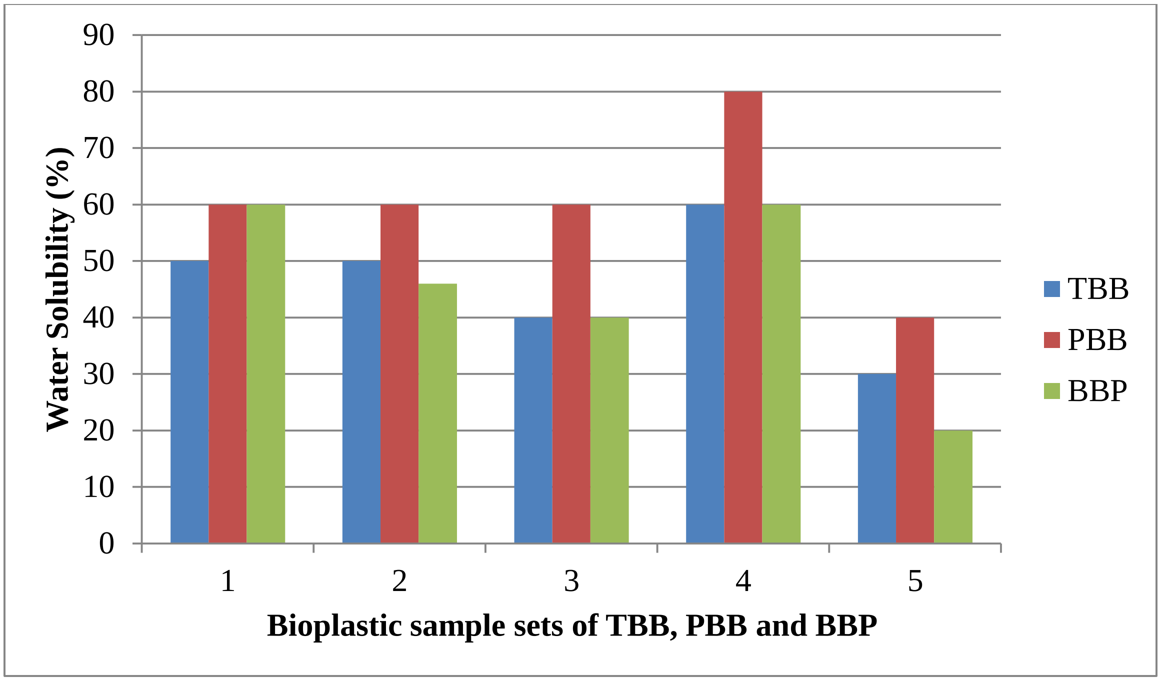


Fig 3: Rate of water solubility of TBB,PBB and BBP

5.9. Solubility in alcohol

Solubility in alcohol was tested for all the three samples of tapioca, banana and potato. It was observed that banana shows fairly low solubility when incubated for 24 hours. Solubility in alcohol increased when plasticizer was added in banana based bioplastics. Starch is not soluble in alcohol at normal room temperature. Addition of filler decreased the solubility in alcohol. They are very slightly or completely insoluble in alcohol because they are mainly made up of starch and cellulose respectively which are insoluble in alcohol as reported by (X.Chen *et al* .,2015)

Tapioca	Not soluble
Potato	Not soluble
Banana	**Fairly soluble**

Table 13 : Solubility in alcohol

5.10. Chemical resistance

The three samples of bioplastics were subjected to acid and alkali test to check their resistance. All the three samples get readily degraded in acid while it was not soluble in base.

Sample	Acid solubility	Base solubility
Tapioca	Yes	No
Potato	Yes	No
Banana	Yes	No

