PRODUCTION OF STARCH-BASED BIOPLASTIC POLYMER FROM LATUNDAN BANANA (*Musa acuminata × balbisiana*) PSEUDO-STEM

A Research Paper
Presented to
The Faculty of Philippine Science High School- Western Visayas Campus
Bito-on, Jaro, Iloilo City

In Partial Fulfillment
Of the Requirements in
SCIENCE RESEARCH 2

by

Diego S. Anabo
Lloyd Edric D. Blancaflor
Princess Monic Q. Velasco

Fourth Year - Photon

APRIL 2015

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This research paper herein entitled:

PRODUCTION OF STARCH-BASED BIOPLASTIC POLYMER FROM LATUNDAN BANANA (*Musa acuminata* x *balbisiana*) PSEUDO-STEM

Prepared and submitted by Diego S. Anabo, Lloyd Edric D. Blancaflor, and Princess Monic Q. Velasco in partial fulfilment of the requirements of Science Research 2, has been examined and recommended for acceptance and approval.

JOSEPH SIMON V. MADRIÑAN
Science Research 2 Adviser

Approved by the members of the Science Research Committee on April 2015.

EDWARD C. ALBARACIN

MIALO L. BAUTISTA

HAROLD P. MEDIODIA

GERALD U. SALAZAR

ERIKA EUNICE P.SALVADOR-GUNABE

Accepted in partial fulfilment of the requirements in Science Research 2.

SHENA FAITH M. GANELA, Ph.D.
Director III, PSHS-WVC

Production Of Starch-Based Bioplastic Polymer From Latundan Banana (*Musa acuminata x balbisiana*) Pseudo-Stem

Anabo, D.S., Blancaflor, L.E.D., and Velasco, P.M.Q.

Philippine Science High School – Western Visayas Campus, Bitoon, Jaro, Iloilo City
diego.anabo@gmail.com; lloydblancaflor@gmail.com; princessvelasco18@yahoo.com

ABSTRACT

Plastic is the source of most of the world's solid waste today. Because of this, scientists have been developing different materials, specifically biodegradable plastics to reduce the effects of non-biodegradable plastics. This study aimed to develop a starch-based bioplastic polymer from Latundan banana (Musa acuminata x balbisiana) pseudo-stem. The isolation of starch from the pseudo-stem was based on the study of Riley *et. al* 2006 with some modifications. The percent degradability was obtained using the Total Organic Carbon test. Approximately 0.02g of the bioplastic was used to perform the test. The produced bioplastic polymer had an uneven and lumpy texture with little bubbles on the surface and was light brown in color. Even without proper tensile strength testing, it appeared that the bioplastic could not be easily broken on its frst ripping. The mean ± standard deviation results showed that the percent carbon has a range of 23.14% to 36.64% and the percent organic matter has a range of 39.89% to 63.17%. Its degradability which is 51.53% compares well with that of bioplastic from cassava starch with a degradability of 41.27%, polyethene with a degradability of 10.33% ,and paper with a degradability of 85.99%. The percent degradability results of the starch-based bioplastic polymer from Latundan banana (Musa acuminata x balbisiana) pseudo-stem may prove possible use of bioplastic from banana pseudo-stem in the future.

Keywords: *bioplastic, starch, banana pseudo-stem, Musa acuminata x balbisiana, Percent degradability, Total Organic Carbon test*

ACKNOWLEDGEMENT

The researchers would like acknowledge the following who made this research study possible by providing the support that they needed throughout the study:

To **Our family,** we felt the love and support you have given us while we were pursuing our study. Your continual encouragement and assistance aided us to never give up in times of despair and lack of confidence. You gave us the financial assistance and moral support that we needed.

To the **Research Panel**, Sir Harold Mediodia, Sir Edward Albaracin, Ma'am Mialo Bautista, Ma'am Erika Eunice P. Salvador – Gunabe, Sir Gerald Salazar and especially our research adviser, Sir Joseph Madriñan, thank you for the approval of the fulfilment of this study. Without your intelligent appraisals and suggestions, we would not have noticed our flaws and the things we lacked in our study.

To **Department of Science and Technology,** we give our deepest gratitude for accommodating us to conduct the Total Organic Carbon test in the laboratory of your agency. Not all of us are given a chance to work with such big institutions and your teachings and guidance helped us improve our research work. Thank you!

Finally, to the **Almighty God**, thank you for your guidance. You never left us hanging during the times that we were about to give up. Your presence encouraged us to overcome each of our problems. If not for your grace and mercy, we may not be able to finish our study with flying colors.

Diego, Lloyd & Princess

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CHAPTER 1

INTRODUCTION

A. Background of the study

Throughout these modern times of the 21st century, non-biodegradable materials, especially plastic, have been used on an everyday basis, from plastic bags to candy wrappers to plastic bottles etc. There are approximately 265,000,000 tonnes of plastics produced and used annually (Terer and Magut 2013). In the United States, synthetic polymers are estimated to be approximately 20% of the volume of municipal solid waste. The estimated solid waste generated in Region VI of the Philippines in 2000, 2005 and 2010 was about 969 tons a day or 4.81%, 1094 tons a day or 4.55%, 1,245 tons a day or 4.31%, respectively. In the whole Philippines, the estimated solid waste generated in 2000, 2005 and 2010 was 19700 tons a day or 100%, 24,059 tons a day or 100%, 28,875 tons a day or 100%, respectively (Atienza 2011). Furthermore, according to Atienza, the waste composition in Metro Manila is composed of 16% plastics.

The recent concerns about problems of the environment, climate change, limited fossil fuel, and petrochemicals brought about the revival of the development of biodegradable materials and plastics, which was first introduced during the early 1970's (Berkesch 2005). The currently known reserves of oil have a total of 1.24 trillion barrels which would only approximately last 41 years. An estimated percentage of 99% of the feedstock of plastic is taken from petroleum; with the current consumption rate of 87.2 million barrels a day in the year 2008 (Terer and Magut 2013). Some certain solutions were formulated for ecological concerns and environmental purposes. Some of these were the development of plant-based starch and polymers from transgenic plants and have been described as a novel and dynamic field with a very positive developmental potential in the future. However, these solutions do not promote complete biodegradability but only the disintegration of the blend also if starch is added with polyethylene, a non-biodegradable plastic; only a portion of it will be degradable.

