



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CHEMICAL AND BIO ENGINEERING

Formulation of Shoe Polish from Wax and Used Water Sachets

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ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
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I declare that this thesis for the M.Sc. Degree at Addis Ababa University, hereby submitted by me, is my original work and has not previously been submitted for the degree at this or any other university, and that all resources of materials used in this thesis have been duly acknowledged.

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A final word

I am aware more than ever before of how much I have learned from this study and will continue to learn from my lecturers, respondents, other authors and readers involved in this field of study. If you have a comment or suggestion for making this research thesis work better, please email me at: betrework68@gmail.com.

Abstract

The conversion of Used Water Sachets to Shoe Polish was investigated. Used water sachets were pyrolyzed at various temperatures to obtain polyethylene (sachet) wax. Polyethylene wax with good melting point, yield was produced between 100 - 200°C, used to produce the shoe polish. Three different formulated shoe polishes were prepared from polyethylene wax and the properties of the three samples were compared with the standard polish (Kiwi). The density, melting point, physical testing of shoe polish, and viscosity of the polish formulated using different percentage of used polyethylene wax, compared favorably with standard commercial polish.

The effects of temperature and pyrolysis time on the properties of polyethylene wax produced from used water sachets were investigated. Used water sachets were pyrolysed at temperatures between 100 -200 °C for 30-60 min.

The effect of temperature and pyrolysis time is significant on the yield and melting point of sachet wax produced. The sachet wax obtained had the melting point of 76 °C while the yield of sachet wax was 35.4 %.Waste sachets pyrolysed at 100 °C for 45 minutes produced sachet wax from used water sachets with yield of 35.4 %, good melting point & viscosity.

Keywords: Used Water Sachets, Polyethylene Wax, Pyrolysis, Shoe Polish.

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List of Acronyms/Abbreviations

Acronyms/abbreviation

MSW

FCI

TCI

WC

IRR

MC

VC

AC

FC

BEP

CSBR

HDPE

LDPE

PVE

PS

PP

Full expression

Municipal solid waste

Fixed Capital Investment

Total Capital Investment

Working Capital

Internal Rate of Return

Moisture Content

Volatile Matter

Ash Content

Fixed Carbon

Break Even Point

Conical spouted bed reactor

High Density Polyethylene

Low Density Polyethylene

Polyvinyl Chloride

Polystyrene

Polypropylene

Chapter One

1. Introduction

1.1. Background

The emergence of polish technology in engineering is apparent offshoot complexities resulting from the indication of substances that produce desired goals and provides a protective coating for the surface of the materials, changing in to a dry adherent film. Therefore, shoe polish is a substance usually wax based, which applied to a surface wax based, which applied to a surface protects, makes it smooth and shiny. It has been discovered that shoe polish industries in Ethiopia are at minimum even though the polish industry is economically very important due to its widespread usage. The manufacture of surface coating materials of which shoe polishes a part has been estimated with more than 10,000 million yearly. This in essence means that its usage is wide spread and in terms of employment, gives lot of opportunities.

The demand for polishes largely met through import. Ethiopia imports a variety of polishes and creams used in different applications. The data source for import statistics i.e. Ethiopian Revenue and Customs Authority classifies import of polishes and creams under the following headings.

34051000 – Polishes, creams and similar preparations for foot wear or leather;

34052000 – Polishes, creams and similar preparations for maintenance of wood work; and

34053000 –polishes, creams and similar preparations for coachwork

Among the above three types of polishes and creams imported during the period 2000-2001 , only the first two types , which are intended for use in footwear and wood are considered in the analysis of past supply and present demand . The quantity and value of the two types of shoe polishes and creams imported in the past 12 years covering the period 2000-2011 is presented in Table 1.1.

Table 1.1 Ethiopia's imported shoe polishes

Year	Amount of Shoe Polish [Ton]	Cost in (000) Birr
2000	382.2	9776
2001	478.8	12,959
2002	393.7	10,825
2003	345	8,642
2004	473.4	12,495
2005	586.2	15,312
2006	587.5	19,159
2007	672.3	20,441
2008	661.1	23,482
2009	495	25,095
2010	568	37,991
2011	442.1	33,313

Source: - Ethiopian Revenues and Customs Authority.

The objective of this thesis research was to convert used water sachets to useful product such as wax and to formulate solid Shoe Polish. The properties of the shoe polish produced were, studied and compared with standard commercial shoe polishes.

1.2. Problem of Statement

All over big cities in Ethiopia and even in the rural communities, it is a common sight that polyethylene films, shopping bags, plastics, water sachets littering and polluting the environment.

Plastic is a light, durable synthetic material that has found a lot of use in the modern world. The plastic material comes in various types depending on its application. Polypropylene (PP) is the most widely used plastic type in the world today followed by Polyethylene (PE). There are many other forms of other plastics whose applications depend on intended purpose. Large production and use of plastics for various applications has resulted in huge volumes of plastic wastes. This has lead to proliferation in the environment as a result of accumulation and fragmentation of plastic waste. Most of this waste is non-degradable and highly resistant to light, acids and other tough conditions. Some of the negative impacts resulting from poor waste plastic disposal include; choking and starving marine and wildlife, littering the surrounding environment and blocking drainage systems and water bodies. Burning of plastics in open fires, landfills or by use of municipal solid wastes (MSW) incinerators releases toxic gas emissions. These gases include the persistent organic

pollutants (POP's) such as dioxins. Studies have proved that this gas are carcinogenic and have endocrine disrupting effects in a wide range of biota. Other emissions include the Green House Gases (GHG's) that cause global warming.

It has been, discover that shoe polish industries in Ethiopia are at minimum even though the shoe polish industry is economically very important due to its widespread usage.

It is, therefore necessary to convert these huge used water sachets in to useful raw material. This material called Polyethylene (Sachet) wax formulated from used water sachets was very important to produce shoe polish.

1.3. Goal and Objectives

1.3.1. General Objective

To formulate shoe polish from wax and used water sachets

1.3.2. The specific objectives of this research are:-

- To formulate polyethylene wax from used water sachets
- To Prepare shoe polish from bee wax & polyethylene wax
- To characterize the product
- To determine the optimum parameters (temperature, time, mixing ratio).
- To evaluate the performances of shoe polish and compare with commercial product
- To optimize the process parameters using experimental design software.

