WOLKITE UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

RESEARCH FINAL THESIS ON "PRODUCTION AND CHARACTERIZATION OF BIOPLASTIC FROM BANANA PEELS"

GROUP MEMBERS:	***ID no_***
1. Haile Alemu	***ENGR/404/11***
2. Kurabachew Asefa	***ENGR/506/11***
3. Malkato Mate	***ENGR/549/11***
4. Mesfin Manamo	***ENGR/581/11***
5. Million Engida	***ENGR/599/11***
6. Ruth Ejersa	***ENGR/ 704/11***

Declaration

This thesis has been submitted for examination with approval as university advisor, department head and examiner. We did this thesis in Wolkite University under the guidance of Mr. Abework and we declare that this thesis paper is our original work that we have done in the campus during the last three months in the university but we use different source to do.

Name of advisor: ____

Signature: ________________________

Date: ______________________

Name of Head: __________________________________

Signature: ______________________

Date: _________________

Name of examiner: _______________________________________

Signature: _________________________

Date: ___________________

Acknowledgement

First, we would like to thank our advisor Mr. Abework for his consecutive guidance in Wolkite University. Next, we would like to thank food process engineering department it become voluntary on requesting to do our thesis lab and for the technical and theoretical aspects for our study. At the last but not the least, we would like to thank to all Wolkite university college of engineering and technology department of chemical engineering instructors especially to our department head DR. Gebre Egnet, for his good contribution to give us important information and sharing his knowledge.

Table of Contents

LIST OF TABLE

LIST OF FIGURE

List of Acronyms

AM: Anti-Microbial

AP: Antimicrobial Packaging

ASTM: American Society for Testing Materials

ATCC: American Type Culture Collection

PHB: Poly-β-hydroxybutyric acid

FCC: Fixed capital cost

FCI: Fixed capital investment

FS: Film Solubility

IC: Indirect cost

ICI: Imperial Chemical Industry

ISO: International Standard Organization

MT: Mega Tone

OL: Operating labor

PDA: Potato Dextrose Agar

PHA: Poly hydroxyalkanoic acids

PLA: Polylactide

PVC: Polyvinyl chloride

RRI: Rate of return on investment

TPC: Total production cost UV: Ultra Violate

Abstract

The aim of this study is to develop bio-plastic from banana peels and tests the durability and the efficiency of the plastic produced. Plastic industry is considered one of the most important industries because plastic is an important factor in the making of many useful products such as sheets, tubes, rods, slabs, building blocks and domestic products. Making bio-plastic from banana peels instead of the traditional petroleum-based plastic is believe to be a successful solution to increase the efficiency of plastic industry and of most bio plastics results in reduced carbon dioxide emissions compared to traditional alternatives. The solution produces the same amount of plastic with higher efficiency and durability and with a little cost in less time than normal plastic, so it meets the design requirements of any successful solution, which are production, efficiency, and cost.

The laboratory scale of this thesis was done in Wolkite University in chemical engineering laboratory room in this laboratory the films were carried out with several durability tests, Mechanical (tensile strength and elongation at break) property, Physicochemical properties (transparency, biodegradability or solubility), the effect of temperature and effect of glycerin was tested. The results showed that the plastic produced could bear the weight one and a half time more than petroleum-based plastic, so it is suitable for being use in the making of traditional plastic products. This study also includes the material and energy balance for laboratorial and industrial scale and sizing of equipment. The economic feasibility of the study calculated that made the thesis feasible that the payback period is 1.72 year.

Keywords: - Biodegradability, Bio-plastic, Durability, Elongation, Solubility, Tensile Strength, Transparency

CHAPTER ONE

1. INTRODUCTION

1.1. Background

When Hermann Staudinger (1920) postulated the existence of polymers in 1920, the world of materials changed forever. ‘Plastic’ has become a universal term encompassing the huge array of polymers now available, with wide-ranging chemical composition, mechanical properties, manufacturing methods and raw material feedstocks. Since 1950, an estimated 8.3 billion tonnes of plastic has been manufactured. The material class is found in almost every aspect of human life, and demand continues to grow. Plastic materials are undoubtedly useful, but in recent years the negative impact plastic can have on the environment and organisms living on earth has begun to be understood. This problem is exacerbated by the potential for polymers to leak from waste streams, or be lost as litter before reaching waste or recycling streams. This unmanaged waste can cause environmental and ecological damage, and poses further risks as it breaks down into smaller parts, known as microplastics, which can be mistaken for food by fish or animals, thereby entering food chains and potentially the human body. Alongside decarbonisation of energy supply and the adoption of renewable energy, plastic has become a focus of efforts to improve the sustainability of human life on earth, and a major campaign issue for environmental groups.

Bio plastics are plastics derived from renewable biomass sources, such as vegetable fats and oils, cornstarch, pea starch or micro biota etc. Common plastics, such as fossil-fuel plastics, are derive from petroleum; these plastics rely more on fossil fuels and produce more greenhouse gas. Some, but not all, bio plastics are design to biodegrade. Biodegradable bio plastics can break down in either anaerobic or aerobic environments, depending on how they are manufacture. There is a variety of materials that bio plastics can be composed of, including: starches, cellulose, or other biopolymers and some common applications of bio plastics are packaging materials, dining utensils, food packaging, and insulation (Stefania, 2002).

Plastics that are made from renewable resources (plants like corn, tapioca, potatoes, sugar and algae) and which are fully or partially bio-based, and/or biodegradable or compostable are called bio-plastics. European Bioplastics has mentioned 2 broad categories of Bioplastics: (1) Bio based

Plastics: The term bio-based means that the material or product is (partly) derived from biomass (plants). Biomass used for bio-plastics stems from plants like corn, sugarcane, or cellulose. (2)Biodegradable Plastics: these are plastics, which disintegrate into organic matter and gases like CO2, etc. In a particular time and compost which are specified in standard references (ISO17088, EN 13432 / 14995 or ASTM 6400 or 6868).

Plastics causing environmental pollution because they have non-biodegradable characteristic, beside plastic can contaminate the packaged food because presence of certain substances are potentially carcinogenic than can move into the packaged food. Monomer-monomer on plastics can enter the packages food next can enter the body of consuming. Accumulation of chemical substance in our body are insoluble in water so cannot waste with urine and fesses. Accumulation of chemical substance can make disruption our healthy and causing cancer. Therefore, we must find packaging which have character biodegradable, elastic, and stand of heat. One of alternative to substitute plastic is edible film. Because has characteristics biodegradable, act as barrier to oxygen uptake, and vapor transfer so edible film is harmless. Raw material of polysaccharides for edible filmmaking is starch from banana peel that has composition 18.5% starch (Hotchkiss,1997).

The environmental impact of bio plastics is often debated, as there are many different metrics for "greenness" (e.g. water use, energy use, deforestation, biodegradation etc.) and tradeoffs often exist. The debate is also complicated by the fact that many different types of bio plastics exist, each with different environmental strengths and weaknesses, so not all bio plastics can be treated as equal. While production of most bio plastics results in reduced carbon dioxide emissions compared to traditional alternatives, there are some real concerns that the creation of a global bio economy could contribute to an accelerated rate of deforestation if not managed effectively. There are associated concerns over the impact on water supply and soil erosion (Wikipedia, 2017).

1.2 Statement of the Problem

Bio plastics are used in a wide variety of fields, today’s consumer driven society demands plastic for the manufacture of millions of products (Jutaporn, 2009). This study was focus on natural renewable resources specifically banana peels which has successfully been used to produce plastic that is biodegradable under certain conditions. Biodegradable plastic made from renewable resources is an important material innovation because it decreases dependence on petroleum and reduces the amount of waste material, while still yielding a product that provides similar benefits of traditional plastics. Over the last fifty years, the production of plastic has reached enormous levels. Approximately two hundred billion pounds of plastic are produced worldwide every year (Stevens). This equates to about forty pounds of plastic per person, per year. Between thirty and forty-two percent of plastic produced is used for packaging (Stevens). The rate of consumption influences the overall price of petroleum, contributing to the current rise in raw material costs. We must implement the use of an alternate raw material given the range of applications for which plastics are used. Plastics derived from petroleum are made from synthetic polymers. However, polymer chains are also found in nature. These chains are common in cellulose, lignin, and starch. Starch is common in plants such as cassava, crossover, potatoes, banana, banana peels and wheat. Plants, wood, cassava, crossover, potatoes, banana peels and wheat are all raw materials that are renewable and readily available. There is a limited amount of petroleum available for human use. According to the toxicologists and nutritionists, the side effects of some synthetic antimicrobials are problematic. For this reason, the search for antimicrobials from natural source has received much interest to replace synthetic ones (Jutaporn, 2009). About the health concerns of the consumers, it is highly interested in the use of bio-preservatives in antimicrobial packaging. Ethiopia is rich in biodiversity and there are many plants in the country with great potential of functional qualities. In this research work sodium meta bisulphite are selected as major raw materials for the development of antimicrobial packaging films. The application of antimicrobial banana peelsbased packaging films in preserving highly perishable foods such as fruits and vegetables, meat and meat products, dairy products etc. can contribute to the development of agricultural sector and agro processing industries in Ethiopia

1.3. Objective

1.3.1. General Objective

The aim of this study work is to develop and evaluate bio- plastic from banana peels.

1.3.2. Specific Objectives

- ✓ Extraction of starch from banana peels.
- ✓ Characterize the extract (size, colour, moister content and PH).
- ✓ Analyze the effect of blended banana peel size on starch and fiber plastic production.
- ✓ Evaluate physicochemical properties (transparency, biodegradability or solubility and water absorption) of the bio-plastic films.
- ✓ Evaluate Mechanical (tensile strength and elongation at break) property of bio-plastic film.