Naturally occurring polymers such as cotton, starch, and rubber were familiar materials for years before synthetic polymers such as polyethene and perspex appeared on the market. Natural polymers are better than the synthetic ones because they are biodegradable materials.

The number of non-biodegradable plastics can be reduced and environmental problems will lessen if more biodegradable plastics can be produced for the consumers, the environment, and the marketing industry. Biodegradable polymers are in demand and can be easily degraded by naturally occuring microorganisms. During the year 2011, an estimated growth of 28% to 40% increase in demand for bioplastics occurred (Terer and Magut 2013).

Bioplastics have been a promising solution to the declining of oil reserves and rapid oil consumption rates through the previous years with the use and utilization of natural renewable resources. Apparently, most bioplastic resources are from starchy crops that are consumed by people worldwide such as potato, corn, and cassava. The usage of these resources consequently contradicts with the global human consumption of the crops as a food source.

Banana is a widely-known and cultivated fruit in tropical and subtropical areas. Being the second largest produced fruit after citrus, banana contributes 16% of the world's total fruit production (Mohapatra and others 2010). It can be used for both food and nonfood application (Noosuk n.d.). Bananas are capable of polymerization due to the presence of starch, glucose, and cellulose.

Latundan banana is one of the common names of *Musa acuminata × balbisiana*. In the Philippines, it is known in many different names like Amorosa, Cantong, Katungal, Letondal, Tordan, Tundan, Turdan and Latundan. Reports say that it originated from the Philippines. Just like the Lakatan and Cavendish bananas, it thrives best in lowland, humid tropical areas with rich, moist, well-drained soils well protected from strong winds.

Banana pseudostems contain starch. The starch granules are irregular in shape and are bigger in size than those of the fruit starch from potato, corn and tapioca.The granules start to swell at 60°C, gradually increase in size, attain their maximum size at 75°C and do not rupture even after heating to 100°C. The intrinsic viscosity of the starch (2.05) is similar to that of potato starch (2.00). The amylose content of the starch compares well with that of banana fruit and potato (tuber) starch (21%). Overall, the banana pseudostem starch resembles potato starch. (Shantha H.S. 2006)

The banana pseudostems could be a reliable and renewable source of starch and that it could not compete with food consumption unlike bioplastics made from potato, corn, cassava, wheat, and tapioca. In addition to that, the starch from pseudostem could be extracted for the purpose of bioplastic polymer production.

B. Statement of the problem

Can a starch-based bioplastic film be produced from Latundan banana (*Musa acuminata × balbisiana*) pseudo-stem?

C. Objectives of the Study

C.1 General Objective:

This study aimed to develop a starch-based bioplastic film from Latundan banana (*Musa acuminata × balbisiana*) pseudo-stem.

C.2 Specific Objectives:

1. To extract a substantial amount of starch from Latundan banana (*Musa acuminata × balbisiana*) pseudo-stem to produce a starch-based bioplastic polymer.
2. To develop a starch-based bioplastic polymer from the Latundan banana (*Musa acuminata × balbisiana)* pseudo-stem.
3. To determine the degradability of the starch-based bioplastic polymer from the Latundan banana (*Musa acuminata × balbisiana*) pseudo-stem by getting its a.) percent carbon content and b.) percent organic matter.

D. Scope and Delimitation

The scope of this study was to make a starch-based bioplastic polymer from *Musa acuminata × balbisiana* pseudo-stem using Propan 1, 2, 3-triol as the plasticizer, Hydrochloric acid for the structure and properties of the polymer, and Sodium hydroxide as the neutralizer. For flour extraction from banana pseudo-stem, 0.9 liters of distilled water was used. This study will also use potassium dichromate, sulphuric acid, sodium fluoride, Diphenylamine indicator, and a Normal ferrous sulphate solution for the Total Organic Carbon Concentarion (TOC) Test procedure for determining the percent degradability. This study was conducted in the DOST Region VI laboratory for the TOC test and PSHS-WVC Research laboratory and instrument room for the extraction of starch and production of the starch-based bioplastic polymer. The study was conducted on the months of December and January, year 2014 and 2015, respectively.

CHAPTER 2

REVIEW OF RELATED LITERATURE

A. Polymer

By heating the monomer and passing it over a catalyst, a polymer is produced. The sort of catalyst used can affect how much the polymer chain branches. These branches are similar to that of tree's branches. They are made of the same stuff as the main chain but go off in a different direction.

Its small units called monomers undergo chemical reactions to form polymers. Processes by which small molecules generally referred to as monomers undergo repeated combination to form very large molecules is called polymerization. The specific physical and chemical properties of polymers are determined both by the structure and by the degree of organization of the structural units. A general knowledge of polymerization reactions and mechanisms involved is a vital study (Terer and Magut 2013).

A.1 Biodegradable polymer

Biodegradable polymer is a polymer that is capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds, and biomass under aerobic and non-aerobic conditions (Kržan n.d.).

Biodegradable polymers are derived from replaceable agricultural feed stocks, animal sources, marine food processing industry wastes, or microbial sources. In addition to renewable raw ingredients, biodegradable materials break down to produce environmentally friendly products such as carbon dioxide, water, and quality compost. Biodegradable polymers made from cellulose and starches have been in existence for decades, with the 1st exhibition of a cellulose-based polymer (which initiated the plastic industry) occurring in 1862. Degradable polymers interest the society to replace the non-degradable ones for short-term applications (packaging, agriculture...) so as to reduce plastic wastes (Avérous and Pollet 2012). The interest of the society to make biodegradable polymers started during the oil crisis in the 1970's. As the oil prices increased, so did the planning and creating of biodegradable materials (Berkesch 2005). Though there are no discoveries yet if biodegradable polymers have extensive applications in industries to mainly replace conventional plastic materials because of their high production costs and sometimes their underperformed properties (Avérous and Pollet 2012). The use of petroleum based plastic cause serious damage to environment and the plastic takes a long time to degrade. Thus, the existence of biodegradable plastic may serve as a promising solution to this problem (Nurul 2010).

A.1.1 Starch-based polymer

Starch is mostly extracted from wheat, corn, rice and tubers like potato. Starch granules can have different shapes (sphere, platelet, polygon…) and size (from 0.5 to 175 lm) depending on the botanical origin of the plant.

The main starch component is amylopectin that has the same monomeric unit as amylose. It is a branched polymer and its molecular weight is much greater than amylose, with light scattering measurements representing molecular weights in the millions. The amylopectin prevents the starch from becoming plastic-like (Nurul 2010).