1.4. The Significance and its applications

Considering the fact that there are few or practically no functional shoe polish industry in the country and the imported shoe polish , most times do not meet up with the local weather conditions due to this ,research thesis was helped a solution to these problems, and at the same time offer local alternatives to these imported products. Importantly, exploiting the benefit offered by this research work was helped in improved the qualities of shoe polish produced. This was help in making the shoe polish industry a viable venture; this product will be exported and there by serving as a foreign, exchange earner for the country.

A waste-to-shoe polish process and technology is valorized as an alternative sustainable energy source. This contributes significantly in solving the socioeconomic, health and environmental problems linked to waste disposal in general and plastic waste management in particular.

Chapter Two

2. Literature Review

2.1. Research Problem Analysis

Wastes are inevitable and can be found everywhere. They are the essential derivatives of every process. Wastes are therefore can be defined as any garbage, rubbish or other discharged materials resulting from industrial , commercial domestic , mining and agricultural activities. In a sense, wastes can be regarded as any material discarded as having no consumer value to the person abandoning it. Wastes pollute the environment if they are not properly disposed and managed. On the other hand if it is properly disposed and managed will not constitute any environment problem and as such, pollution will eradicated. This is because wastes are just (useful) materials in the wrong place. (Ahmadu, 2007). Thus wastes can simply be considered as nothing but unsorted scraps. Scraps are useful raw materials that can be recycled in to new products. Thus , the enormous problems caused by used and wrongly disposed polyethylene products (used water sachets) can be reduced to barest minimum if properly sorted and recycled in to useful products typical of shoe polish production.

Municipal waste plastic represents about 8% wt. of the municipal solid waste and it generally consists of different kind of plastics. This waste is difficult to be treated or recycled due to its complex nature and composition, structural deterioration of the polymeric components and the contamination with various organic, inorganic and biological residues.(Ademiluyi F. Oboho E, JULY 2013).

All over big cities in Ethiopia and even in the rural communities, it is a common sight that polyethylene films, shopping bags, plastics, water sachets littering and polluting the environment.

The increase of plastic waste and its harm in Ethiopia environment has attracted the concern of the political and technological circles. These days, the waste polyethylene (often called used water sachets) is known to cause blockage of drainage systems in our townships and in rural commodities, since these waste films are non biodegradable this has resulted in the flooding of our communities whenever it rains and subsequent destruction of houses and farmlands.

Polyethylene is a macromolecular hydrocarbon that can be converted into useful products such as oil and waxes but since the molecular chain of polyethylene is composed of -CH₂-, the freezing point of the diesel obtained is very high and the research octane number of

Gasoline is very low. Thus it is not a feasible way to convert polyethylene to oil. It is, however a profitable way to convert polyethylene waste to polyethylene wax (Jixing *et al.*, 2003).

Several studies have been carried out to produce wax from waste. A study on the conversion technology of waste polyethylene plastic (Used water sachet) to polyethylene wax was carried out by Jixing *et al.*, (2003). The effect of the reaction conditions including pyrolysis temperature, pyrolysis time, and the content of the additive on the yield and quality of the polyethylene wax such as melting point, density were discussed.

The polyethylene wax obtained has a melting point of 65-125°C, the yield of PE wax is over 30 %. Using used polyethylene water sachets of 97.72 % at 130-190°C, they obtained fuel oil of 18.30 %, 76.14 % of wax and 3.28 % of gaseous products. This result showed that more wax can be obtained at temperatures lower than 190°C , but the property of wax obtained was not determined in this study. This result showed that more wax can be obtained at temperatures lower than 190°C. Owolabi and Amosa (2010) studied the effective management and potentials of conversion of water sachet to a more useful product such as super wax. Four different samples wax were formulated, but only solidification time of 30-60 minutes was observed for each of the samples. Also the properties of wax such as melting point, density of the wax obtained from the waste sachets were not determined in this study. In order to produce quality wax that meets industrial standard with this polyethylene waste, there is need to control the operating variables such as pyrolysis temperature and time during the pyrolysis process. (William *et al.*, 1955).

Therefore, in this paper the conversion of used water sachet to polyethylene wax and their characterization and optimization of shoe polish would be studied. The effect of pyrolysis temperature, and pyrolysis time, on the yield, and melting point of polyethylene wax produced from waste water sachets was discussed.

The Existing Technology of the production of shoe polish mainly based on using Inorganic constitutes, this raw material are their own disadvantage, they are toxic, unhealthy, environmental impact on the society, due to this it is better to use alternative technology of producing shoe polish from organic raw materials (Bee wax , olive oil), this raw materials are very important in terms of reducing wastes ,technology transfer ,reducing foreign currency, cleaning environment ,so that due to this ,it is better use alternative production process of shoe polish from used water sachet.

2.2. Introduction about Shoe polish

Shoe polish is a waxy paste or cream used to shine waterproof or improve and restore the appearance of leather footwear and products and it, issued both liquid and semi-solid form. Weather inexpensive or high end, all leather shoes require a good polishing to prolong their lives and keep them looking new. Shoe polish consists of waxes and solvents. Shoes polish is available in a number of colors e.g. black, brown, transparent etc. Liquid polishes are also available where the waxes exist as an emulsion. Shoe polish not only used on footwear but can also applied to all leather materials including bags, etc. Floor polishes are pastes, creams, or lotions used to clean, protect, and shine floor. These products originally made from natural waxes, which were hard to apply and tended to leave a heavy buildup over time. Today these formulations combine natural waxes and oils with petroleum based ingredients and synthetic polymers (Secchi., *et al*, 2005).

Shoe polish products are low-value items that are infrequently purchased, as a single can be last several months for even the most frequent user. Consumer demand is inelastic and largely insensitive to price change, while sales volumes are generally low. In the shoe polish market as a whole, some 26% of turnover is accounted for by pastes, 24% by creams, 23% by aerosols, and 13% by liquids. In recent years, the demand for shoe polish products has either been static or declined; one reason is the gradual replacement of formal footwear with sneakers for everyday use. There are numerous branded products available, as well as generic store brands. There are two chief areas of shoe polish sales: to the general public, and to specialists and trade, such as shoe repairers, and cobblers. The sales percentages between the two outlets are roughly comparable.

Kiwi remains the predominant shoe polish brand most of the world, being sold in over 180 countries but is often see as a mass market product more known for its cheap prices rather than quality. Today, it is manufactured in Australia, Canada, France, India, Pakistan, South Africa, Spain, the United Kingdom, and the United States.