Table 14: Chemical resistance test of bioplastics

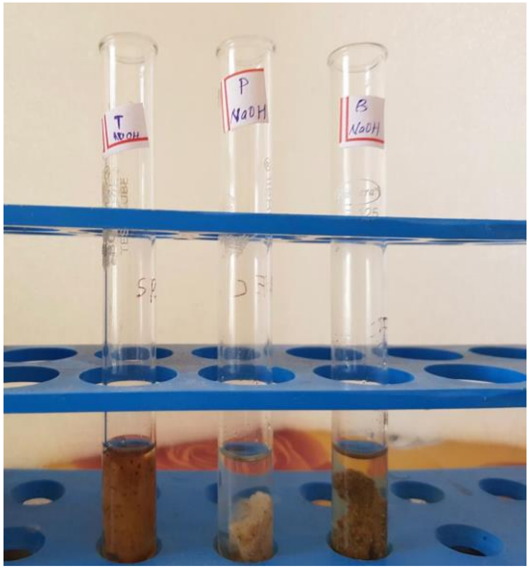


Plate 10: Bioplastic samples immersed in NAOH and HCl

5.11. Biodegradability test

The bioplastics are made by natural sources of starch and water, small amount of glycerol. Starch and glycerol naturally biodegradable. Biodegradability test was carried out and banana based bioplastic shows high degree of biodegradability with respect to the other two samples. Physiochemical properties like chemical structure, molecular weight, affinity to water and surface area etc. of the bioplastics determine their biodegradation ability Adding plasticizer was detected to increase the biodegradation of the bioplastics samples, while adding fillers (5% w/v) was detected to reduce biodegradation ability in plasticized samples and improve it in unplasticized sample Adding plasticizer improving the biodegradation of samples can be attributed to better water absorption capacity of the samples which is because of the affinity of both the plasticizers (glycerol and sorbitol) towards water. Samples with glycerol exhibited the highest level of biodegradation. (Y.Tokiwa *et al*., 2009). Biodegradability is strongly dependent on the amount of plasticizer but the amount of plasticizer in commercial bioplastic is unknown. Therefore it is thought that some additives may have been added to commercial bioplastic for improving mechanical properties such as durability, flexibility etc. For example, additives used for enhancing antimicrobial properties may reduce or eliminate the biological degradability of bioplastics. Because of this, the structure of commercial bioplastic may have changed and this change may have also affected biological degradability. Furthermore, due to the natural conditions are not controlled, commercial bioplastics can biodegrade within a long time or cannot biodegrade. (Spaccini *et al*.,2017)

Sample	Initial weight (W1)	Final weight (W2)	Biodegradability (%)
Tapioca	10	5.6	44
Potato	10	4.8	52
Banana	10	3	70

Table 15 : Biodegradability test of different samples

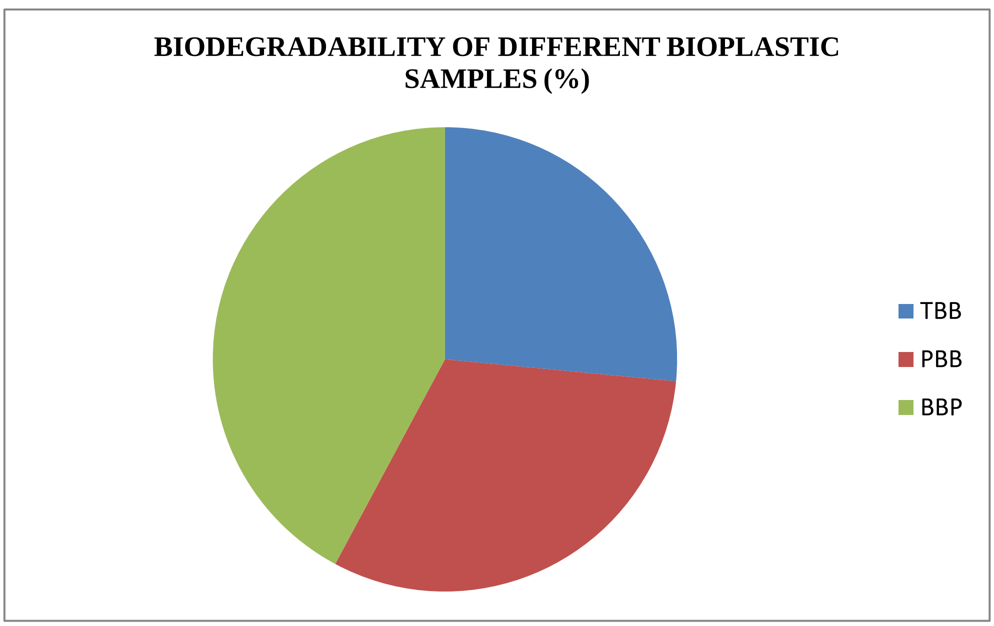


Fig 4: Rate of biodegradability of TBB, PBB and BBP

5.12. Hot water solubility test

The bioplastic is fully degraded in hot water. The bioplastic is dissolved in 80°c of hot water. And also this is the meeting point of the cassava starch based bioplastic

5.13. Flame test

When the three samples of bioplastic were burn, it gets degraded and it doesn’t release harmful gases to the environment so that these bioplastics are ecofriendly and also it burn like a normal paper.