The amylose is mainly a linear polysaccharide. High content of amylose in starch provide strong, flexible films which are thermally stable upto 180°C (Cheorun and others 2005) (Nurul 2010).

Starch is probably the most promising material for the production of biodegradable plastics and it comes from renewable resources. These granules are composed of two a D-glucopyranose homopolymers, the amylose and the amylopectin. Other compounds of starch are proteins, lipids and minerals in much lesser proportions. The starch granule organization consists in alteration of crystalline and amorphous areas leading to concentric structure (Avérous and Pollet 2012). Starch is an inexpensive and abundant product available in nature. It is totally biodegradable in a wide variety of environments and can be used in the development of totally degradable products for specific market needs. Degradation or incineration of starch products recycles the atmospheric CO trapped by starch-producing plants during their growth, thus closing the biological carbon cycle (Ezeoha and Ezenwanne 2013).

Starch-based plastics began to be an extremely versatile product. 20% of starch is now being used for different non-food materials such as paper, cardboard, textile sizing and adhesives. Starch-based polymers are now also processed into eating utensils, etc. (Berkesch 2005). This biodegradable starch–based polymer is achieved using conventional plastic technology such as injection molding, blow molding, film molding, foaming, thermoforming and extrusion (Mohanty 2004).

Starch-based polymers, which swell and deform when exposed to moisture, include amylose, hydroxylpropylated starch, and dextrin. Other starch-based polymers are polylactide, polyhydroxyalkanoate (PHA), polyhydroxybuterate (PHB), and a copolymer of PHB and valeric acid (PHB/V). In addition, biodegradable films can also be produced from chitosan, which is derived from the chitin of crustacean and insect exoskeletons. Chitin is a biopolymer with a chemical structure similar to cellulose (Ezeoha and Ezenwanne 2013).

A.2 Non-biodegradable polymer

Non-biodegradable polymers have very high effect on the environment like pollution and wildlife destruction when dispersed in nature. This kind of plastic bags adversely affects sea-life. Burning plastic wastes begins environmental issues for it emits toxics like dioxin. Also, we cannot just get rid of plastic wastes easily. Even plastic recycling finds it hard to reduce the number of plastic wastes every day (Avérous and Pollet 2012).

B. Bioplastic

Biodegradable plastic is a degradable plastic in which the degradation results from the action of naturally occurring microorganisms such as bacteria, fungi and algae (Ezeoha and Ezenwanne 2013). Also known as biopolymers, they are derivatives of renewable biomass resources e.g.plant proteins and starch. These biopolymers can be fabricated in many different organisms e.g. plants and microbes. Bioplastics can be defined as derivatives of renewable biomass resources, which are largely biodegradable and may provide similar functional advantages (e.g. packaging materials) as those of traditional plastics (Song and others 2009). Biopolymers (lipids, proteins, and polysaccharides) constitute the principle raw material for bioplastic production. Bioplastics derived from these biopolymers are biodegradable, renewable and environment friendly materials as compared to petro-based plastics (Murphy and Bartle 2004) (Rasheed 2011).

An alternative source of biodegradable plastic from blue green algae and sweet potato starch was produced to obtain a sustainable source of plastic synthesis. Different concentrations of starch and dried green algae were used to produce biopolymers. There is high potential in the algae plant ranging from bioplatics, food supplements to biofuel production. High percentages of dry algae produced material with high strength with a deep black colour (Terer and Magut 2013). In Nsukka, a biodegradable plastic film was produced by blending cassava starch and a synthetic biodegradable polymer (PVA). The potential of producing biodegradable packaging plastic film from cassava starch is encouraging and should be further explored because of its high tensile strength and biodegradability percentage than that of polythene and paper. A biodegradable biocomposite film from starch, chitosan and gelatin was also produced. The film at 3% starch blended with 2% of chitosan and 2% gelatin showed the highest density, the lowest moisture and water absorption and exhibits a smooth surface with less agglomerates and no visible pore. These properties make the film perfect for food packaging application.

The most challenging point for bioplastic production is not to violate the potential food sources. This obligation can be overcome by utilizing the non-food resources for the purpose. Bioplastics, when subjected to biodegradation under anaerobic conditions release methane in landfills. In order to compete with the problem and to produce valuable composts for the soil improvement, bioplastic products should be collected separately from other non-biodegradable materials and then can be composed at industrial level (Song and others 2009) (Rasheed 2011).

C. Petroleum-based plastic

Petroleum-based products are creating a number of environmental problems. Petroleum and oil resources are also threatened to become depleted due to the massive utilization. Therefore, it is important to replace the petroleum-based products with products that are instead derived from renewable resources e.g. the replacement of petro-based plastics with bioplastics can be a good option. Petroleum-based plastics are a risk to environment, land and water ecosystems (Rasheed 2011).

As to chemical industry, the highest priority area for the utilization of fossil feed stocks is for polymer fabrication (Mecking 2004). The annual plastic production will be increased up to 300 million tonnes by the year 2010 (Thompson and others 2009). The petro-based plastics possess a range of divergent properties e.g. they can be rigid or elastic, breakable or resilient, transparent or brightly colored, and can have many added advantageous properties (e.g. cheap, recyclable, insulators) (Momani 2009). Plastic production is directly affecting the petroleum consumption due to the fact that tonnes of plastics are fabricated from petroleum products every year. Many types of plastics e.g. ethylene, propylene, and styrene are directly extracted from crude oil enhancing crude oil consumption (Gervet 2007). The known oil reserves which are almost 1.24 trillion barrels will last for 41 years, the total world's petroleum consumption was 98.3 million barrels per day in 2009 (Momani 2009). CO_2 is released from the plastic industry further contributing to global warming. Increased use of petro-based plastics has created many health hazards. These dumps of plastics are contaminating almost every ecosystem including marine, fresh water, terrestrial and deserts posing numerous environmental problems (Thompson and others 2009). Plastics are generally resistant to microbial degradation making them even more hazardous to the ecosystems (Domenek and others 2004). It is estimated that more than 260 species of insects, birds, reptiles and mammals have perceived disabilities in movement, feeding habits, sterility and even death due to ingestion of plastics (Gregory 2009) (Rasheed 2011).