2.2.1. Composition and Toxicology

Shoe polish consists of a waxy colloidal emulsion, a substance composed of a number of partially immiscible liquids and solids mixed together. It is usually made from ingredients including some or all of naphtha, lanolin, olive oil, turpentine oil, wax (Bee wax), gum Arabic, ethylene glycol, and if required a colorants, such as carbon black or an azo dye (such as aniline yellow). It typically has a specific gravity of 0.8, is negligibly soluble in water, and is made of between 65 and 77% volatile substances—usually naphtha. The high amount of volatile substances means that the shoe polish will dry out and harden after application, while retaining its shine. (Ademiluyi F.Taiwo, April 2013).

Lanolinis, hydrophobic grease from wool-bearing animals such as sheep or goats, acts as both a waterproofing wax and a bonding agent, giving the shoe polish its greasy feel and texture. It prevents the naphtha from evaporating until the polish has been spread and buffed into a thin film on the leather surface. An essential ingredient in shoe polish is a thickener; without this, the polish would be too runny, making it difficult to use. Gum Arabic, a substance from two sub-Saharan species of the acacia tree, is commonly used to increase the viscosity of the product.

Shoe polish contains chemical substances which can be absorbed through the skin, or inhaled. When handling shoe polish, one should ideally wear gloves, and stay in a well-ventilated area. Shoe polish should be kept out of reach of children and animals. It can stain the skin for a protracted period of time, and will cause irritation to the eye if there is direct contact.

2.2.2. Non -toxic Shoe polish

Commercial shoe polish contains various toxic substances. Generally, shoe polish is made from ingredients including naphtha, lanolin, wax, bicarbonates of potassium and various types of coloring pigments. It also contains carbonates and bicarbonates of sodium and potassium. The burning of shoe polish results in the yielding of carbon dioxide, carbon monoxide and traces of oxides of nitrogen and various toxic materials depending upon the chemicals, and solvents used to make the shoe polish. To make a good and non -toxic shoe polish, olive oil, bee wax and sachet wax are collected. Bee wax a tough wax formed from a mixture of several compounds including hydrocarbons (14 %) , monoesters (35 %), dieters (14 %),trimesters (3 %),hydroxyl monsters (4%),hydroxyl polyesters (8%),acid esters (1 %),acid polyesters (2%),free acids (12%),free alcohols(1%) and some unidentified materials.(Honeybee Natural 2006)

2.3 Motivations for the Study

As shown in figure 2.1, Plastic waste is produced by manufacturers and consumers of products are dumped and burned; this study focuses on consumer plastic wastes from used water sachets. Obtaining plastics components from used water sachets in a reusable form and quality is highly doubtful implying that recovered high calorific mixed plastics are most appropriate for Pyrolysis.

Recycling reduces waste volumes and contributes to energy and resource conservation. Thermal or tertiary recycling (hydrolysis, pyrolysis or gasification) is a technique that uses heat to decompose plastics in the absence or limited amount of oxygen for the formulation of shoe polish. This process applies to mixed plastics from MSW which cannot be cost-effectively recycled (Noda et al., 2001). The success of this technique is supported by the economic and energy feasibility resulting from Recuperating and sorting of plastics ,generating income and creating jobs, Thermal conversion is efficient without pollution, Residue treatment, and waste dumping or landfill costs are minimized

However, depending on the source, type and quality of the waste plastics, the economic benefits may vary. In addition, markets for certain recycled plastics are only available at rates of 10-15% of plastics recycled due to their inferior quality and recycling cost compared to virgin polymers (Williams & Williams, 1997).Due to this it is very efficient to convert waste plastic, used water sachets in to shoe polish.



Figure 2.1 Consumer waste plastics form a complex mixture

2.4. Theoretical Basis of Plastic Waste

Plastic is a light, durable synthetic material that has found a lot of use in the modern world. The plastic material comes in various types depending on its application. Polypropylene (PP) is the most widely used plastic type in the world today followed by Polyethylene (PE). There are many other forms of other plastics whose applications depend on intended purpose.

Large production and use of plastics for various applications has resulted in huge volumes of plastic wastes. This has led to proliferation in the environment as a result of accumulation and fragmentation of plastic waste. Most of this waste is non-degradable and highly resistant to light, acids and other tough conditions. Some of the negative impacts resulting from poor waste plastic disposal include; choking and starving marine and wildlife, littering the surrounding environment and blocking drainage systems and water bodies. Burning of plastics in open fires, landfills or by use of municipal solid wastes (MSW) incinerators releases toxic gas emissions. These gases include the persistent organic pollutants (POP's) such as dioxins. Studies have proved that these gases are carcinogenic and have endocrine disrupting effects in a wide range. Other emissions include the Green House Gases (GHG's) that cause global warming.

The disposal of mixed waste in landfills, dump sites and open burning without material and energy recovery leads to resource loss, causes health problems, pollution and littering. Increasing energy demand for industrial and domestic application with rising costs due to scarcity motivates a constant search for alternative clean energy sources.

Recovering wax from waste presents various incentives e.g. creating jobs, alleviating poverty, combating and mitigating climate change, protecting the environment and reducing dependence on traditional fuels sources. Unfortunately, most non-biodegradable, high calorific value waste fraction (plastics) has little or no application in most developing world communities. Hence, plastics end up in landfills, surface waters and ocean bed with serious negative impact on terrestrial and aquatic biodiversity.

Plastic waste with high calorific value (36-46MJ/kg) occupies the greatest portion of landfill space given their very slow degradability. When openly burned, plastics produce high pollutants such as VOCs, PAHs and PCDD/F (dioxins). The formation of these pollutants is not inherent of the polymers but is consequent of limitations of the combustion process. Hence, using an appropriate technology to transform waste plastic to sachet wax which is burned and mixed with Bee wax to produce Shoe polish.

Polymers can define as materials made from many units. Polymer is seeing as a chain, made up of various smaller units, these units could be carbon, hydrogen, oxygen, and silicon.

A plastic material is an organic solid, essentially a polymer or combination of polymers of high molecular mass. A polymer is a chain of several thousand of repeating molecular units of monomers. The monomers of plastic are either natural or synthetic organic compounds. The term resin is sometimes used as synonym of a commercial polymer.