Plate 11: Bioplastic sample after flame test

5.14. Density

The highest density value was found for banana based bioplastic. Plastics with lower density tended to have open structure which can be penetrated by fluids, such as H_2O, O_2 or CO_2. Plasticizers also effect the density of bioplastics as increasing plasticizers content causes network to swell and results in the decrease of network density. (Bierley et al.,1988)

Sample	W1	W2	Mass (g) W2-W1	Volume (L)	$Density = Mass / Volume$
Tapioca	106	126	20	60	0.33
Potato	211.24	190.36	20.88	60	0.34
Banana	122	94	28	60	0.46

Table 16 : Density of different samples

CHAPTER 5
SUMMARY AND CONCLUSION

The bioplastics were produced in this research was odorless and smooth. The glycerol was increases the flexibility of the bioplastic. And also different physical properties of the bioplastics were checked. Starch powder was obtained from the peels of tapioca, potato and banana by washing , drying and grinding them into fine powder.5 different samples of each were prepared using different amounts and combination of glycerol and vinegar. They shows various gradients of brown colour. Egg shell powder is added as a filler in both potato and banana to improve its texture. The moisture content of the bioplastic films were increased when plasticizers were added. Bioplastic samples with glycerol had the highest values of moisture content. Thus glycerol comprises of hydroxyl group which has an affinity for water molecules that allowing them to make hydrogen bonds and enabling glycerol containing films to easily retain water within their matrix. When comparing all sample set of TBB, PBB and BBB bioplastic films, TBB shows more water absorption percentage compared to PBB and BBB. In all bioplastic samples water absorption was observed to decrease with increasing the amount of filler added because as filler percentage increases bioplastic becomes more flexible. Potato based bioplastic show better result when compared to other two. When comparing all the three samples, most soluble sample of bioplastic has high concentration of glycerol when compared to vinegar. Solubility in alcohol was tested for all the three samples of tapioca, banana and potato. It was observed that banana shows fairly low solubility when incubated for 24 hours. Solubility in alcohol increased when plasticizer was added in banana based bioplastics. The three samples of bioplastics were subjected to acid and alkali test to check their resistance. All the three samples get readily degraded in acid while it was not soluble in base. The bioplastics are made by natural sources of starch and water, small amount of glycerol. Starch and glycerol are naturally biodegradable. Biodegradability test was carried out and banana based bioplastic shows high degree of biodegradability with respect to the other two samples. When the three samples of bioplastic were burn, it gets degraded and it doesn't release harmful gases to the environment so that these bioplastics are ecofriendly and also it burn like a normal paper. The bioplastics is fully degraded in hot water. The bioplastic is dissolved in 80°C of hot water and also this is the melting point of the cassava based bioplastic

Bioplastic product is a developing field in biotechnology. Many methods are newly developed inorder to overcome the flaws in each attempt but there is still long way to go. It is clearly evident that quite a lot has been done in the development of starch-based products in an attempt to create biodegradable plastics. In this project, it is further leveled up by producing bioplastic from waste materials which are usually discarded. This attempt is not only cost effective but also helps in recycling of waste into something useful. Starch has basically been used in two forms, that is granular (native or modified) form and thermoplastic (plasticized) form. Bioplastic blends with synthetic biodegradable and non-biodegradable polymers have also been explored. Various factors tend to affect the performance of these products, some of which include starch particle size, amylose/amylopectin ratio, starch modification, plasticizer, processing method and condition, reinforcement and compatibilizer. Though lots of work has been done and still doing, most of the starch-based composites made have not made it to the market owing to their inherent material deficiencies particularly in terms of strength and water resistance. There is also complex interplay of performance factors such as an increase in one factor may improve the performance property of one while decreasing the other. This therefore stresses the need for performance optimization which, in turn necessitates the need for maintaining a well-organized rich database. As evident in this work, most of the work done is on root/tuber crops. There is therefore the need to widen the scope of this research by incorporating other sources of starch like the legumes. In conclusion, while acknowledging the significant scholarly progress made on this noble course, the need for further work cannot be over-emphasized in the attempt towards developing bioproducts that can successfully rival against existing petroleum-based plastics in service and economics.

This study further shows that starches from different natural sources can be used, individually or in combined form, with and without the addition of different plasticizers and kinds and amounts of natural fillers to produce a variety of different kinds of bioplastics showing different physical and chemical characteristics. The differences in these properties will allow the bioplastics to be suitable for varying applications. All the bioplastics produced were biodegradable and environmental-friendly, thus being a good substitute of petroleum-based plastics and an efficacious way to alleviate the problem of plastic pollution.

Since many countries around the world are struggling with food shortages, producing bioplastics from wastes instead of foods is the best way to go. This study clearly suggest that food wastes could be used for bioplastic production. The present study also illustrate clearly the biodegrable nature of bioplastic produced using different sources. The development of mechanical properties should be investigated for the utilization of it in different industrial areas.. Bioplastics usage has increased in recent years in the world. Therefore, for the sustainability of those called as 'biodegradable', the standards should be developed.

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