D. Latundan Banana (*Musa acuminata × balbisiana*) and Parts of banana plant with starch

Banana is a widely-known fruit in tropical and subtropical areas. The banana is a tropical herbaceous plant; its stem is composed of concentric layers of leaf sheaths. The banana is one of the most heavily consumed fruits in the world, with a global annual production 72.5 million tons (FAO 2006). It is an important fruit crop, which are grown extensively in Thailand. It is easy to grow, readily available and can be used for both food and non-food application (Noosuk and others n.d.).

There is an estimated 26,855 hectares of land area planted with bananas in year 2006 and the number increased by 2,035 in year 2010 with approximately 294, 530 tons of fruit, which is equivalent to a production value of RM 432, 375, 826 in 2010 (MOA 2010).

Banana is rich in carbohydrates providing calories. One component of green bananas is starch. Banana starch is considered to be a source of resistant starch. Resistant starch is a starch resistant to a-amylase and glucoamylase hydrolysis showing that 75-84% of starch granules ingested reached the terminal ileum. Resistant starch is said to have health benefits preventing colorectal cancer, heart disease and bowel diseases such as diabetes and diverticulitis (Hung and others 2013).

Latundan banana is a comparatively short, herbaceous banana plant; pseudo-stem 3-3.6 m high, robust, shiny green-yellow with underlying pink purple pigmentation and watery sap.

Leaves are broad, and intermediate. It has a midrib light green dorsal surface, large brown blotches at petiole base (Lim 2012).

The banana pseudo-stem has been reported to contain high-quality starch (Shantha and Siddappa 1970) (Ho and others 2012). Numerous banana pseudo-stems are being wasted every day because after banana fruits are harvested, the bare pseudo-stems are cut (Cordeiro and others 2004). Also, large amount of pseudo-stem waste creates major agro-waste problem and an environmental nuisance.

Banana starch is mostly found in green banana fruits. As banana ripens, the starch content decreases because the starch is converted into sugar through enzymatic breakdown process (Blankenship and others 1993) (Mohapatra 2010). The average bunch weight of a banana is 10-14 kg with 5-9 hands and 12-16 fingers per hand. Its sizes are from small to medium, 10-20 cm by 3-6 cm diameter (Lim 2012). Banana peel has 3% starch content (Mohapatra 2010). Its color is yellow-green to yellow. Banana peel is thin, usually with tiny brownish dark speckles. It tends to split once fully ripe, the transverse section is slightly ridged and the apex is lengthily pointed.

E. Degradability

Degradability pertains to a compound that breaks down into simpler compounds. During the degradation of a degradable compound, well defined simpler products are created. The biodegradability test is to be conducted using the Total Organic Carbon Test procedure following a titration method with specified chemicals and equations used to compute and determine the %Carbon and % Organic Matter present within the samples (Ezeoha and Ezenwanne 2013).

CHAPTER 3

METHODOLOGY

A. Overview of the study

A.1 Short Description

This study produced a starch-based bioplastic polymer from Latundan banana (*Musa Acuminata × Balbisiana)* pseudo-stem and identified its percent degradability. Bioplastics have been a promising solution to the declining of oil reserves and rapid oil consumption rates through the previous years with the use and utilization of natural renewable resources. Apparently, most bioplastic resources are from starchy crops that are consumed by people worldwide such as potato, corn, and cassava. The usage of these resources consequently contradicts with the global human consumption of the crops as a food source. Banana pseudostems contain starch very similar to that of potato's, corn's and tapioca's. The amylose content of the starch compares well with that of banana fruit and potato (tuber) starch (21%). Overall, the banana pseudostem starch resembles potato starch. (Shantha H.S. 2006). The banana pseudostems could be a reliable and renewable source of starch and that it could not compete with food consumption unlike bioplastics made from potato, corn, cassava, wheat, and tapioca. In addition to that, the starch from pseudostem could be extracted for the purpose of bioplastic polymer production.

A.2 Time and Place of the study

This study was conducted during the months of December and January year 2014 and 2015, respectively. It was conducted in different laboratories and testing facilities. The starch extraction and bioplastic polymer production were done in the research laboratory and instrument room of Philippine Science High School- Western Visayas Campus. The Total Organic Carbon test was conducted at the DOST Region VI laboratory and they have provided some required chemicals of the said procedure.

B. Collection of Latundan Banana pseudo-stem

Latundan banana pseudo-stem was obtained from a small banana plantation in Jaro, Iloilo City. There is only one species of banana identified; Latundan banana (*Musa acuminata × balbisiana*). The random sampling technique was done to attain the samples of Latundan banana pseudo-stem.

C. Film Preparation

C.1 Isolation of starch from banana pseudo-stem

The banana pseudo-stem was processed by manual peeling of several layers of the skin (epidermis) of the banana pseudo-stem with a clean knife. The samples were then rinsed with running tap water and cut into small pieces to avoid malfunction of the blender due to the fibers present in the pseudo-stems. Isolation of starch from banana pseudo-stem was based from the method of Riley *et. al* 2006 with some modifications. One kilogram of the sliced pseudo-stem was homogenized with 0.9 liters of distilled water using a Magic bullet commercial blender (model: DLJ). The slurry was filtered using triple-layered cheesecloth for the starch to be separated from the mixture. The starch was washed and decanted at least four times with distilled water. After having the starch granules to be settled at the bottom for the fourth time, the supernatant was then discarded. The remaining starch was allowed to air dry overnight at room temperature. The isolated starch was kept in a petri dish until intended use. The extraction process was repeated numerous times until a considerable amount of starch was obtained.

C.2 Starch to polymer production

Twenty-five milliliters of distilled water was measured using a graduated cylinder then was poured into the beaker and was added 2.5g of Banana pseudo-stem starch weighed using an analytical balance. Three milliliters of 0.1M hydrochloric acid and 2mL propan-1,2,3-triol was measured using a micropipette and was added in the mixture. The hydrochloric acid breaks down the amylopectin and changes the structure and properties of the polymer. By blending starch with Glycerol, significant improvements in both tensile strength and elongation at break can be seen. Glycerol also reduces the interaction between protein molecules and increases the flexibility and extensibility of the final product. The procedure of Terer and Magut (2013) was used. The watch glass was placed on the beaker and the mixture was heated using an alcohol lamp. It was brought carefully to boil gently for 15 minutes until the mixture achieves a rather viscous jelly-like consistency. The glass rod was dipped into the mixture and dotted onto the indicator paper to measure the pH. 3 ml of 0.1 M sodium hydroxide should was added to the solution to neutralize the mixture, after each addition was tested with indicator paper. A sodium hydroxide solution was used to neutralize the mixture of the starch-based polymer. It was made sure that it did not boil dry and if it looks like it might, then the heating was ceased. The mixture was then poured onto a labeled flat rectangular foil with the dimension of 5 in x 1 in. and was pushed around with the glass rod so that an even covering was achieved. The mixture was labeled and was left to dry out for 24 hours. Afterwards, It was allowed to be heated in an oven at a temperature of 65 ˚C for 2 hours.