Plastics can be classified by chemical structure, i.e. by the main monomer of the polymer's backbone and side chains. Some important groups in these classifications are the acrylics, polyesters, polyolefin, silicones, polyurethanes, and halogenated plastics.

Plastics can also be classified by the chemical process used in their synthesis, such as condensation, and cross-linking. Other classifications are based on properties that are relevant for manufacturing or product design, e.g. thermo plasticity, biodegradability, electrical conductivity, density, or resistance to various chemical products.(Alejandro Villanueva, End-of-waste criteria for waste plastic, 2014).

Majority of plastics that are used today are non biodegradable in nature, they remain in environment for long period which affects environmental quality. As there is no effective segregation and recycling system for these plastic waste generated, it Increases load on landfill sites because of their non-biodegradable nature and ultimately cause environmental problems like air, soil and ground water pollution as well as loss of marine biodiversity.

Plastic waste recycling for energy recovery is yet to be exploited in most of the developing countries where advanced Municipal Solid Waste (MSW) management technologies such as pyrolysis are yet to be fully implemented. Recycling of post-consumer plastic waste for shoe polish production through a cost effective and an environmentally friendly process could become an alternative means of obtaining shoe polish.

2.4.1. Polyethylene (PE)

Polyethylene is a macromolecular hydrocarbon that can be converted into useful products such as oil and waxes but since the molecular chain of polyethylene is composed of $-CH_2-$, the freezing point of the diesel obtained is very high and the research octane number of gasoline is very low near 88. Thus it is not a feasible way to convert polyethylene to oil. It is, however a profitable way to convert polyethylene waste to polyethylene wax (Jixing *et al.*, 2003).

Waxes derived from petroleum products are basically paraffinic wax and microcrystalline wax. Several studies have been carried out to produce wax from waste. A study on the conversion technology of waste polyethylene plastic to polyethylene wax was carried out by Jixing *et al.*, (2003).

2.4.1.1. Low density polyethylene (LDPE)

In LDPE some of the carbon atoms are attached to three carbon atoms instead of two, this causes a branch on which other polyethylene chains are attached. These branches are relatively long and link with other polyethylene molecules. LDPE is like one long piece of spaghetti, with lots of large pieces of spaghetti attached to it. In contrast to HDPE, LDPE has more branching that results in weaker intermolecular force, thus lower tensile strength and hardness. However, LDPE has better ductility than HDPE since the side branching causes the structure to be less crystalline and easy to be molded.

It has an excellent resistance to water, soft, waxy, and smooth to touch, and has a shiny appearance. It is normally used in garbage bags, cling wrap, sandwich bags, squeezable bottles thus widely applied as plastic bags, wrapping foils for packaging, trash bags and much more. All these items are commonly used in our daily lives and therefore, and LDPE wastes have a great potential to be used in pyrolysis process since it can produce high solid yield depends on the set up parameters for shoe polish formulations. LDPE waste has been accumulated day to day that it is known as the second largest plastic waste. (Shafferina Dayana Anuar Sharuddin, A review on pyrolysis of plastic wastes, 2016)

2.4.1.2. High density polyethylene (HDPE)

HDPE is characterized as a long linear polymer chain with high degree of crystalline and low branching which leads to high strength properties. Due to its high strength properties, HDPE is widely used in manufacturing of milk bottles, detergent bottles, oil containers, toys and more. The various applications contribute about 17.6% in plastic waste category which is the third largest plastic type found in municipal solid waste .HDPE wastes have a great potential to be used in pyrolysis process since it can produce high liquid yield depends on the set up parameters. Many studies have been conducted on HDPE pyrolysis at different operating parameters to investigate the product yield obtained. (Shafferina Dayana Anuar Sharuddin, A review on pyrolysis of plastic wastes, 2016).

Used water sachets is Low Density Polyethylene , It has an excellent resistance to water, soft, waxy, and smooth to touch, and has a shiny appearance, compared with High density polyethylene , due to waxy nature it is better use LDPE ,for the formulation of shoe polish instead of HDPE.

The use of low-density polyethylene for packaging treated water is on the increase in Ethiopia. Polyethylene films (commonly called pure water sachets in Ethiopia) are therefore seen littering the cities, schools, stadium, wedding reception venues etc. During packaging of the water, lots of waste polyethylene is generated. These polyethylene films are non-biodegradable and can remain on the ground for years.

Pyrolysis is a thermal treatment process where waste is subjected to heating in an atmosphere with a deficiency of oxygen below the stoichiometric combustion level. The thermal degradation of polyethylene generates a mixture of gases, oils and waxes (Bertolini et al, 1987).

2.4.2. Plastic Waste (used water sachets) Disposal as a Global Problem

The high calorific value of plastics underscores the need for an alternative material recovery technology that is affordable, efficient, safe and user-friendly. Little attention has been paid to using plastic waste as an alternative source especially in the developing countries which lack technical know-how and appropriate plastic-to-wax technologies.

2.4.2.1. Alternative Technology as Multiple Problem-solution Packages

Developing a waste-to-shoe polish production technology guarantees rational resource utilization as basis for sustainable development. Although this technology can be use for both biodegradable and non-biodegradable (plastics) waste, the later is preferred due to ;Plastics are functional, highly versatile leading to increase usage but have low cost-effective recyclability and are non-biodegradable and disposal by dumping or land filling offers a global problem with major adverse ecological impacts due photo-degradation, low compressibility, resilient surfaces, extremely long rotting time and forming of cavities within air inclusion in landfills etc (Angyal et al., 2007; Biniecka et al., 2005; Blasi, 1997: Boer et al., 2005).

2.4.3. Properties of Polyethylene

Polyethylene is an addition polymer that is created by the polymerization of ethylene monomer units, ethylene polymerized by a radical mechanism under very high pressures and temperatures with the addition of an organic peroxide radical initiator.

Polyethylene is created through polymerization of ethene. It can be produced through free radical polymerization, anionic addition polymerization, ion co-ordination polymerization or cationic addition polymerization. This is because ethylene does not have any substituent groups, which influence the stability of the propagation head of the polymer. Each of these methods results in a different type of polyethylene.

The process requires a highly purified ethylene feed and the operating pressure ranges from 1000 to 3000 atm and a temperature range of 120 - 3000°C. Temperatures exceeding 3000°C cause ethylene to decompose and are not recommended in practice (Dhibet *et al.*, 2002). Therefore, the development of mathematical models to predict the process behavior is important to ensure a stable operation, associated with an improvement in the properties of the produced polymer (Secchi, *et al.*, 2005).