1.4. Significance of the Study

Banana grows in a wide range of agro-climatic conditions in Ethiopia. Biodegradable plastics made from renewable resources can retain all the benefits of petroleum-based plastic without the negative environmental impacts. As oil prices rise, more consideration is given to replacing oil derived polymers with polymers produced from renewable resources. So that the use of banana peels would not only create an economic alternative for banana agriculture but would also lead to a reduction in the impacts caused by the intense use of packaging film derived from oil. In addition to renewable raw ingredients, biodegradable materials break down to produce environmentally friendly products such as carbon dioxide, water, and quality compost. Packaging has a significant role in the food supply chain, and it is an integral part of both the food processes and the whole food supply chain. Food packaging must perform several tasks as well as fulfilling many demands and requirements like protect the food from environmental conditions, such as light, oxygen, moisture, microbes, mechanical stresses and dust. Other basic tasks have been to ensure adequate labeling for providing information e.g., to the customer, and a proper convenience to the consumer and a suitable dosing mechanism. In general, the application of biodegradable plastic packaging films make from banana peels will reduce the price of petroleum oil and avoid environmental pollution by replacing petroleum-based packages.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Production of Bio-plastic

2.1.1. From Microorganism

The occurrence of polyhydroxyalkanoic acids as storage polymers in prokaryotic cells is now known to be very widespread indeed. They are water-insoluble compounds. Many bacteria produce an intracellular carbon and energy storage compound - poly-β-hydroxybutyric acid (PHB) - in relatively large quantities. While this property is absent from enteric species, it is widely found in Pseudomonad and related species including the plant symbiotic Rhizobium and also in nitrogenfixing Azotobacter spp. Accumulation is normally a response to unbalanced growth in the presence of excess carbon and energy source. Under appropriate conditions the polymer can amount to more than 50-80 per cent of cell dry weight. The storage product is found as granular inclusion bodies within the cytoplasm. However, many of these compounds represent in relatively small amounts or because of their short chain lengths or other properties are unsuitable as potential bio plastics. Among species synthesizing PHB and PHV are some Archae including Haloferax mediterranea. These halophytic bacteria might present advantages for production as their culture requirements of salinity and relatively high temperature provide little opportunity for growth of contaminants. In species such as Azotobactervinelandii, simultaneous production of large amounts of exopoly saccharide diverts substrate to alternative products and makes recovery of PHB difficult. Development of highyielding mutant strains resulted in conversion rates of 65 percent for PHB and eventual PHA yields of 71 per cent dry weight (Stevens, 2002)

2.1.2. From Natural Resources

Biodegradable plastics – biopolymers on the base of hydroxybutyrate or hydroxyvalerate acids, which are produced in nature during biosynthesis; biodegradable (undergo decomposition under enzymatic action of microorganisms: bacteria, fungi), non-recyclable; another type of biodegradable plastic are blends of synthetic polymers with starch (from cassava, banana peels, potatoes, rise, corn) or cellulose, in which only natural component undergoes decomposition to oxygen dioxide and water (in air conditions) or to water and methane (in oxygen-free circumstance), whereas the synthetic component only breaks up to small pieces and dissipates; relatively expensive (Cuq, B., 2002).

To make plastic from natural sources, the polymers are isolated from the raw material. Depending on the material used, different technologies are required to produce plastic. Typically, the polymers are synthesized using chemicals, physical or by fermenting the sugars. When using banana to produce plastic, the starch is extracted from the banana peels. The first documented interest in producing plastic from renewable resources came from Henry Ford around 1910. Ford was interested in making plastic from agricultural waste. In 1941, he succeeded and produced a “plastic car” from soybean waste mixed with other components to increase strength. Although not a new technology, public enthusiasm for biodegradable polymers did not gain momentum until the 1960s. During this time period, many people felt that too much plastic was being produced and the waste was adversely affecting the environment. New awareness in relation to the human impact on earth gave way to an environmentalist movement that helped push research in the area of plastic. Although not a new idea, the use of biodegradable plastics made from renewable resources for use in packaging has only recently been implemented (Buonocore, 2004).

Natural polymers do not always possess the characteristics desired in a plastic. It is common for natural polymers to be mixed with petroleum-based polymers to obtain desired characteristics. For example, polymers produced from starch are not very strong and can be mixed with petroleumbased plastics such as polyethylene and polyvinyl alcohol to increase their strength. In the 1980s, these mixtures were marketed as biodegradable plastics (Scott 468). These plastics were quickly accepted by consumers but soon came under harsh scrutiny. These polymers present a problem when composted because the starch easily biodegrades, but the polyethylene and polyvinyl alcohol do not. Labeling these polymers as biodegradable is considered deceptive because the residues of these plastics stay in the compost for many years. Polymers produced entirely from renewable resources degrade completely and are not misleading in their claims. When the plastic degrades, it yields carbon dioxide, nitrogen, water, and other minerals. Because of the disagreement over what constitutes degradation, standards have been developed by associations currently involved in the plastic industry. Key organizations that regulate biodegradable plastics are the International Standards Organization and the American Society for

Testing and Materials. Guidelines specify the conditions at which a polymer biodegrades, what constitutes a biodegradable plastic, and the number of additives used in a plastic. Minimum allowances for contaminant levels once the plastic has degraded are outlined and monitored with toxicity tests. These tests determine the impact of any toxic substances on the environment. In order to prove that the polymer is indeed degrading, the weight loss of the polymer mass is measured. In 2002, the production of biodegradable plastics was less than one percent of the production of plastics (Scott 10).

A characteristic of successful innovation is when a technology can be incorporated into many areas. Biodegradable plastic has been successful in many applications. Many farmers use blankets of biodegradable plastic made from petroleum to cover their fields and increase their product yield. Biodegradable plastic produced from natural resources degrade completely, while current polymers leave residues. The medical industry uses large amounts of one-time use products every day. Plastic gloves and other hygienic products are not recycled and are thrown into landfills. In the United States, there is a growing interest in using biodegradable plastics for compost bags. These bags would replace paper and plastic bags. Not only would the yard waste inside the bag be biodegradable, but the bag would also degrade (Buonocore, 2004).

2.1.3. From Plants

The major limitation associated with the production of bio plastics in bacteria is the high cost when compared to the petroleum-derived plastics. Potentially, in turn, the plant offers an alternative approach to synthesize these bulk commodity products at low cost. Whereas PHA production in bacteria and yeast requires costly fermentation process with an external energy sources such as electricity, in plant systems it is considerably less expensive as it relies on water, soil nutrients, atmospheric CO2 and sunlight. In addition, a plant production system is much more environment friendly. While in bacteria PHB synthesis and its accumulation is limited in the cystol, in plants PHB can be produced in a number of sub cellular compartments like cystol, plastids, mitochondria and paroxysms (A. H. Mistry, 1992)

Arabidopsis thaliana was the first plant to be used for PHA production. In Arabodopsis, a small amount of PHB production was first demonstrated by expressing in its cytoplasm two enzymes (acetoacetyl-CoA reductase and PHB syntheses) from the bacterium Ralstoniaeutropha. The polymer produced was of high molecular weight and similar in structure and properties to PHB but the yield was low and plants were stunned in growth. The yield was later increased from 1% to 14% dry wt. The achievement was ground breaking, producing one transgenic plant with 14% dry wt. of PHB in its leaves. Later on, low amount of medium chain length PHA copolymers were synthesized in peroxysomes by polymerization of 3-hydroxyacyl-CoA intermediate generated by degradation of fatty acids in peroxisomes of Arabidopsis plant. After the success of synthesizing PHB in plants, PHB copolymers were produced in both A. Thaliana and seeds of Brassica napus (oilseed rape) (Daniel Hardin, 2013)

Plastic is often used to improve the mechanical properties of fiber-based composites. In case of cotton, R. Eutrphapha genes when successfully expressed in the cystol of its fibers, the fibers from its transgenic plants contained 0.34% PHB, which was sufficient to improve the insulating properties of the fiber. Similarly, in stems of transgenic flax (Linnum usitatissimum), bio plastic has also been produced with an aim to improve the quality of fiber rather than providing a plant source of PHB for extraction. Interestingly, seed production as well as plant growth and morphology were found to be enhanced in these transgenic plants.

2.1.4. From Starch

Starch-based polymers can be thermally processed and can undergo extrusion, injection molding, compression, and film casting Lui’s group showed extensive work on processing techniques that can be used on starch-based materials as well as phase transitions during processing. They also tested processing properties of the starch-based polymers by observing effects of water, glycerol, citric acid and other plasticizers and additives. His group showed that after processing, there was some loss in mechanical function due to temperature changes during processing. The group also showed that processing needed to be controlled and mechanical function of the polymers was based largely on the processing technique and control of moisture within each stage, as an increase in moisture greatly affected the mechanical function in the end stage of processing. Several other studies also found difficulties in working with starch-based polymers and attribute it to difficulties with phase control and control of heat and moisture during processing. (Rafael, 2011)

The thermal processing of starch-based polymers involves multiple chemical and physical reactions such as water diffusion, granule extension, gelatinization, decomposition, melting and crystallization. Between the various phase transitions, gelatinization is particularly important because it is closely related to the others, and it is the basis of the conversion of starch to a thermoplastic. Furthermore, the decomposition temperature of starch is higher than its melting temperature before gelatinization. The well-accepted concept of ‘gelatinization’ refers to the destruction of the crystalline structure in starch granules which is an irreversible process that includes, in a broad sense and in time sequence, granular swelling, native crystalline melting (loss of birefringence) and molecular solubilisation (Bostos & Nilsson, 1998)

Starch is also one of the least expensive biodegradable materials used for many non-food items such as in paper making, cardboard, textile sizing and adhesives. Recently, starch has been used as the main polymer in thermoplastic compositions and has been processed into eating utensils and as raw material for film production. Starch offers an interesting alternative for synthetic polymers where long-term durability is not needed and rapid degradation is an advantage.(M. Hendra, 2015)

2.2. Chemical Composition of Banana Peels

Bananas belonging to the family Musaceae are one of the most important tropical fruits in the world market. Global production of bananas is estimated to be around 48.9 mega tone. India is the largest producer of banana with a production of 39 thousand tons. The states of Maharashtra and Gujarat in Western India, Karnataka in Southern India and Assam in the northeast are large banana growers. Bananas are used fresh or processed into many products such as chips, puree/pulp, powder, jams, juice, bar, biscuits, wine etc. Significant quantities of banana or plantain peels, equivalent to 40% of the total weight of fresh banana, are generated as a waste product in industries producing banana-based products. At present, these peels are not being used for any other purposes and are mostly dumped as solid waste at large expense. It is thus significant and even essential to find applications for these peels as they can contribute to real environmental problems. The manipulation of food processing wastes is now becoming a very serious environmental issue. Peels are the major by-products obtained during the processing of various fruit and some studies show that these are good sources of poly phenols, carotenoids and other bioactive compounds which possess various beneficial effects on human health.

Potential applications for banana peel depend on its chemical composition. Banana peel is rich in dietary fiber, proteins, essential amino acids, polyunsaturated fatty acids and potassium. Banana and tomato peels have been reported to be a good source of carotenoids. Reports are also available on medicinal benefits of banana extract which include relief from pain, swelling, itching, bruising, wrinkles and sunburn. However, there is limited information about the nutritional composition and antioxidant activities of banana peel.

Once a mere waste product, the banana peel has become a source of nutrients, an animal feedstock and a fertilizer. Bananas are the second most popular fruits consumed in the United States. The banana plant is large herb -- a member of the Musaceae family – that originated in tropical southern Asia. It grows to a height of between 6 and 20 feet. In modern times, it is the foremost fruit cultivated in tropical regions worldwide (Buonocore, 2004).