D. Obtaining the Percent degrdability of polymer from Latundan banana (*Musa Acuminata* × *Balbisiana*) starch

D.1 Preparation of chemicals and apparatus

A specified amount of 69.05 grams of ferrous sulfate ($FeSO_4*7H_2O$) was diluted into 500 ml of deionized water to obtain 1 normality for the usage as a titrant. A magnetic stirrer is used to completely dilute the $FeSO_4*7H_2O$ powder and then it is placed in a volumetric flask to acquire exact measurements. One normal potassium dichromate ($K_2Cr_2O_7$) is also dilluted in deionized water. One gram of sodium fluoride is measured using a closet-type analytical balance. One percent of Diphenylamine indicator is prepared and set aside, also a burette is thoroughly cleaned with distilled water then attached tightly on a metal clamp and set aside for latter titration.

D.2 Safety Handling

Potassium dichromate ($K_2Cr_2O_7$) is carcinogenic chemical and gloves were used during it's dillution and transferred with caution. Sulphuric acid (H_2SO_4) is a corrosive chemical in the form of an aqueous solution and gloves are also used. The addition of a strong acid H_2SO_4 to the Potassium dichromate solution will bring about hazardous fumes thus the transferring of the strong acid using a glass pipette was conducted within a fume hood.

D.3 Total Organic Carbon Test

The percent degradability test was conducted using the Total Organic Carbon Test procedure. The sample was cut into miniscule pieces, and a mass of approximately 0.02g each was used to perform the test. The samples were each placed in a 500ml conical flask which contains a biodegradable plastic labelled Blank which contains no sample, 1,2, and 3 to obtain three replicates. The Blank labelled flask was used to make sure that what was being looked for in the test was there in the samples. Ten milliliters of 1 normal potassium dichromate ($K_2Cr_2O_7$) which is a potent oxidizer was pipetted and added to each of the flasks and swirled gently. The samples were allowed to set aside and cool for 30 minutes after 20ml of sulphuric acid was also added which was an oxidizing agent. Thereafter, 200 ml of distilled water was equally added to each flask. One gram of sodium fluoride was added to each flask and was allowed to cool for about 15 minutes. Then 1% of Diphenylamine indicator was added and as a result, will turn the samples black. Titration of the flasks was done using 1 Normal ferrous sulphate solution; titration was stopped when its color changed and shifted from black to green and then the values of the titre were recorded. The instruments used for the testing of the Total Organic Carbon Concentration (TOC) were the usage of a 500ml Erlenmeyer flask, closet-type analytical balance, magnetic stirrer, volumetric flask, stirring rod, fume hood, 50ml burette, and a 20ml bulb pipette.

E. Data Analysis

The % carbon content of the material was given by equation :

$$\% \text{ carbon} = \text{Titre difference} \times 0.003 \times 1.33 \times 100/\text{wt}, \text{ wt} = 0.02\text{g}$$

Wherein the titre difference equals to the Blank titre value minus the titre value of each of the material, 0.003 equals 1 normal $K_2Cr_2O_7$ = 3mg carbon, 1.33 equals correction factor, and wt = weight of sample equals to 0.02g each. The percent organic matter is given by equation:

$$\% \text{ organic matter} = \% \text{ carbon} \times 1.724$$

Where 1.724 is from the relationship; 100g of carbon = 58g of organic matter. (Ezeoha and Ezenwanne 2013).

CHAPTER 4

RESULTS AND DISCUSSION

This study aimed to develop a starch-based bioplastic polymer from Latundan banana (Musa acuminata x balbisiana) pseudo-stem. The objectives of this study include the determining of percent carbon and percent organic matter of the bioplastic from banana pseudo-stem and the testing of its tensile strength.

A. Total Organic Carbon Test Results

Table 1 shows the results on the mean ± standard deviation of the % organic matter and % carbon content of the three titrated samples. The % Organic matter and % Carbon using the equations below:

% Carbon= Titre difference x 0.33 x 1.33 x (100/wt)

%Organic matter= % Carbon content x 1.724

Wherein, the titre difference is equal to the difference between the titre diff of the blank and each of the trial's. 0.33 is equal to 1N potassium dichromate=3mg Carbon, 1.33 is the correction factor. The 1.724 is the relationship between 100g Carbon = 58g Organic matter.

Table 1. Percent Organic matter and Percent Carbon content of the titrated samples

	Mean ± STDEV	Range of Results
% Organic Matter	**51.53 ± 11.64**	**= 63.17** **= 39.89**
% Carbon content	**29.89 ± 6.75**	**= 36.64** **= 23.14**

B. Discussion

The previous executed trials of the starch extraction process obtained after filtered through the triple layered cheese cloth going through a centrifuge at 3000 g for 10 minutes, was a layer of white starch and a dark brown layer above that is an impurity. The slurry that was not thoroughly decanted caused the impurity which consists of minute brownish particles from the slurry, and it is actually not a starch granule. The initial trial for bioplastic production using the starch with impurity produced a dark brown bioplastic which was susceptible to breakage. Another batch of pseudo-stems was used for starch extraction and this time a centrifuge was not used. It was thoroughly decanted with distilled water and it had yielded pure white starch granules after blending, filtering, and decanting. An approximate amount of less than one gram of starch was extracted from one kilogram of banana pseudo-stem. The final product of the produced a bioplastic film had a smooth feel and a light grayish to opaque in visualization of color.