For initiation, usually peroxides are used. Here, a mixture of different initiators is used; each of them decomposes into radicals depending on the temperature. In the presence of radicals, monomer starts to react with them, forming longer and longer radicals, so-called "living polymer". The third main step in the free radical polymerization process is the termination step, which ends the reaction.

Polyethylene is probably the polymer we see most in our daily life. It is the most popular plastic in the world. It has a very simple structure, the simplest of all commercial polymers. It is produced by addition polymerization of ethylene $\text{CH}_2=\text{CH}_2$. The properties of polyethylene depend on the manner in which ethylene is polymerized. When catalyzed by organometallic compound at moderate pressure (15-30 atm), the product is high-density polyethylene (HDPE), under these conditions, and the polymer chains grow to a very great length and molecular weight average many hundred thousand.

HDPE is hard, tough and resilient. Most HDPE is used in the manufacture of containers such as milk bottles and laundry detergent bags. When ethylene is polymerized at high pressure (1000-2000 atm) and elevated temperature (190-210°C) as well as catalyzed by peroxides the resulting product is Low-density polyethylene (LDPE). This form of polyethylene has molecular weight ranging from 20,000-40,000 g and is relatively soft and most of them are used in the production of plastic films such as those used in sandwich bags. These polymeric materials are generally thermoplastic as such are heat convertible and can be recycled from one product to the other type of used-water sachet polyethylene.

Used water sachet polyethylene can be recycled in to useful products, However many of these recycled products e.g., grocery bags, shampoo bottles, toys, footwear, etc are still non-biodegradable. This will still lead to another environmental disposal (Pollution problem).(Owolabi, June 2010), therefore it is recommended using LDPE as a raw material for the production of shoe polish using pyrolysis.

2.5. Plastic wastes recycling techniques

2.5.1. Mechanical recycling techniques

It comprises of some processes, which are shredding, melting and pelletizing of waste plastics. Plastics must be sort prior to mechanical recycling techniques. Mostly, sorting is performing by manually.

The technology introduced in sorting plastics automatically includes using X-ray fluorescence, infrared and near infrared spectroscopy, electrostatics and flotation. These sorting techniques are using in large scale recycling. Owing to the expensive nature of this sorting technology, sorting will be doing manually. After the sorting exercise, the plastics are shredded into smaller sizes (between 5 mm²– 10 mm²). The shredded plastics are, melted and molded directly into a new product or melted and formed into pellets or granules.

Mechanical recycling refers to the processing of waste plastic by physical means (grinding, shredding, and melting) back to plastic products. The chemical structure of the material remains almost the same. At present, the recycling of waste plastic is dominated by mechanical processes. This recycling path is viable when waste plastics are or can easily by cleaned and sorted properly. Added to this, the process requires large and quite constant input.

The five predominant plastic families, i.e. polyethylene (including low density-LDPE, linear low density-LLDPE, and high density-HDPE), polypropylene (PP), polyvinylchloride (PVC), polystyrene (solid-PS, expandable-EPS) and polyethylene terephthalate (PET), which are all thermoplastic, are also the most significant for mechanical recycling. One waste stream currently being treated in large amounts using mechanical recycling is packaging waste. (Alejandro Villanueva, 2014)

2.5.2. Chemical or feedstock recycling techniques

Feedstock recycling technique describes a range of plastic recovery procedures to make plastics, which breaks down polymers into their constituent monomers, which in turn, can be, used again in refineries, or petrochemical and chemical production. Some of the numerous ranges of feedstock recycling techniques currently being explore include: (I) Pyrolysis, (ii) Hydrogenation, (iii) Gasification and (IV) Thermal cracking.

Feedstock recycling has a greater flexibility over composition and is more tolerant to impurities than mechanical recycling. It is very expensive and requires very large quantities of used plastic for reprocessing to be economically viable.

In practice, chemical recycling or feedstock recycling refer to the same processes, and are appropriate for mixed or contaminated waste plastics. Processes include:

2.5.2.1. Chemical de polymerization

This process involves the reaction of the plastic polymer with chemical reagents, yielding its starting monomers that can be processed to produce new polymers. Different processes exist, depending on the chemical agent; glycolysis, methanolysis, and hydrolysis being the most common. Chemical de polymerization is only applicable to condensation polymers, mainly polyesters like PET and nylon, and cannot be used to reprocess addition polymers such as PE, PP or PVC.(Alejandro Villanueva, End-of-waste criteria for waste plastic, 2014).

2.5.2.2. Thermal cracking (also called pyrolysis)

This involves the degradation of the polymeric materials by heating (usually in temperatures between 500-800°C) in the absence of oxygen. The plastics are converted back into the liquid petroleum products used to produce plastics and new plastics, synthetic fibers, lubricants and gasoline are the end products of the process. It also yields small amounts of carbonized char and a volatile fraction that may be separated into condensable hydrocarbon oil and a non-condensable high calorific gas that can be reused onsite. Therefore, the classification of the pyrolysis process as recycling (tertiary/feedstock recycling) or recovery may vary depending on the final use of the resulting use of output fractions.

The proportion of each fraction and their composition depends primarily on the nature of the waste plastic but also on process conditions. Thermal de polymerization of poly olefins, such as PE or PP, tends to break into a variety of smaller hydrocarbon intermediates

whereas cracking of some other addition polymers, such as PS and poly methyl methacrylate, yields a high proportion of their constituent monomers.

The main advantage of this technology when it is integrated with a traditional mechanical recycling process is that it can recycle mixed or commingled streams of plastics with high levels of contamination. Germany and Japan have several such plants already in operation.(Alejandro Villanueva, End-of-waste criteria for waste plastic, 2014).

2.5.2.3. Catalytic conversion (also called catalytic cracking)

This involves the degradation of the polymers by means of catalyst. This type of conversion offers many advantages compared to thermal cracking including lower degradation temperatures and consequently lower energy consumption, higher conversion rates, and a narrower distribution of hydrocarbon products. Most processes produce higher quality fuels (gasoline and diesel fractions), gaseous olefins and aromatic compounds for the use as raw materials. Therefore, the classification of the catalytic cracking process as recycling (tertiary/feedstock recycling) or recovery may vary depending on the final use of the resulting use of output fractions.(Alejandro Villanueva, End-of-waste criteria for waste plastic, 2014).