Components	**Sub components**	**Composition(%)**
Organic matter	**Proteins**	**0.9**
	Lipids	**1.7**
	Carbohydrates	**59.1**
	Crude fiber	**31.7**
Water		**6-8**
Minerals	**Potassium**	**0.078**
	Manganese	**0.076**
	Calcium	**0.019**
	Sodium	**0.024**
	Iron	**0.00061**
Anti-Nutrients	**Hydrogen cyanide**	**0.0013**
	Oxalates	**0.00051**

Table 2.1. Composition of banana peels

2.2Functions of Plasticizers in Film Production

Films prepared from pure polymers tend to be brittle and often crack upon drying. Addition of food-grade plasticizers to film-forming solution alleviates this problem (McHugh and Krochta, 1994). When a plasticizer is added, the molecular rigidity of a polymer is relieved by reducing the intermolecular forces along the polymer chain. Plasticizer molecules interpose themselves between the individual polymer chains, thus breaking down polymer-polymer interactions, making it easier for the polymer chains to move past each other. The plasticizer improves flexibility and reduces brittleness of the film. Polyethylene glycol, glycerol, propylene glycol, and sorbitol are the most commonly used plasticizers in edible film production (Aydinli and Tutas, 2000).

Several researchers have conducted studies to evaluate the efficiency of different plasticizers in protein-based films and have developed empirical models to describe the observed phenomena. Sothornvit and Krochta, (2001) found glycerol to be the most efficient plasticizer in a whey protein film matrix. According to Bourtoom, (2008) increasing the plasticizer concentration will decrease tensile strength and the type and concentration of plasticizers can affect the film solubility.

Increasing the plasticizer concentration results in higher solubility. The amount of plasticizer added can cause adverse effects on film properties such as increasing mass transfer through the films. Hence, plasticizers must be used with caution.

When the plasticizer concentration exceeds its compatibility limit in the polymer, it causes phase separation and physical exclusion of the plasticizer. This leads to development of a white residue on edible films which have been referred to as “blooming” (Aultonet al., 1981). Polymeric films should be uniform and free from defects for their applications. Uniformity of the films is critical for their functionalities. During the film-forming process, shrinkage of the films due to evaporation of water or rapid drying often causes defects such as cracks or curling in the films (Obara and McGinity, 1995). Addition of plasticizers such as glycerol or sorbitol is often used to reduce such defects.

2.4.Factors Affecting Plastic Production from Starch

A. **Temperatures: -** reaction temperature is the important factor that affects the yield of bio plastic. For example higher reaction temperature increases the reaction rate and shortens the reaction time due to decreasing activation energy. Bio plastics produced at different temperature have different tensile strength; this tensile strength is characterizing the type of bond created during mixing process.

B. **Type of process followed:-**bio plastics produced using different methods have different chemical and physical characteristics.
C. **Type of raw material:-** starch from different crops have different composition of amylose(linear) and amylopectin (branched) so, bio plastics from different raw material resulted to have different properties(tensile strength, biodegradability etc. properties).Also bio plastic can be produced from fibrous materials with different property.(Chan s.park,2004)

2.5.Market and Price of Bio Plastics

Worldwide bio plastics demand has grown tremendously over the past several years, albeit still representing a small fraction of global plastics demand. As of 2007 it was estimated that worldwide production of bio plastics amounted to approximately 360,000 metric tons (890,000 metric tons by 2012) and was projected to reach 1.5 to 4.4 million metric tons (Mt) by 2020(Matiwos Ensermu, 2012). Another report by the European Bioplastics Association determined global bio plastic production reached 725,000 metric tons in 2010 and forecast production of 1.7 million metric tons by 2015(Rafael, 2011). The Society of the Plastics Industry (SPI) Bioplastics Council estimates the bio plastics industry will grow more than 20 percent annually through 201. According to European Bio-plastics Association, the global production capacity for bio plastics is projected to grow four times by 2020. The prices of any biopolymer are likely to be high when it is only produced on a small scale. The scale of production is likely to have a greater influence on the price than the costs of the raw material source and of the chemistry involved. According to EBA, Bioplastics consumption is likely to reach two million tons by 2018(Rafael, 2011).

2.6. Advantages and Disadvantages of Bio-plastics

a) Advantages

- Reduced CO2 emissions: One metric ton of bio plastics generates between 0.8 and 3.2 fewer metric tons of carbon dioxide than one metric ton of petroleum-based plastics.
- Cheaper alternative: Bio-plastics are becoming more viable with volatility in oil prices

- Waste: Bio-plastics reduce the amount of toxic runoff generated by the oil-based alternatives.
- Benefit to rural economy: Prices of crops, such as maize, have risen sharply in the wake of global interest in the production of bio-fuels and bio-plastics, as countries across the world look for alternatives to oil to safeguard the environment and for attaining energy security.
- Reduced carbon footprint: Oil based plastics require fossil fuel as a key raw material. In addition, oil based plastics like PP and PS require more energy during the plastic development process when compared with bio plastics. A Life Cycle Analysis for a typical PP or PS plastics shows a carbon footprint of approx 2.0 kg CO_2 equivalents per kg of plastic (from cradle to factory gate). These CO_2 emissions are 4 times higher than the CO_2emissions for Poly Lactic Acid (PLA) resin.
- Multiple end-of-life options: valuable raw materials can be reclaimed and recycled into new products, reducing the need for new virgin material and negative environmental impact of 'used' plastic products can be greatly reduced, if not, eliminated.

In the future, bio-plastic products might be recycled in to bio-diesel. Even it is used as a food Sustainable alternative to traditional plastic

- Reduce dependence on fossil fuel and foreign oil
- Fully compostable

b) Disadvantages of bio-plastic

- Cannot be recycle
- Can compete with starch consumers.

Source: http:// www.wikipedia, advantage/disadvantage/htlm.com, 2019)

CHAPTER THREE

3. Material and Methods

3.1. Materials

Materials used for extraction of starch: Banana peels that found at local in Ethiopia, knife which is stainless steel to peel banana and cut the peels, blender to shred the peal, cloth to filter and portable water to wash.

Materials used for film production: Starch, glycerol, vinegar(acetic acid), sodium meta-bisulphite and water. Glycerin is a simple poly compound. It is a colorless, odorless, viscous liquid and has a high boiling point and freezes to form a paste. It is the plasticizer used in the film production. A plasticizer is an additive that softens the material. Evaporating dish for drying purpose. Stove to boil the mixture. Stirrer for well mixing. On the other hand, sodium meta-bisulphite were used for the antimicrobial extraction.

Materials used for validity tests of films: Oven, moisture content analyzer, and PH meter were used for the evaluation of moisture content and PH respectively. Instruments required for testing solubility were 500ml flask, weighing balance, 50ml burette, bulb pipette and incubator shaker. Universal Testing Machine (Instron 5567, USA), equipped with a 1KN load cell at a crosshead rate of 12.5 mm/min. were used to evaluate the mechanical properties of the film. A pair of scissors were used to cut the specimen to the desired size.

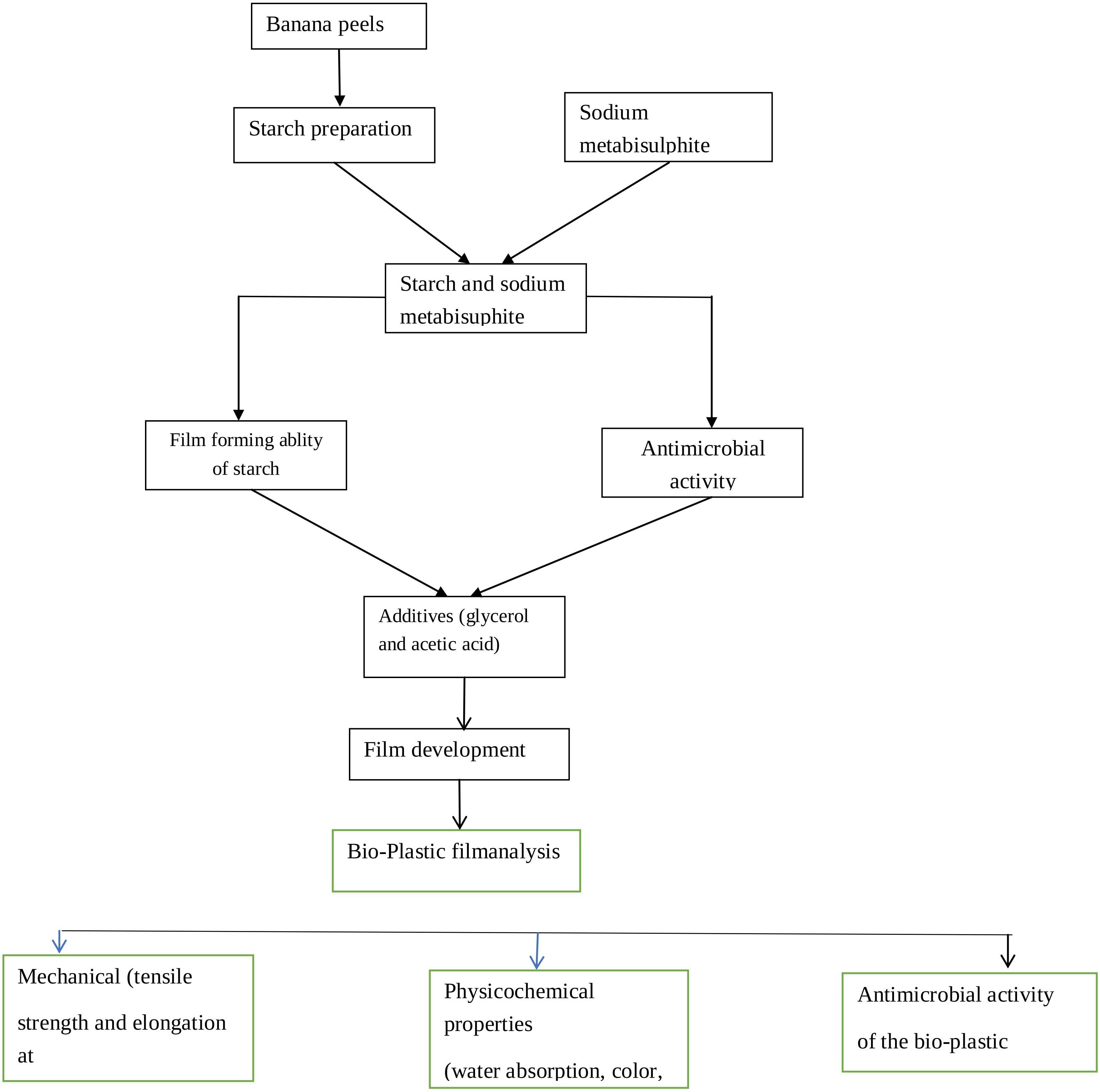
Sample collection and experimental location

The research materials used for this study were banana peels starch, water, vinegar(acetic acid), glycerol, and sodium meta-bisulphite. The banana peels were collected from gubre juice house, a place found in Wolkite zone. All the peels were collected and transported to Wolkite University where they are processed in to extracts. Glycerol (chemical formula $C_3H_8O_3$, Batch G120313) were obtained from campus laboratory chemical store room.