Bioplastic produced from banana pseudo-stem starch has a mean of 51.53% organic matter or biodegradability and a carbon content of 29.89%. In 2013, a study by Ezeoha and Ezenwanne determined the carbon content of the bioplastic from cassava, polythene and paper to be 23.94%, 5.99% and 49.88%, respectively.They also found out that the bioplastic from cassava starch has a biodegradability of 41.27%, and polythene and paper have 10.33% and 85.99% biodegradability, respectively. It is evident that the obtained values are greater than that of cassava, thus this is a very good indication that starch from banana pseudo-stem is indeed a potential source for bioplastic production.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

This study aimed to develop a starch-based bioplastic polymer from Latundan banana (Musa acuminata x balbisiana) pseudo-stem. The objectives of this study include the determining of percent carbon and percent organic matter of the bioplastic from banana pseudo-stem and the testing of its tensile strength.

A. Summary of findings

1. An approximate amount of less than one gram of starch was extracted from one kilogram of banana pseudo-stem.
2. The produced bioplastic polymer had an uneven and lumpy texture and was light brown to opaque in color. Even without the proper testing of tensile strength, it appeared that the bioplastic was quite tough and could not be easily broken upon mannual testing.
3. The results obtained from the statistical analysis of mean ± standard deviation shows that the bioplastic polymer acquired from the Latundan banana (*Musa acuminata x balbisiana)* pseudo-stem starch has a 51.53% organic matter and a 29.89 % carbon content.

B. Conclusion

Bioplastic from cassava starch has a biodegradability of 41.27%, polythene and paper have 10.33% and 85.99% biodegradability, respectively (Ezeoha and Ezenwanne 2013). Bioplastic produced from banana pseudo-stem starch having a mean of 51.53% biodegradability. Therefore it is concluded that it excellently indicates the capability of starch extracted from the Latundan banana pseudo-stem is indeed a potential source of starch for the production of bioplastics. It could also be concluded that the tensile strength of the produced bioplastic product is similar to the conventional polyethylene plastics due to manual testing. The actual tensile test is yet to be further conducted at the Central Philippine University using a tensile strength testing machine specialized for plastics in the Packaging engineering department laboratories. The profound innovation of starch-based bioplastic products could be one of the key solutions in the near future when the petroleum reserves derived from fossil fuels have completely depleted which is the source of the currently conventional petroleum-based non-biodegradable plastics.

C. Recommendations

It is recommended that the coextersion of thermoplastic starch-polyester laminate sheets is to be conducted to obtain a better enhanced water resistant and wear resistant product. The coextersion of thermoplastic starch-polyester laminate sheets can also result to a finely improved equally even layer and thickness, also the quality control of producing the product. The said procedure can also lessen the formation of bubbles within the bioplastic that could cause breakage and low tensile strength.

It is further recommended that the determination of the biodegradability be tested by the process actual degradation of bioplastics by microorganisms present in soil for a certain period of time. It is greatly recommended that extraction of starch is to be done on more various species of banana pseudo-stems for bioplastic production and compare the attained results with the results of the current study and results from other articles for a wider scope of basis.

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APPENDIX A

RAW DATA TABLE

Table 1. Total Organic carbon test was done with 3 rsamples with 1 normal ferrous sulphate ($FeSO_4*7H_2O$) solution, and titration was ceased when the color has shifted from black to dark green

	Weight of samples (grams)	Initial volume (ml)	Final volume (ml)	Titre difference *	% Carbon **	%Organic Matter ***
Sample 1	**0.0209**	**0**	**10.8**	**1.4**	**26.73**	**46.08**
Sample 2	**0.0205**	**0**	**10.9**	**1.3**	**25.30**	**43.62**
Sample 3	**0.0212**	**0**	**10.1**	**2.1**	**37.64**	**64.89**
Mean values	-	-	-	-	**29.89**	**51.53**

Notes: * - The titre difference is equal to blank titre value which is 12.2 mL minus the final obtained volume after titration.
** - %carbon= Titre difference x 0.003 x 1..33 x 100/wt
Wherein the titre difference equals to the Blank titre value of each of the material, 0.003 equals 1 normal $K_2Cr_2O_7$=3mg carbon, 1.33 equals correction factor, and wt= weight of sample.
*** - %organic matter=%carbon x 1.724
Wherein 1.724 is from the relationship; 100g of carbon= 58g of organic matter. Formulas based on *Ezeoha and Ezenwanne, 2013* were used in the computations of data.

Table 2. Statistical analysis obtained raw data by standard deviation for samples

		Mean ± SD*	Range
% Organic Matter Sample 1 Sample 2 Sample 3	**46.08** **43.62** **64.89**	**51.53± 11.64**	**63.17** **39.89**
%Carbon Sample 1 Sample 2 Sample 3	**26.73** **25.30** **37.64**	**29.89 ± 6.75**	**36.64** **23.14**

Notes: * - All values are expressed as mean percent organic matter and percent carbon ± SD. Furthermore, all values are expressed as percentage.

APPENDIX B

PICTURES

Plate 1. The Latundan banana pseudo-stems were thoroughly cleaned with tap water Twas cut into smaller pieces.

Plate 2. The slurry is filtered through a triple layered cheesecloth to a beaker after blending with listilled water.

Plate 3. The remaining starch granules are left to air dry overnight at room temperature then stored in a petri dish until intended use and the extraction process was repeated numerous times.

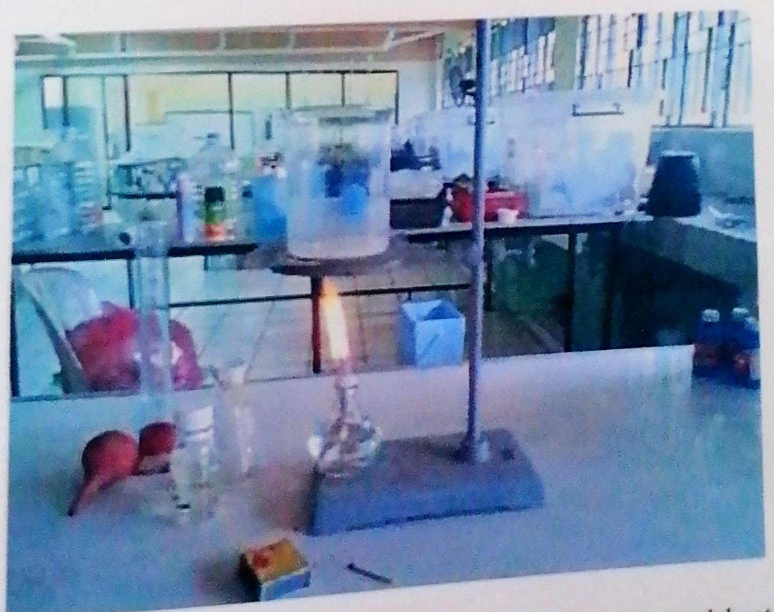


Plate 4. The starch is mixed with distilled water and specified chemicals and heated with an alcohol lamp.