2.5.2.4. Gasification

Gasification refers to the production of synthesis gas (syngas) by partial oxidation of organic matter at high temperatures (typically between 1200-1500°C) under mildly oxidizing condition (usually steam, CO₂ or sub-stoichiometric oxygen) which differs from the incineration process. Syngas, which consists primarily of CO and hydrogen and is free of dioxins and furan compounds, can be used in the synthesis of chemicals (e.g. methanol and ammonia) and to produce synthetic diesel, or may be combusted directly as a fuel.

2.5.2.5. Coke oven chemical feedstock recycling

Plastics can substitute part of the coal used to generate coke for use as the reducing agent in coke ovens (as in blast furnace process above). Hydrocarbon oil and coke oven gas, also produced during this process, are used, respectively, as chemical feedstock and to generate electricity. The classification of the coke oven chemical process as recycling (tertiary/feedstock recycling) or recovery may vary, depending on the use of output fractions.

As the products of chemical/feedstock recycling processes may be used both as raw chemicals or fuels, there is no classification of these processes as closed-loop recycling or

open-loop recycling, as different compounds can be obtained and used for two different purposes. Consequently, the environmental assessment of one chemical recycling process may even vary depending on the end uses of each plant. Even if the cracking of plastics into its monomers may be more energy intensive than mechanical recycling, a chemical recycling process may have greater environmental benefits than a mechanical downgrading process, depending on the final product's quality.

Chemical recycling is an elegant concept, and despite attracting scientific attention, it has not been widely commercialized so far because the process economics and because the quality of the products is lower than normal commercial grade feedstock. Also, back-to-monomer recycling is so far only operational for certain types of polymers (PU, PA and polyester) while back-to-feedstock recycling (splitting polymers into raw materials substituting fuel or gas) is less demanding. (Alejandro Villanueva, End-of-waste criteria for waste plastic, 2014)

2.6. Pyrolysis of plastics

Fundamentally, different types of plastics have different compositions that normally reported in terms of their proximate analysis. Proximate analysis can be defined as a technique to measure the chemical properties of the plastic compound based on four particular elements which are moisture content, fixed carbon, volatile matter and ash content. Volatile matter and ash content are the major factors that influence the liquid oil yield in pyrolysis process. High volatile matter favored the liquid oil production while high ash content decreased the amount of liquid oil, consequently increased the gaseous yield and char formation. (Shafferina Dayana Anuar Sharuddin, A review on pyrolysis of plastic wastes, 2016). These characteristics indicate that plastics have high potential to produce large amount of wax through pyrolysis process. Since the results of plastics proximate analysis are very convincing, the following discussion would focus more on the process parameters involved during the pyrolysis process that would have major influence in the wax production. (Shafferina Dayana Anuar Sharuddin, A review on pyrolysis of plastic wastes, 2016).

2.6.1. Pyrolytic process parameters condition

Parameters play major role in optimizing the product yield and composition in any processes. In plastic pyrolysis, the key process parameters may influence the production of final end products such as liquid oil, gaseous and char, waxy. Those important parameters

may be summarized as temperature, type of reactors, pressure, residence time, catalysts, type of fluidizing gas and its rate. The desired product can be achieved by controlling the parameters at different settings. In-depth discussions of the operating parameters are reviewed in the following subsections. (Shafferina Dayana Anuar Sharuddin, A review on pyrolysis of plastic wastes, 2016)

2.6.1.1. Temperature

Temperature is one of the most significant operating parameters in pyrolysis since it controls the cracking reaction of the polymer chain. Molecules are attracted together by Van der Waals force and this prevents the molecules from collapsed. When temperature in the system increases, the vibration of molecules inside the system will be greater and molecules tend to evaporate away from the surface of the object. This happens when the energy induced by Van der Waals force along the polymer chains is greater than the enthalpy of the C–C bond in the chain, resulted in the broken of carbon chain. (Shafferina Dayana Anuar Sharuddin, A review on pyrolysis of plastic wastes, 2016).

2.6.1.2. Type of reactors

The type of reactors has an important impact in the mixing of the plastics and catalysts, residence time, heat transfer and efficiency of the reaction towards achieving the final desired product. Most plastic pyrolysis in the lab scale were performed in batch, semi-batch or continuous-flow reactors such as fluidized bed, fixed-bed reactor and conical spouted bed reactor (CSBR).

2.6.1.3. Residence time

Residence time can be defined as average amount of time that the particle spends in the reactor and it may influence product distribution. Longer residence time increases the conversion of primary product, thus more thermal stable product is yielded such as light molecular weight hydrocarbons and non-condensable gas. Nevertheless, there is a temperature limitation in the process that may influence the product distribution where until that instant; the residence time has not much effect on the product distribution. (Shafferina Dayana Anuar Sharuddin, A review on pyrolysis of plastic wastes, 2016).

After reviewing literature on modern waste disposal technologies and the challenges of applying them in developing countries, shoe polish formulation from plastic waste has been given little

or no attention; therefore this thesis research will use the pyrolysis technology to produce wax from used water sachets, compared with other technologies.

2.7. Natural Wax

Waxes are a diverse class of organic compounds that are hydrophobic, malleable solids near ambient temperatures. They include higher alkanes and lipids, typically with melting points above about 40 °C (104 °F), melting to give low viscosity liquids. Waxes are insoluble in water but soluble in organic, non-polar solvents. Natural waxes of different types produce by plants and animals and occur in petroleum.

Waxes are organic compounds that characteristically consist of long alkyl chains. Synthetic waxes are long-chain hydrocarbons (alkanes or paraffin) that lack substituted functional groups. Natural waxes may contain UN substituted hydrocarbons, such as higher alkanes, but may also include various types of substituted long chain compounds, such as fatty acids, primary and secondary long chain alcohols, ketones and aldehydes. They may also contain esters of fatty acids and long chain alcohols.

2.7.1. Plant and animal waxes

Waxes synthesized by many plants and animals, those of animal origin typically consist of wax esters derived from a variety of carboxylic acids and alcohols. In waxes of plant origin, characteristic mixtures of UN esterifies hydrocarbons may predominate over esters.