Framework of the experiments:

The research were conducted to develop and evaluate bio-plastic from banana peels starches. The overall frame work of experiments of the research is shown in Figure 3.1.

Overall framework of experiment



3.2. Methods

3.2.1. Extraction of Banana Peel Starch

First, some mildly ripe bananas were picked out as raw material that has to be good in starch content. Banana and its peels were washed until clear, to separate dirt on banana peels. And then, banana peels were cut and shred with blender. Next, it was put in a fresh water to dissolve the starch.

Banana peels which has been mixed with water will filter with addition of water and press with cloth filter until grouts not produce filtrate. After that, filtrate was precipitated for 22 hours until all starch has precipitated. Supernatant liquid were discarding, and precipitate were washed repeatedly until starch precipitate clearer. Next, starch precipitate was dried with oven on 60℃ for 2 hours until dry.

3.2.2. Bio plastic production from banana fiber

3.2.2.1. Preparation of Banana skin

Step 1: Banana peels are removed using stainless steel knife and converted into small pieces. Then peels are dip in sodium metabisulphite (0.2M) solution for 45 minutes.It is used as antioxidant and preservative. This would increase the biodegradation period of plastic.

Step 2: Banana peels are boiled in distilled water for about 30 minutes.

Step 3: The water is decanted from the beaker and the peels are now left to dry on filter paper for about 30 minutes

Step 4: After the peels are dried, they are placed in a beaker and using a hand blender, the peels are pure until a uniform paste is formed.

Figure 3.2 blending banana peels

3.2.2.2 Production of bioplastic:

Step 1: 25gm of banana paste is placed in a beaker.

Step 2: 3ml of (0.5 N) HCl is added to this mixture and stirred using glass rod.

Step 3: 2ml Plasticizer (Glycerol) is added and stirred.

Step 4: 0.5 N NaOH is added according to pH desired, after a desired residence time.

Step 5: The mixture is spread on a Ceramic tile and this is put in the oven 120C and is baked.

Step 6: The tile is allowed to cool and the film is scraped off the surface.

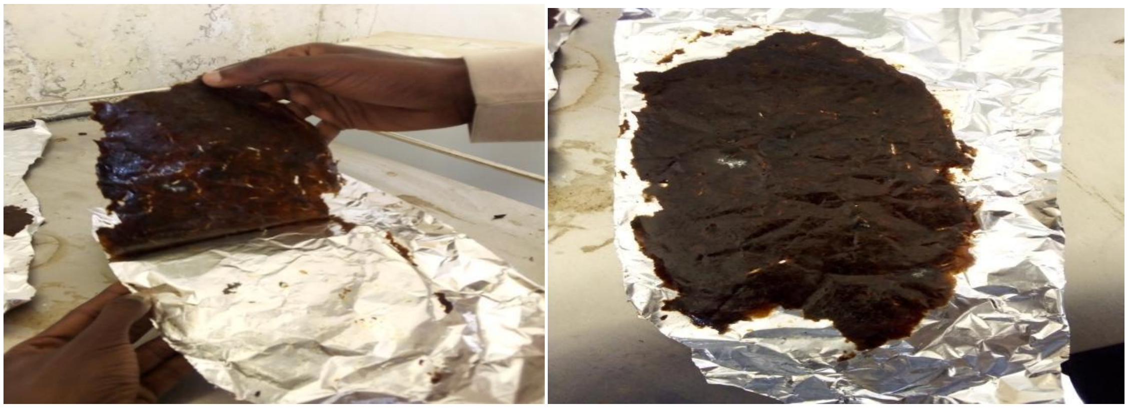


Figure 3.3 Film forming from banana peels

3.2.3. Characterization of the Extracts

3.2.3.1. Size of blended peels

The sizes of blended banana peels affect the amount of starch obtained from the peels, so the size of blended peels were measured by sieve analyzer and should <5µm to obtain appropriate amount of starch.

3.2.3.2. Color and transparency of the extracts

The colors of the two extracts (banana peels pate and banana peels starch powder) were analyzed by visual inspection. Their transparencies at 600 nm could measure by Spectrophotometer (UV 7804C spectrophotometer) but there is no spectrophotometer in the lab to analyze it.

3.2.3.3. Moister content of starch

The produced starch weighed after and before dying. The moisture content is calculated using the equation:

$$Mn= \frac{(W1-Wm)- (W2-Wm)}{W1-Wm}*100$$

Where as: W1= wet weight

W2= dry weight

Wm= plate weight

Mn= percentage moisture content of starch

3.2.3.4. PH value of the extracts

The pH values of peels pate (fiber) and banana peels starch powder will be measured by pH meter at room temperature.

3.2.4. Preparation of Film

First, the starch will extract as explained above and then 10g of the starch will dissolve in 40ml distill water. The mixture will be stirred with hand for 15minute and heat on the stove at temperature of 85°C for 15 minutes. Next, 5ml, 10ml and 15ml glycerol and vinegar(acetic acid) were added.

After, bubbles disappeared and cool, 0.4ml ginger oil will add as antibacterial agent. After that, the solution will be poured on Petridis which its sides clean with glycerol. Lastly, film will have baked for 22hr at different temperature: - 35,50,60,80 and 110°C.

3.2.5. Test for Validity

Different tests were performed for the product validity. These include: Test for physicochemical properties (biodegradability, moisture content, color, transparency, solubility and water absorption), Test for mechanical properties (tensile strength and elongation).

3.2.5.1. Physicochemical Properties Test of Bio-plastic film

3.2.5.1.1. Biodegradable test of plastic film

Test procedure: - Half kilo fertile soil and half kilo of animal dang are prepared with 500ml of distilled water and then the specimen dried in an oven after weighing, buried in the prepared soildung the bio plastic for a week. Then mass lose calculation is done.

Mass loss=Mbefore – Mafter

$$\text{Mass loss rate} = \frac{\text{mass loss}}{\text{No\_ of buried days}}$$

3.2.5.1.2. Moisture content

The moisture contents of composite films were determined by Moisture Analyzer. The results were expressed as an average of two random measurements.

3.2.5.1.3. Color and Transparency of films

The colors of the films were analyzed by visual inspection and the transparencies of the films could determine using spectrophotometer (UV 7804C). The film samples cut into rectangles and place in the internal side of the spectrophotometer cell. The transmittance of films will determinate 600nm as described by Eraricaret al. (2009) but there is no spectrophotometer in our lab.

3.2.5.1.4. Solubility of films

The film solubility (FS) were determined according to the methodology of (Bourtoom, 2009). Film strips with dimension of (2cm x 2cm) were immersed in distilled water (50 ml) for 24 h with slow mechanical stirring using shaker (Excella E24, incubator shaker) at room temperature. Samples were then removed from the solution by filtration and dried in electrical oven (105 °C for 24 h). The initial dry mass were determined from the sample moisture content (determined by gravimetric analysis), and the difference in weight use to calculate the water-soluble matter as a percentage of the initial weight. Then film solubility were calculated by the following equation.

$$FS= \frac{W1-W2}{W1} *100$$

Where FS is film solubility

W1 is initial weight of the film

W2 is final weight of the film after immersion

3.2.5.1.5. Water absorption test

For the water absorption test, the specimens are dried in an oven for 30 minutes at 60°C and then placed in a desiccator to cool. Immediately upon cooling the specimens were weighed. The material is then immersed in water at 25℃ for an hour or until equilibrium. Specimens removed, patted dry with a lint free cloth, and weighed. Water absorption is expressed as increase in weight percent.

3.2.5.4. Test for Mechanical Properties

3.2.5.4.1. Test for Tensile Strength and Elongation

The test were carried out at break The test were carried out at the Strength of Material Section in wolkite university mechanical engineering department, The test specimens were conditioned to conform to standard requirements of thin plastic sheeting in accordance with ASTM D882. From the development plastic sheet, film strips of uniform width and thickness 1" x 6" (25.4 mm x 152.4 mm) will cut. Tensile testing of the bio-films were performed according to ASTM D 882 by using Universal Testing Machine (Instron 5567, USA), equipped with a 1 KN load cell at a crosshead rate of 12.5 mm/min. All teste specimens will require in rectangular shape differing from the conventional dumb bell shape of tensile testing. The test specimens were placed within the grips of the Instron universal tester; tighten evenly and firmly to the degree necessary to minimize slipping during the test. The machine is operating until the specimen fails under load. At rupture, the force and deformation were determined.

Type of bio-plastic	Temperature (°C)	Starch to water ratio	Residence Time(minute)
Bio plasic1	35	1:4	15
Bio plasic2	50	1:4	15
Bio plasic3	60	1:4	15

Table 3.1 Laboratory trials

CHAPTER FOUR

4. Result and Discussion

4.1. Starch Production

From the first trial 110g of starch, from the second trial 125g, from the there'd trial 105g, And from the fourth trial 125g of starch were obtained. Totally 585g of starch was obtained from 2000g of banana peels.

There for:-

$$\% \text{ of starch} = \frac{\textbf{weight of starch}}{\textbf{Weight of peels}} * 100$$

$$= \frac{585\text{g}}{2000} * 100 = 29.25\%$$

Comparison with the theoretical

The Theoretical production of starch is 54% so, the result 29.25% is not the same as the expected value because of the blender efficiency.

4.3. Characterization of the Extracts

4.3.1. Size of Blended Peels Effect

The experimental result shows that, as the size of blended banana peels increase the amount of starch that obtained from it is reduced and it also reduce the properties of bio-plastic obtained from the fiber.

From 1kg well blended banana peels (by using blender) 243g starch was obtained and from 1kg large size (blended by mortar) 198g starch was obtained. And the bio-plastic produced by using large size fiber is easily breakable and have a crack.

Figure 4.1 Bioplastic made from large size fiber

4.3.2. Color and Transparency of the Extracts

The colors of the two extracts (banana peels pate and banana peels starch powder) were analyzed by visual inspection. The experimental result shows that the color of starch powder is whitish brown and the color of fiber is grey. But there is no any Spectrophotometer to measure their transparencies

4.3.3. Moisture Content of the Starch

The produced starch weighed after and before dying. The moisture content is calculated using the equation; -

$$M_n = \frac{(W1-Wm)-(W2-Wm)}{(W1-Wm)} *100$$

Where: W_1=wet weight

W_2=dry weight30

W_m=plate weight

M_n=percentage moisture content of starch

$$M_n = \frac{(72.3 - 12.0) - (58.5 - 12.0)}{(72.3 - 12.0)} *100$$

$$= 22.88\%$$

Theoretical moisture content of starch is 20%; therefore, the starch contains the correct amount of moisture.