Plate 5. The mixture is heated for 15 minutes and heating was ceased until it attained a jelly-like consistency.

Plates 6-7. After oven drying for 2 hours at 65^{0}C, the final product of the produced bioplastic film had a smooth feel and a light grayish to opaque in visualization of color. It was quite thick and strong by manual testing.

Plate 8. An exact amount of 1 gram sodium fluoride(NaF) was weighed using a closet-type analytical balance at the DOST chemical laboratory.

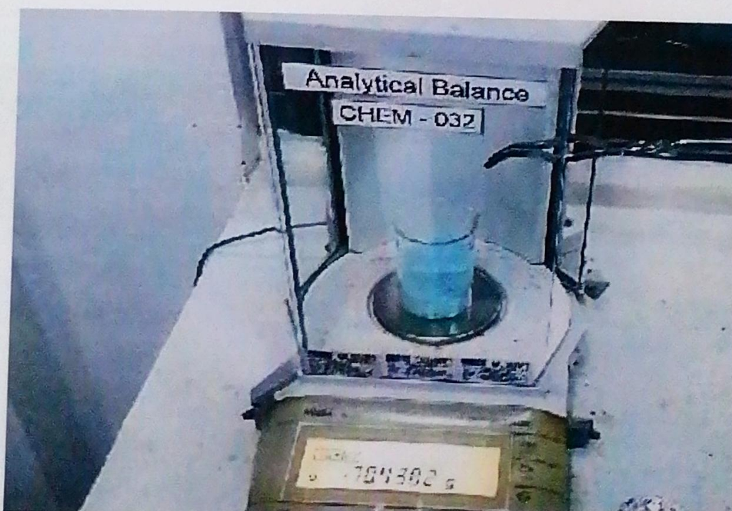


Plate 9. A closet-type analytical balance was used to weigh 69.05 grams of ferrous sulfate ($FeSO_4$*$7H_2O$).

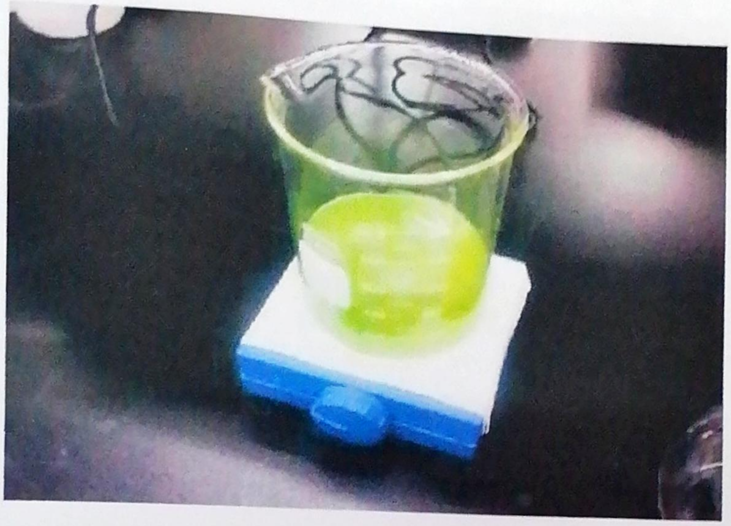
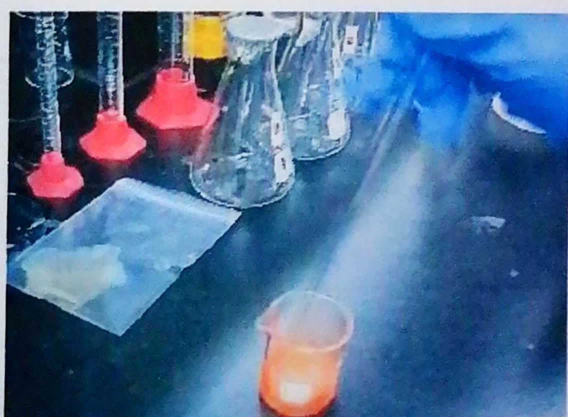


Plate 10. The ferrous sulfate was dilluted into 500 ml of deionized water to obtain 1 and a magnetic stirrer is used to completely dissolve the powder.




Plates 11-12. One normal potassium dichromate (K2Cr2O7) is diluted in deionized water. It is carcinogenic chemical, thus it is diluted and transferred to individual flasks handled with caution.

Plate 13. Sulphuric acid (H_2SO_4) is a corrosive chemical and is also handled with caution.

Plate 14. The addition of a strong acid H_2SO_4 to the Potassium dichromate solution will bring about hazardous fumes thus it was conducted within a fume hood.

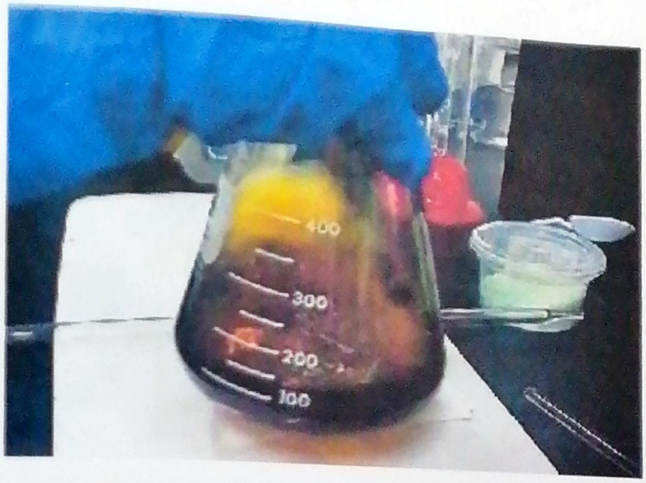


Plate 15. The samples and blank flasks were titrated with 1 normal ferrous sulphate ($FeSO_4$*$7H_2O$) solution, and titration was ceased when the color has shifted from black to dark green end point.