2.7.1.1. Animal waxes

The most commonly known animal wax is beeswax, but other insects secrete waxes. A major component of the beeswax used in constructing honeycombs is the ester myricylpalmitate which is an ester of triacontanol and palmitic acid. Its melting point is 62-65 °C. Spermaceti occurs in large amounts in the head oil of the sperm whale. One of its main constituents is cetylpalmitate, another ester of a fatty acid and a fatty alcohol. Lanolin is a wax obtained from wool, consisting of esters of sterols.

2.7.1.2. Plant waxes

Plants secrete waxes into and on the surface of their cuticles as a way to control evaporation, wet ability and hydration. The epicuticular waxes of plants are mixtures of substituted long-chain aliphatic hydrocarbons, containing alkanes, alkyl esters, fatty acids, primary and secondary alcohols, diols, ketones, aldehydes. From the commercial perspective, the most important plant wax is carnauba wax, a hard wax obtained from the

Brazilian palm *Coperniciaprunifera*. Containing the ester myricylcerotate, it has many applications, such as confectionery and other food coatings, car and furniture polish, floss coating, surfboard wax and other uses. Other more specialized vegetable waxes include candelilla wax and ouricury wax.

2.7.2. Bee Wax

Bee wax produced from a long chain of alcohols, this alcohol was reported to give a neutral compound on treatment with strong alkali in contrast to the alcohols of a plant. This would mean that bee wax alcohol was a secondary alcohol which was dehydrogenated to ketones, or the neutral material would have been hydrocarbon impurities in the alcohols. Fractionation on a silicic acid column gave hydrocarbons (37%), Monoesters (29%) and a more polar fraction (34 %).

2.7.2.1. Bee wax use at present

Besides its use for foundations, which is probably the main use, wax is also used for following purposes: cosmetics 25-30 %, pharmacy 25-30 %, candles: 20 % and other purposes: 10-20 %. From the above different types of wax it is better to use bee wax for the formulation of shoe polish because bee wax is waxy organic raw materials ,non toxic, flexibility of operation, easily availability in Ethiopia compared to other types of wax, due to this it I recommend using bee wax as a raw material for shoe polish formulation.

2.8. Research Methodology Frame Work

An integrated methodology that involved the assessment of raw material characteristics and availability, and optimization of the sample preparation using pyrolysis technology and evaluation of its economic and application efficiency was adopted. The methodology was classified into blocks as shown in Fig.2.2

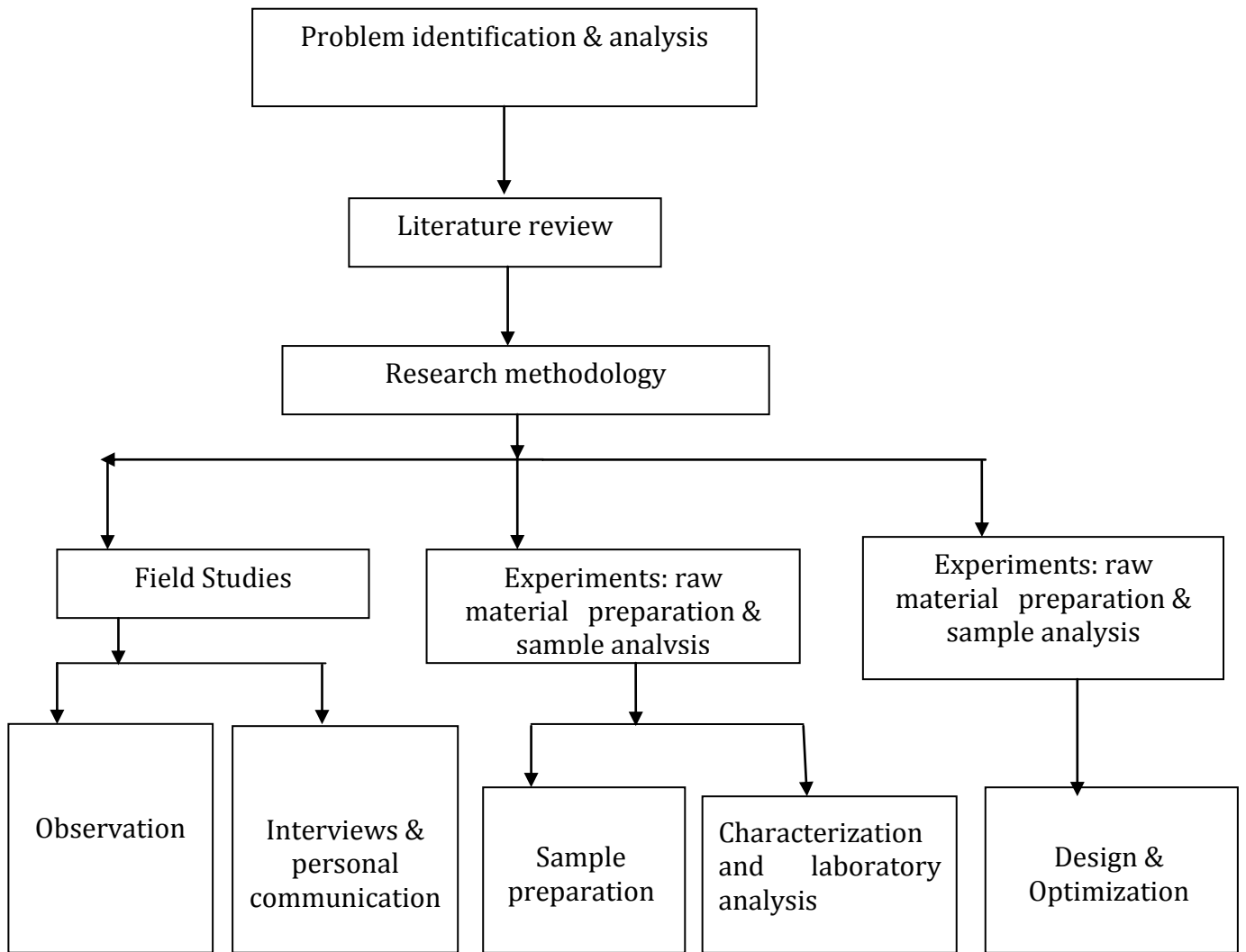


Figure2.2 Schematic representation of methodology frame work

The optimization process involved various laboratory evaluation and statistical analysis (Fig. 2.3).