4.3.4. PH of Solution

The pH values at room temperature of banana peels paste and banana peels starch powder are given in Table 4.1

Products	pH value
Banana peels paste(Bpp)	5.96
Banana peels starch powder(Bps)	5.89

Table 4.1: The pH value of banana peels paste and banana peels starch powder

All of the samples have pH values in acidic range; these can contribute to the antimicrobial effectiveness of the extracts too. The pH of the extracts can also affect many properties of the packaging film. Nevena et al.,(2010) reported the pH value had significant influence on light transmission, colour, and film solubility.

4.4. Film-forming ability of banana peels paste and Starch extracted from banana peels

The result of the study showed that banana peels paste is poor in producing films. The film was weak in mechanical property and poor physical appearance. Starch powder of banana peels has better film-forming ability than banana peels paste and also reported that films made of starch powder alone were brittle and not easy to handle. Combination of different biomaterials to form composite or blend is a useful solution to enhance the mechanical and/or functional properties of bioactive materials (Rivero et al., 2009). To increase the film-forming capability of the extract, it is advisable to incorporate other suitable film-forming materials with the starch to form bio-plastic films.

This study used glycerol as a film-forming material. As a common edible film-forming material, the applications of glycerol used for bio-plastic films or coatings are reported in the material and methods section. Glycerin is a simple polyol compound. It is a colorless, odorless, viscous liquid and has a high boiling point and freezes to form a paste. It is the plasticizer used in the film production. It has been successfully used to form films that are transparent, flexible, water resistant, and impermeable to oxygen (Hebert and Holloway, 1992).

Polysaccharide and Protein are both hydrophilic biopolymers and have been combined to form composite edible films (Pudji Astuti1, et al., 2014), thus it is reasonable for glycerol and the banana peels starch to be formulated together to form composite films or coatings.

4.5. Bio-Plastic Production

Bio plastic=f (vinegar, water, oil, starch additives, temperature and residence time) change or replacing one item changes the characteristics of plastic. For example, we have tried to observe the influence of glycerol by making plastic without glycerol also for vinegar as well in the laboratory.

Vinegar(acetic acid): - bio plastic without vinegar has characteristics

- ✓ colour less
- ✓ Easily breakable 30
- ✓ Tiny cracks are present on its surface these information tells what vinegar is.

From the above observation, vinegar is polymerizing agent; it helps to connect the monomers each other to form the plastic (polymer) also make the plastic hard.

Glycerin: - the trial bio plastic without glycerol is too hard and brittle from this observation; glycerin helps bio plastic to be flexible and to be more colour less plastic.

Therefore, it is possible to say that by changing concentration of glycerol it is possible to make different materials that have different application. This means when soft and flexible material is needed the concentration of glycerol should increase and when hard material like plastic spoon is needed the concentration of glycerol decrease with respective the others compositions

4.6. Physicochemical Properties Test of Bio-plastic Film

4.6.1. Test for Validity of the Biodegradable plastic Film

Before starting the discussions of the properties of the films obtained, it may be proper to explain some ideas about the film-forming processes and conditions. Several different film forming techniques are available including acid removal, solvent removal, thermal gelation and solidification of melt. In this study acid removal technique were used to produce the films. Elif Bilgin (2013) reported that, acid removal is typically used to produce hydrocolloid bio-plastic films like banana peels-based films. This process, a continuous structure is formed and stabilized by chemicals and physical interactions between molecules.26

When the cohesive strength of the polymer molecules is relatively high, continuous surfaces of the polymer material coalesce. Coalescence of an adjacent polymer molecule layer occurs through diffusion. Film forming process was highly environmental sensitive. The most influencing conditions were the composition of film forming solution, temperature, and duration of heating of the film forming solution, the drying condition, the support used etc. There is a chance of getting plastic films and non-plastic films from deviations of these parameters. Starch, protein and lipid based films have their own optimum temperatures of heating and cooling. For example, starch should be heated about 85°C for its gelatinization to produce starch based films (Eraricar et al., 2009). Protein films could be developed by heating the protein solution at about 40°C (Bower et al., 2006).

The drying condition was important parameter which could influence the quality of films. Milda and Kerry, (2009) reported that drying can either enhance or damage properties of the coating. This study has tried to identify the relatively better temperature of drying for the film-forming

solution in the range 50-70°C and has found that 60°C is relatively better temperature. It does not mean that 60°C is the optimum temperature. Films produced above 60°C were not attractive. They look like burnt and did not have elastic property. This may be the result of denaturation of the starch molecules and became unable to develop bond with each other and other molecules. Films developed bellow 50°C were full of morphological defects such as inclusion of air bubbles shape defects etc. This may result from limited interaction between different molecules. In addition to this, the packaging films were developed under normal atmospheric conditions.
It was difficult to obtain films by drying the film-forming solution at normal atmospheric condition. The film forming solution took longer time (22h) to dry and it has started to ferment instead of drying. Films produced by the tray dryer were homogenous. But determining of optimum drying conditions is still a big issue. The properties of the packaging films obtained are discussed in the following sections.27

Biodegradability test

Table 4.2. Comparison of biodegradability bio plastic and petro plastic in one week

Type of plastic	Initial mass(g)	Final mass(g)	Mass loss(g)	Time to disappearance(day)
Bio-plastics (60°C)	10	8.96	1.04	67.295
Petro based plastics	3	3	0	∞

Mass loss of Bio plastic=10-8.96=1.04gm

Assuming equal mass is lost per day

$$\text{Mass loss rate} = \frac{1.04\text{gm}}{7\text{ days}}$$

$$= 0.1486\text{gm/day}$$

Maximum days needed to completely disappear the 3gm bio plastic is

No days=(10gm)/(0.148gm /day) = 67.295 days

This is the approximate value because it considers 1.01gm bio plastic loss per week, but in reality, this cannot happen due to the organisms around the bio plastic increases exponentially from day to day because the bio plastic used as food.

Figure 4.2 Biodegradable test on bioplastic

4.6.2. Moisture Content

Moisture content of a film at a given air temperature and humidity is an important property of a film that can limit its application in food packaging. The films were developed by varying the proportions of glycerol, starch and baking temperature based on the experimental design given earlier.

Among the nine different treatments, only three were effective to build a film. Banana peels paste (fiber) in the film forming resulted in somewhat plastic films but which are difficult to further process. Second treatment (0ml glycerol and 1g starch/10ml water at 60°C banana peels starch powder in the film forming solution was unable to give stand-alone film. It was resulted in brittle films which are difficult to handle.

The moisture contents of the films are shown in Table 4.3

Table 4.3. Moisture content of the films that developed at 35°C, 50°C,60°C

Product	*Temprature (°C)*	*Moisture Content(%)*
BP1	*35*	*12.17*
BP2	*50*	*10.10*
BP3	*60*	*6.99*

Compared to previous study conducted by Pudji Astuti et al., (2014), the films have somewhat the same moisture content. The difference in moisture content could be related to the difference in composition of the films. In this study starch solution and glycerol were added. The increase in moisture content could also be related to the hydrophillicity of glycerol and starch solution.

Increase of starch solution and glycerol percentage and decrease of baking temperature has the same effect. 32

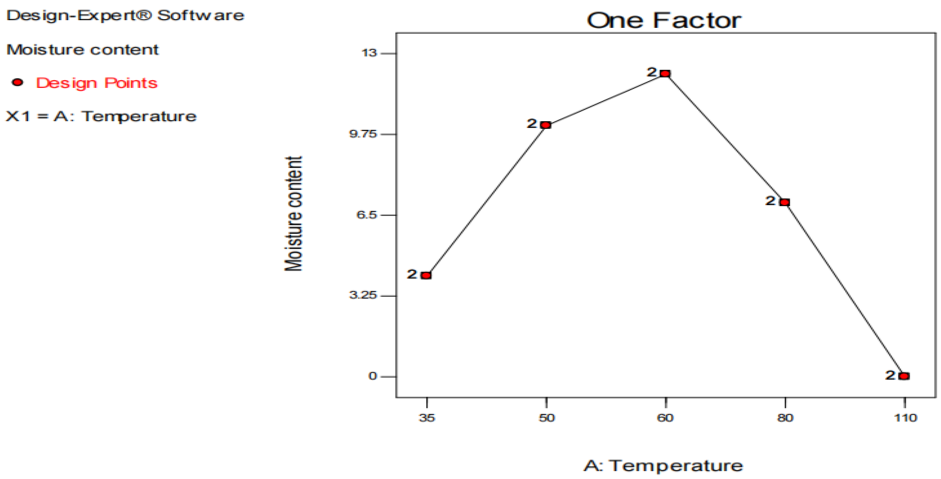


Figure 4.3. The effect of temperature on moisture content

4.6.3. Colour, Transparency and Solubility

Colour attributes are of prime importance because they directly influence consumer acceptability. Visually, all the films developed from banana peels starch powder were darkish. Transparency is also one of the common optical properties of light permeable materials. Development of transparent materials which allow product visibility is a general trend and requirement in films. Transparency was significantly affected by the concentration of glycerol and starch solution. % of transmittance of film increased with increasing glycerol content whereas decrease with increasing of starch solution Pudji Astuti et al., (2014)

Product	Temprature(°C)	Solublity(%)
BP1	35	88.66
BP2	50	60.39
BP3	60	57.68

Table 4.4 *Solubility of the films developed at different temperature*

Film solubility (FS) is a parameter of biodegradability of films and it was expressed as the percentage of film dry matter solubilized in distilled water. Solubility in water is an important property of bio-plastic films, since potential applications may require water insolubility to enhance product integrity and water resistance.