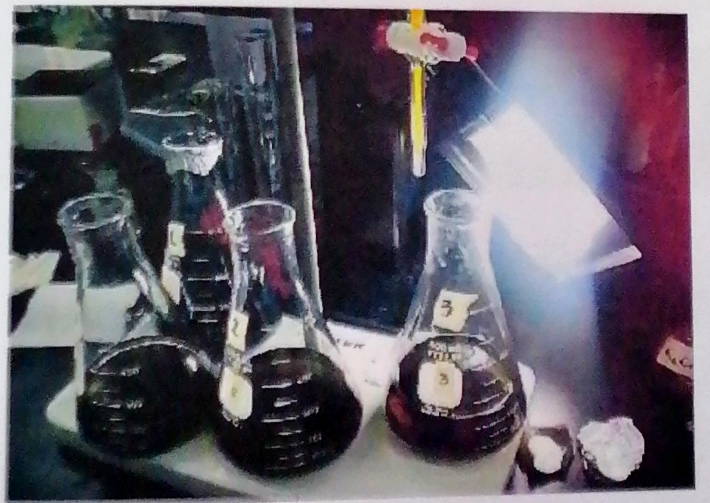
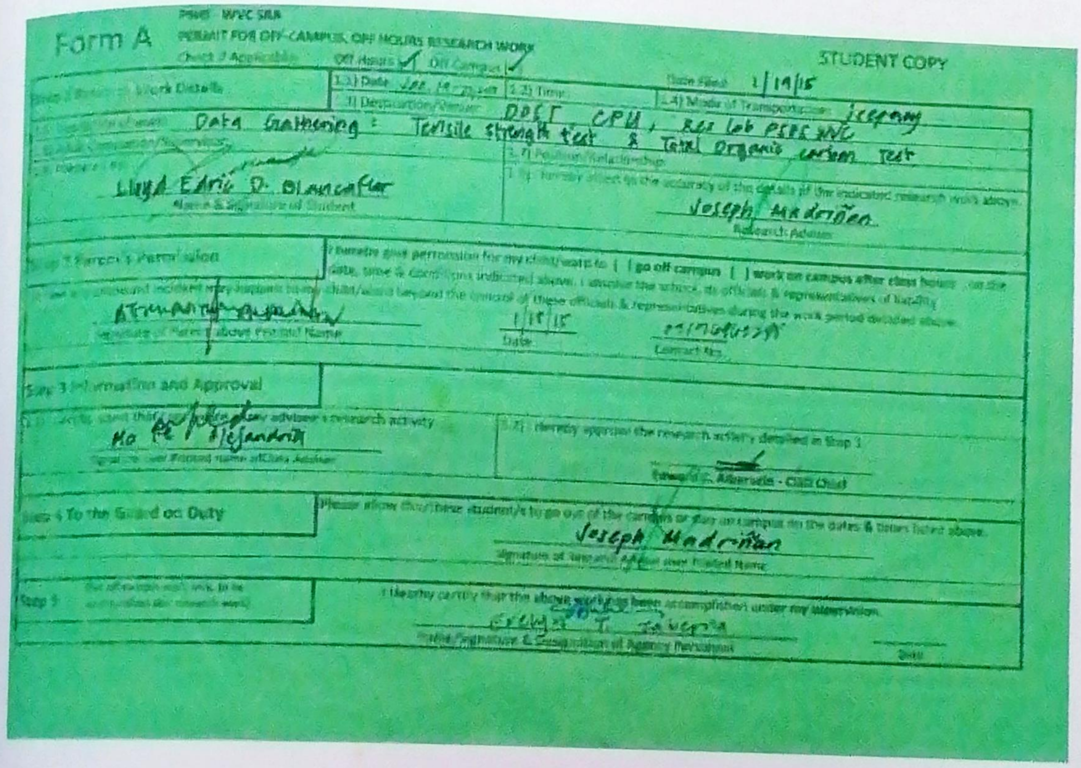


Plate 16. After each titration during every few milliliters of interval it is compared ensure the end point and the titer values were then recorded.

APPENDIX C

LETTERS, PERMITS, AND REQUESTS



Form A

PERMIT FOR OFF-CAMPUS, OFF HOURS RESEARCH WORK

Off Hours ✓ Off Campus ✓

STUDENT COPY

Work Details

Date Filed: 1/19/15

Data Gathering: Tensile strength test & Total Organic carbon test

DOST CPU, Res lab PSPC WVC

Lloyd Edric D. Blancaflor

Name & Signature of Student

Joseph Madriñan

Research Adviser

Step 2 Parent's Permission

I hereby give permission for my child/ward to [ ] go off campus [ ] work on campus after class hours on the date, time & conditions indicated above. I absolve the school, its officials & representatives of liability during the work period detailed above.

Date: 1/15/15

Contact No.

Step 3 Information and Approval

advisee's research activity

Signature over Printed name of Class Adviser

I hereby approve the research activity detailed in Step 1

Step 4 To the Guard on Duty

Please allow this/these student/s to go out of the campus or stay on campus on the dates & times listed above.

Joseph Madriñan

Signature of Research Adviser over Printed Name

Step 5

I hereby certify that the above work has been accomplished under my supervision.

Date

Form B

Permit to Use Research LABORATORY / EQUIPMENT

Date: 1-8-2015

USE OF LABORATORY	DATE(s)	TIME	PURPOSE
Instrument Room	1-8-14	6-8pm	Polymer Production
	1-9-14	6-8pm	Polymer Production
Research Lab Area No: [illegible] (to be filled up by SRA)	1-8-14	6-8pm	Polymer Production
	1-9-14	6-8pm	Polymer Production

QTY	EQUIPMENT / MATERIAL	DATE(s) 1	TIME 1	DATE(s) 2	TIME 2
1	oven	1-9-14	6-8pm		
1	iron ring	1-8-14	6-8pm		
1	iron stand	1-8-14	6-8pm		
1	wire gauze	1-8-14	6-8pm		

We have read and understood the policies and guidelines for the Use of [illegible] the equipment, and keep/dispose materials properly during the entire period given to use. Failure to follow these policies and guidelines would mean suspension of student privilege to use and borrow equipment and facilities under the SRA.

Diego [illegible] — Student Signature over printed name

[illegible] Blanco — Student Signature over printed name

[illegible] — Student Signature over printed name

[illegible] Saven Matrian — Teacher's Signature over printed name

Issued by:		Received by:		Returned by:		Received by:	
[illegible]	1-8-2014	[illegible]	1-9-14				
SRA	Date	Student	Date	Student	Date	SRA	Date