However, in some cases water solubility of the film before consumption of the product might be beneficial (Perez-Gago et al., 1999)

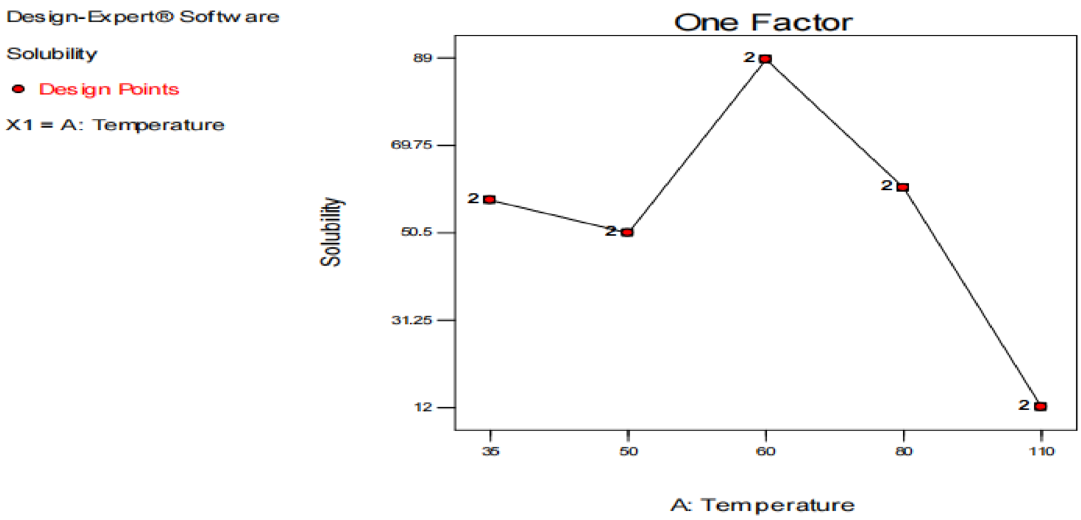


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Figure 4.3 effects of temprature on solublity

Generally, the results indicate that films were soluble. The highest solubility was 98.62% of film composed of 15ml glycerol and 10 g/40ml of starch water at 80°C while the lowest solubility was 12.12% of film with composition of 5ml glycerol and 10g/40ml of starch water at 110°C. Films with even more solubility have been reported earlier. Mahamadou et al., (2007) reported 97.98% film solubility for whey protein isolate films. Film solubility increased significantly as the content of glycerol and starch solution increased and decreased as the baking temperature increased. Cuq, (2002) reported that, in general, hydrophilic plasticizers, such as glycerol, enhance water solubility. It is probably because increasing the plasticizer content in the film increased the water-soluble dry content. The relationship between water-soluble dry matter and hydrophilic plasticizer content is linear (Hernandez -Munoz et al., 2004). Furthermore, the increase of film solubility might be related to the hydrophillicity of starch solution Jutaporn et al., (2011) reported that an increase in phayom wood extract in edible films led to an increase in film solubility. It could be hastily concluded that starch solution enhances film solubility in water.

Figure 4.5. Solubility test of bio-plastic

5. Material and energy balance

5.1 Mass Balance across Each Unit during Plastic Production

Assumption:-from practical laboratory point of view for quality of plastic production the ratio of starch to water to be 1gm/4ml.

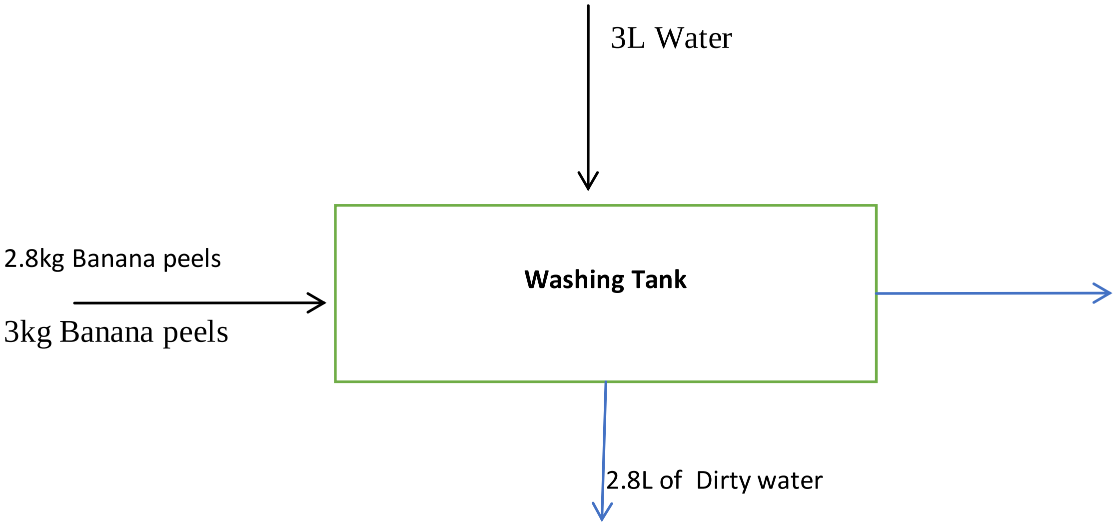
- ✓ Production capacity = 750.08kg/day
- ✓ The total working days = 14days/year.
- ✓ Density of starch = 1792kg/m3
- ✓ Density of glycerol =103kg/m3
- ✓ Density of vinegar(Acetic Acid) =1051kg/m3 @20°C

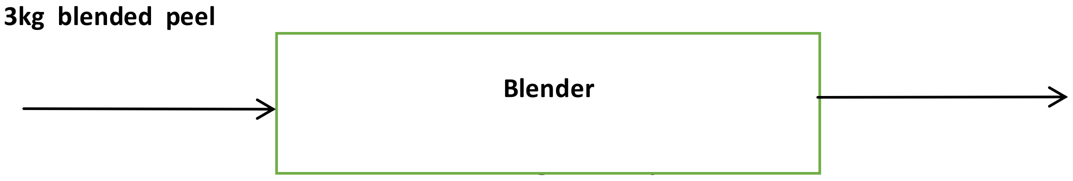
5.1.1. Mass Balance on Laboratory Scale

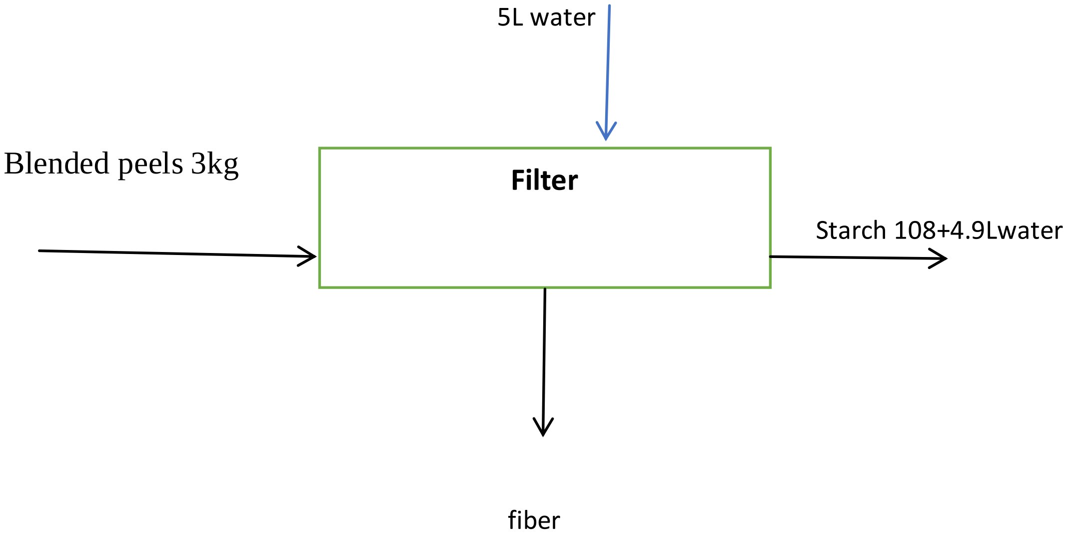
Input+ generation – accumulation - consumption = out put

Assuming steady state process will be used, then generation, accumulation and consumption become zero.

Therefore, input =output



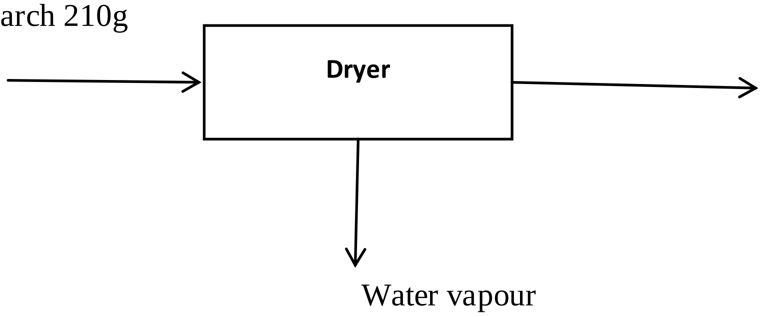




Wet fiber = (3000+5000) g-1080g+4900g=**2020g**

Wet starch 1080g

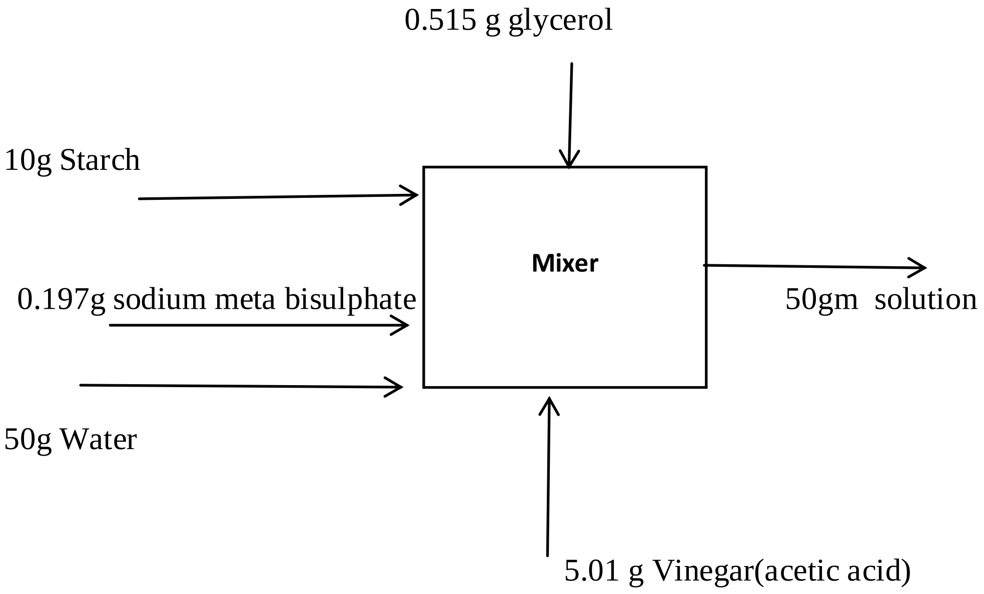
dry starch 210g



Water vapor =1080g-210g

Water vapour=870g

Mass of starch+ M glycerol +M of water +M vinegar(acetic acid) = solution



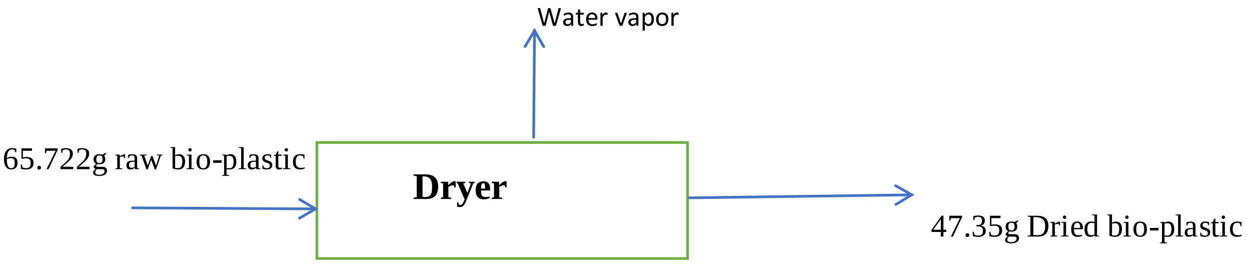
Mass of solution = mass of water + mass of starch +mass of glycerol +mass of vinegar + mass of Sodium meta bisulphate

=50gm +10gm+0.515gm+5.01gm+0.1972g

=65.722

Mass of raw bio-plastic = mass of solution

= 65.722g



Dried plastic = Raw plastic –Water vapor

65.722g = 50.685g + Water vapour

Mass of water vapour=18.369g

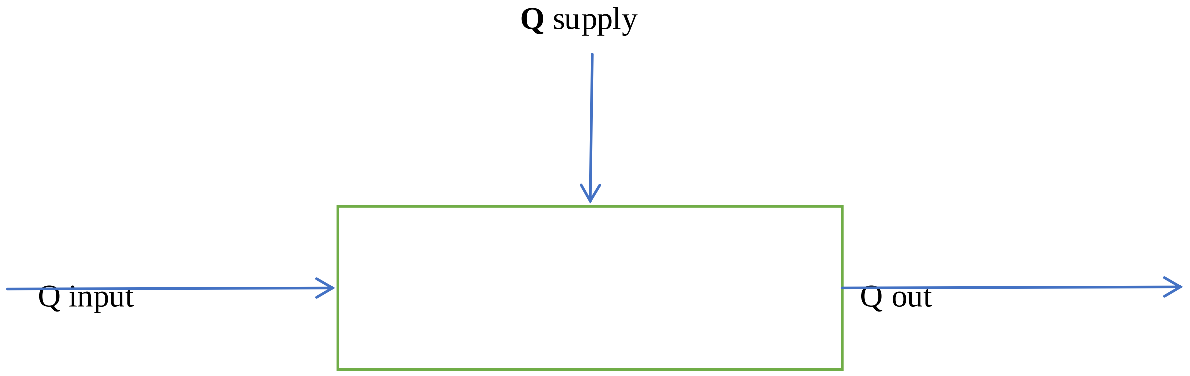
Percentage water evaporated=13.723g /65.722g ×100= 27.95% of the total solution evaporated

5.2. Energy Balance

5.2.1. Energy Balance on Reactor

Table 5.1. Physical properties of substances

Substance	Chem.formula	Mw(kg/kmol)	Input temp	Cp(kJ/kg.k))	Mass(kg/hr	Massfraction
Starch	$C_{27}H_{48}O_{20}$	692	25	0.8	16.52	0.153
Vinegar	CH_3CO_2H	60	25	2166.6	7.877	0.0761
Glycerol	$C_3H_8O_3$	92	25	2227.2	0.861	0.0079
Water	H_2O	18	25	4185.5	80.203	0.763
Total					105.461	1



Heat supply +heat of reaction +energy with input material- energy with output material=0

$$\mathbf{Qsup+Qrxn+Qin-Qout=0}$$

$$\mathbf{Qsup + (\sum nHp- \sum nHr) + (MsoluCpT) - (Mplastic\sum YiCp = 0}$$

Msolun= mass of vinegar+ mass of glycerine+ mass of starch+ mass of water

Simplifying gives:

Qsup = (7.877kg/hr×2166.6J/kgo c×25o c) + (0.861kg/hr×2227.2J/kgo c×25o c) + (16.52 kg/hr ×0.8J/kgo c×25o c) + (80.203 kg/hr ×4185.5J/kgo c×25o c)

= (426,657.705+47,940.48+330.4+8,392,241.41) J/hr

Q supply =**2,463.1w**

CW (cooling water) inlet temp T= 25 o C

Cs (starch) inlet T =25 o C

Cs outlet, T = 60 o C (Temperature of starch from water-bath)

CW outlet T = 85 o C (water from jacket)

Reactor temperature T = 85o C

Approaches minimum temperature differences of the cooling jacket and the reactor

ΔT1=85 – 60 = 250C =298K

ΔT2= 85 – 25 = 600 C= 333K

LMTD = (ΔT1 - ΔT2)/ ln [ΔT1 /ΔT2]

LMTD = 315.18K

5.2.2. Energy Balance on Dryer

Initial moisture content of plastic (Y1) =67%

Final moisture content to be (Y2) = 35%

Inlet temperature of bio-plastic=60 oc

Out let temperature bio plastic=80 oc

Wet plastic flow rate to dryer (Gs) = 72.92kg/h

Inlet gas temperature =100 oc

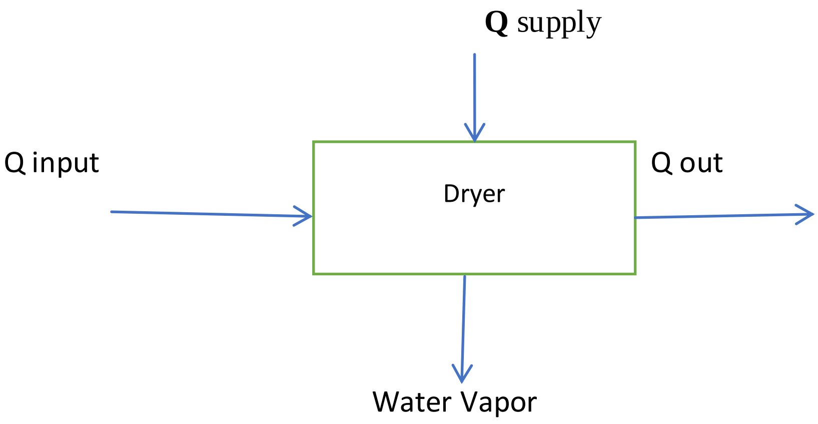
Gas outlet temperature =80 oc

Inlet gas moisture content(X1) =1.5%

Out let moisture content(X2) =4.3%

Cp of gas at T=100 o c =1010J/K oc

U-of dryer under good condition is =60W/m oc



Qinput+Qsupply-Qvapour-Qoutput=0

Qsupply= Qoutput+ Qvapour-Qinput

Qsupp=$m_s$cp(Tin-Tout)+ $m_v\lambda$- $m_g$cp(Ti-Tout)

Where λ=2257KJ/kg

6. Financial Evaluation and Site Selection

6.1. Financial Evaluation

This design project aims to present a process that is capable of operating under conditions which will yield profit. As a necessity the economic viability of this manufacturing business must be addressed considering the society and government with which it will operate. The primary concern of an investors lies in the rate of return (ROR) based on accurate cost estimates and sound data.

Basis of economic analysis:

- ✓ Start of construction: January 2024G.C
- ✓ Completion of construction: January 2026G.C
- ✓ Production start January 2024G.C
- ✓ Plant operation: for 24 hour 3 shifts per day
- ✓ Process: continuous
- ✓ Plant production rate:1750kg plastic per day
- ✓ Plant operates 14days/year
- ✓ Tax rate based on our country rule and regulation=35%
- ✓ The service life of the plant estimated to be 20 years
- ✓ The depression value is $2800/year
- ✓ Maintenance period two wise a year

The financial analysis of our plastic production plant project is based on the current raw material cost tabulated & the diagrammatic relationship of different costs.52

Table 6.1. Costs of equipment

Equipment name	Materials of construction	Equipment Cost ($)	Type	Size of the equipment
Reactor	Stainless steel	7252	Jacketed and agitated	5283gal.
Mixer	Stainless steel	6210.5	Homogenizer	175gal
Blender(extruder)	Carbon steel	7680	Screw molding	173.45gal
Dryer	Stainless steel	9540.5	Drum drier	5283.4galon
Total		30683		

Can found from http://www.alibaba/machines.com/equipment corresponding to their size.

6.1.1. Estimation of Total Capital Investment Cost

Direct cost

Direct cost is the type of fixed capital investment costs that directly applicable for plant erect

Table 6.2. Direct cost

Direct cost component	Assumed (%) of equipment	cost Cost (%)
Total purchased equipment	100E	56,351
Installation	39E	21,976.89
Instrumentation and control cost	13E	7,325.63
Piping cost	31E	17,468.81
Cost of electrical system	10E	5,635.1
Cost of buildings and structures	29E	16,341.79
Cost of yard improvement	10E	5,635.1
Service facility and utility cost	55E	30,993.05
Cost of land	6E	3,381.06
Total		**165,108.43**

In Direct Cost(IC)

Indirect cost is another type of fixed capital investment cost that applicable for plant erect indirectly.

Table 6.3. Indirect cost with ranges and selected percentage

Indirect component cost	Assumed (%) of equipment cost	Cost ($)
Engineering and supervision cost	32E	18,032.32
Construction expenses	34E	19,159.34
Contractors' fee	18E	10,143.18
Contingency fees	36E	20,286.36
Total		**67,621.2**

Therefore:

Fixed capital investment cost (FCI) = DC + ID =$165,108.43+ $67,621.2=**$232,729.63**

Total capital investment

The total capital investment = fixed investment + working capital investment

In most plants working capital investment takes (10-20) % of total capital investment. In this plant, it is assumed that 15% of total capital investment cost.

Therefore, Total capital investment = fixed capital investment + working capital investment

TCI = FCI + 0.15TCI

TCI = $232,729.63+ 0.15%TCI

TCI (1-0.15) = $232,729.63

$$TCI = \frac{\$232,729.63}{0.85} = \mathbf{\$273,799.56}$$

Working capital = 0.15TCI = 0.15*$273,799.56= **$41,069.93**

6.1.2. Estimation of Total Product Cost

Total product cost = manufacturing cost + general expense

Manufacturing cost = direct production cost + fixed charge + plant-overhead cost

Total raw material cost = 10 – 50% 0f total product cost

Table 6.4. Raw material cost with transportation

Material	Mass Kg/year	Unit Price ($)	Total price ($)
Vinegar	840,000	1.028	863,520
Glycerol	90,000	4.7	423,000
Sodium meta bisulphate	5,000	1.7	8,621
Total			1,286,520

Assume raw material cost 30% of total production cost.

Fixed charges

- ✓ Depreciation (10% of FCI for machineries) = 10%*$232,729.63**=$23,272.963**
- ✓ Local taxes (1-4%of FCI) assume 3% = 3%*$232,729.63= **$6,981.889**
- ✓ Insurance (0.4-1% of FCI) assume 1% = 1%*$232,729.63= **$2,327.296**

Total fixed charges = **$32,582.1482**

Total fixed charges = 15% of total product cost

Total product cost **=** $32,582.1482= **$217,214.321**

Direct production cost

- ✓ Raw material (10-50% of TPC), assume 30% = 30%*$217,214.321= **$65,164.296**
- ✓ Operating labor (OL) (10-20% of TPC) assume 15% = 15%*$217,214.321=**$32,582.148**
- ✓ Direct supervisory and electric labor (10-25% of OL) assume 15% = 15%*$32,582.148**= $4,887.322**
- ✓ Utilities (10-20% of TPC) assume 15% = 15*$217,214.321= **$32,582.148**
- ✓ Maintenance (2-10% 0f FCI) assume 6% = 6*$232,729.63= **$13,963.778**
- ✓ Operating supplies (OS) (10-20% of maintenance) assume 15% = 15%*$13,963.778=**$2,094.567**
- ✓ Laboratory charges (10-20% of OL) assume15%=15%*$32,582.148**= $4,887.322**55
- ✓ Plant and loyalties(2-6% of TCI) assume 4%=2%*$273,799.56= **$5,475.991**
- ✓ Plant overhead cost (5-10% of TPC) assumes 5% = 5%*$217,214.321**= $10,860.716**
- ✓ Patent and royalties (0-6% of TPC) assumes 2%= 2%*217,214.321=**$4,344.286**

Total Direct production cost = **$176,842.574**

Manufacturing cost = fixed charges + direct production costs

Manufacturing costs = $32,582.1482+$176,842.574**= $209,427.723**

General expense

General expense = administrative cost + distribution and selling costs + research and development costs + interest

- ✓ Administrative cost (2-6% of TPC) assumes 2% = 2%*$217,214.321**=** $**4,344.286**
- ✓ Distribution and selling costs (2-20% of TPC) assume 3% = 3%*$217,214.32=**$6,516.43**
- ✓ Research and development cost (2-5% of TPC) = 5%*$217,214.321= **$10,860.716**

- ✓ Interests (0-10% of TCI) assume 3% = 3%*$273,799.56= **$8,213.987**

General expense = **$29,935.419**

Total expense = general expense + manufacturing expense= $29,935.419+ $209,427.723=

$239,363.142

6.2. Project Evaluation

In this part the profitability of the plant is evaluated by finding the profit of the factory obtains from the sale of bio-plastic. From the plant capacity that we decide the annual production rate of the plant is 15,000kg bio-plastic/day or 3,750,000kg bio-plastic/year at the full capacity.

The average unit selling price for bio-plastic = $1.034/kg

Total selling price = total production*unit price

= 1750kg/day*$1.034/kg = $1,809.5/day

Since the company works 250days in a year, 115day is for maintenance and break.

= $1,809.5/day *280day/year = **$452,375/year**

A. Profitability analysis

Gross profit = total income – total expense 56

Total expense=$239,363.142/year

Total income = $452,375/year

Gross profit =$452,375/year– $239,363.142/year= **$213,011.858/year**

Net profit

Net profit = Gross profit*(1-income tax)

Tax in Ethiopia is 35% of income.

Net profit = $213,011.858/year *(1- 0.35) = **$138,457.708/year**

B. Rate of return on investment (RRI)

RRI = (net profit average / total capital investment)*100

= ($138,457.708/year/$273,799.56/year)×100

=50.57%

C. Payback period

Payback period = total capital investment-working capital/ (net profit/yr+ Depression/yr)

= $273,799.56-$41,069.93/ ($138,457.708+$2,800) = 1.72 year

Payback period =1.72year, it is almost 2 years to pay the whole investment cost.

Since the payback period is less than 5 years the project is feasible and acceptable.

D. Annual cash flow

In addition to the initial investment ($273,799.56), the manufacturer states that the reactor, blender,

driers, conveyors and the filter machine will need to be replaced two wise in a 1year. The

associated cost for this will work out to be $15,354/year. The total life of the plant is 20 years.

So, our maintenance cost is= $15,354/year

Assuming $351salvage value at the end of the 20-year period.

Depreciation cost of the company is= $\frac{(\$273,799.56 - \$351)}{20}$ = $13,672.428

6.3. Site Selection

It is obvious that plastic is a highly demandable goods and services in the whole part of ethiopia.

But in Arbaminch there is a surplus raw material of banana is easily cultivated throughout the year also it makes more feasible to erect this plant in the Arbaminch.

The selection of this site is based on the following conditions.

1. The selected site is near to raw material source, so that the transportation cost to the site is the minimum.

2. The selected site power availability is nice and have a good transportation.

3. Have a good working environment that are preferable for workers and if we want to expand the plant it have enough man power and human power.

4. The cost of transporting finished goods, advertising and distribution is reduced since it is located near to the capital Hawassa Wolita sodo and Shashemene.

Labour cost is an important item of the total production in manufacturing and in the selected site labour is highly available and the cost of labour is very cheap.

7. Conclusion and Recommendation

7.1. Conclusion

Bio plastics are plastics derived from renewable biomass sources, such as vegetable fats and oils, corn starch, banana starch, orange starch, pea starch or micro biota, potato starch and etc. It is one of the most innovative materials being developed in the packaging industry and producing bioplastic from starch reduce dependence on fossil fuel and foreign oil and also fully compostable or degradable after use. This study indicated that banana peels starch, vinegar, ginger oil and glycerol can be used to formulate bio-plastic films. The film forming ability of the banana peels starch was highly improved by the addition of glycerol and vinegar. The experimental trial of bio plastic without glycerol and vinegar is too hard, brittle, easily breakable and forms cracks. From this observation; glycerol and vinegar help bio plastic to be flexible plastic. Addition of more plasticizer (glycerol) made the films more hydrophilic, sticky, and difficult to handle.

Therefore, the optimized concentration should be known. This work was determined that the optimized value of starch, glycerol concentration and baking temperature were 1g, 31% and 60$_{o}$c respectively.

The antimicrobial system formed by banana peels bio-plastic packaging films, showed better antimicrobial activity on bacteria and fungus. The antimicrobial property of the film-forming solution has been improved by the addition essential oil from ginger. The films developed were strong enough. At beginning, tensile strength was significantly decreased with increasing glycerol because plasticizers weaken the intermolecular forces between the chains of adjacent macromolecules, increasing the free volume and causing a reduction of mechanical resistant (Sobral et al., 2001). Elongation at break was significantly increased by the addition of glycerol.

And they were increased with increasing baking temperature. The strength increases when the temperature increases from 35-80 $_{o}$c. The bio plastic plant will be construct with capital investment of $239,363.142 in Arbaminch and the expected payback period is 1.72 year. The erection of this plant will solve economic, social, political and environmental problems of the country is feasible. Generally, these bio-plastic packaging films may have the potential to prolong the shelf-life of foods and reduce the burden of petroleum products on the environment.59

7.2. Recommendations

Development of bio-plastic from banana peels starch using glycerol as plasticizer is studied before this study but the methods that we used to extract starch and film is for the first time in this research in Ethiopia; Even though a biodegradable plastic film was produced in this work, a better result would have been obtained if the necessary techniques and equipment needed were available. More research should be continued in this field, especially in developing countries so that we can have cleaner nations by reducing the conventional plastic waste in the environment and to create sustainable development.

Extensive researches are still needed on the following two major aspects:

1. Concerning the film

✓ Study the permeability (water vapor and gas transmission rates) of films.

✓ Evaluating the barrier properties of these films.

✓ Study the effect of hydrophobic plasticizers on the properties of these films.

✓ Study the effectiveness of these films on different foods during storage.

✓ Study migration kinetics of the antimicrobial component from the film to the food.

✓ Study the effect of stirring time and temperature on the both physico-chemical and

mechanical properties of this film.

✓ Study on production of fuel by using waste film.

2. Concerning banana peels

✓ Qualitative and quantitative determination of antimicrobial substances in banana peels

extracts.

✓ Study the effect of processing condition on the extraction of starch from banana peels.

✓ Study on fast precipitation method of starch solution during starch preparation.

✓ Qualitative and quantitative determination of antioxidant substances in banana peels extract.

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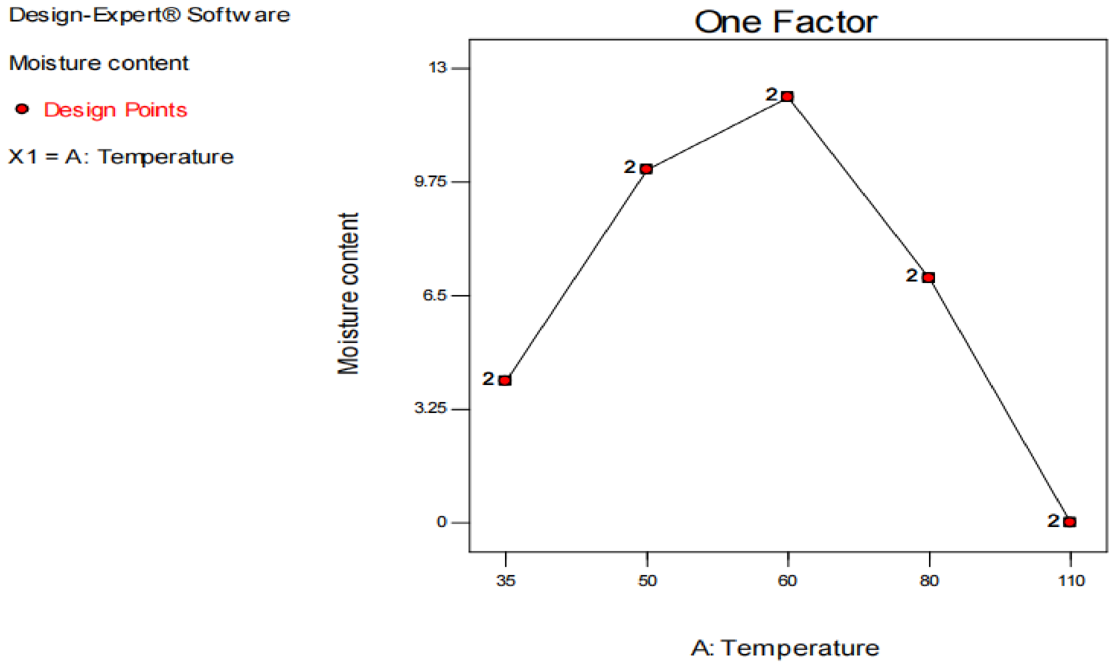
APPENDIX

Effect of temperature on moisture content, solubility, and water absorption.

I. Effect of temperature on moisture content



II. Effect of temperature on solubility