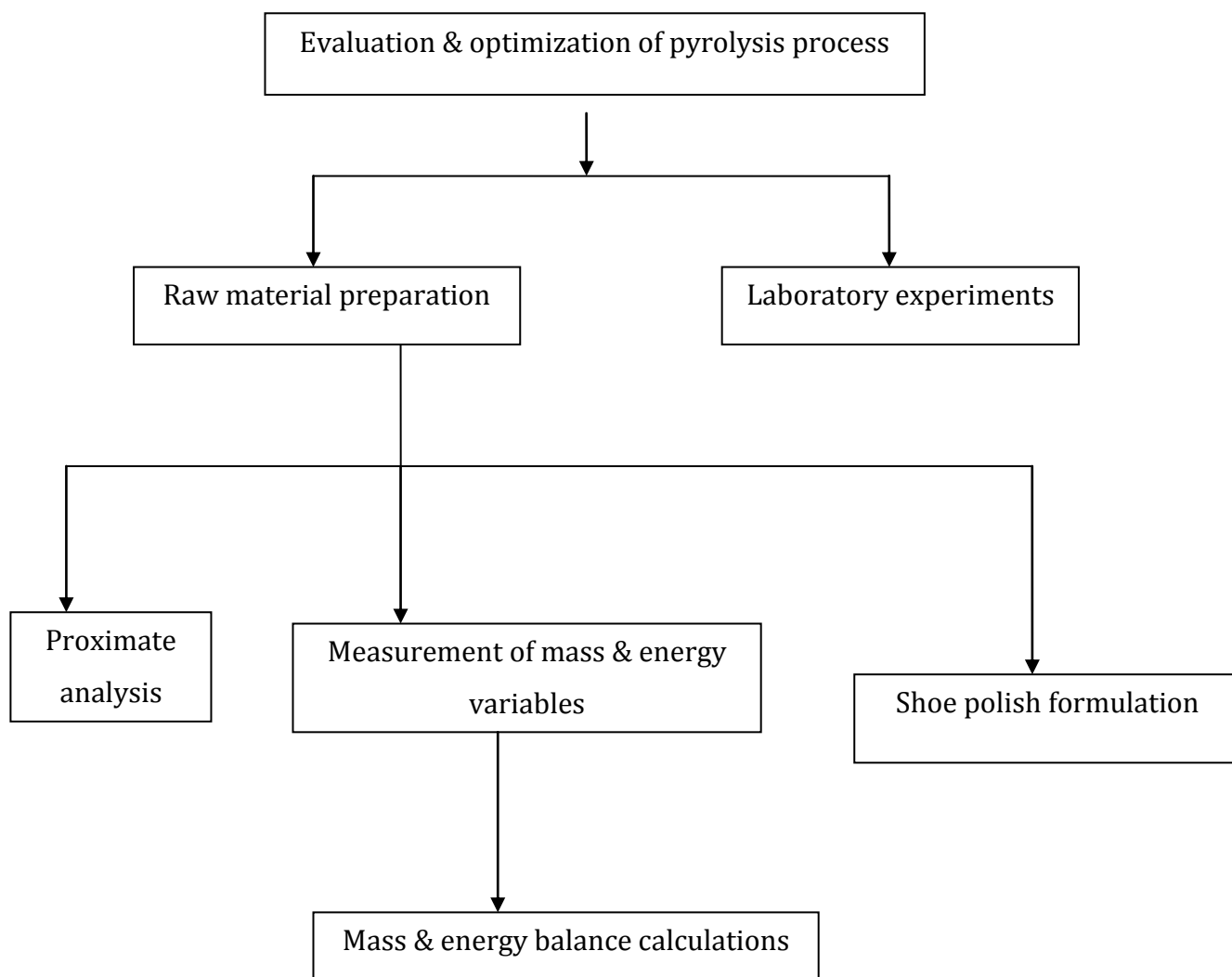


Figure 2.3 Optimization stages

Chapter Three

3. Materials and Methods

3.1. Materials

Equipment's and materials used for this analysis was, batch reactor, cutting mill, Electric heater, water bath, electric heater, electric mixer, temperature controller, bee wax, thermocouple, lagging materials, beaker to receive the wax and weighing balance, gloves , scissors , polyethylene bags ,waste low density polyethylene films (used water sachet), lagging materials, test tubes, muffle furnace, crucible, desiccators, cylinder, cotton, formulated shoe polish, commercial shoe polish (Kiwi), rotary viscometer, water bath, test tube, thermometer, cylinder.

3.2. Methods

3.2.1 Bee Wax Melting

The wax was melted in water bath at a temperature of 70°C.

3.2.2. Pyrolytic Reactor Process

The pyrolysis process was conducted in a pyrolysis reactor made of mild steel and stainless steel. The reactor has a height of 20 cm, an external diameter of 11 cm and an internal diameter of 8 cm and a 2 kW electric coil. The reactor was capped with a ball valve to make it airtight and fitted with an outlet tube system at the top. The tubes had an outer diameter of 300 mm and an inner diameter of 200 mm. A pressure gauge of 1- 250 bars was connected to the top of the reactor. A thermocouple with digital temperature readout was connected to the reactor to control and monitor the internal reaction temperature during the pyrolysis process. high purity nitrogen gas was purged into the reactor at a flow rate of 2 L/min to maintain an oxygen free environment. The reactor was heated to a temperature range of 100 to 200 °C using a 2 Kw electric coil for a period of 30-60 minutes.

3.2.3. Pyrolysis of used water sachet plastics

Batches of 100 g of used water sachet were introduced in the pre- warmed reactor between 100 - 200 °C. Nitrogen gas was purged into the reactor, at a flow rate of 2 L/min. The sample was heated at temperatures ranging between 100-200 °C and with heating rate of 10 °C /minute. The non-condensable gases produced from the reactor were evacuated using the outlet tube system. The sachet wax was weighed for each batch and stored in pre-cleaned desiccators. Optimization studies were carried out by varying reactor temperature

within the range of 100-200 °C and 10 °C /minute. Reaction times were also varied. The effects of temperature, reaction times were correlated.

3.2.4. Preparation of shoe polish from Bee wax and used water sachet

3.2.4.1. Preparation of shoe polish

Used water sachets were collected, washed and dried to make them clean. They were weighed into samples of 100g each. Each of these samples was charged into a batch pyrolytic reactor, at three different temperatures and different reaction time (100 °C , 150 °C , 200 °C). The reactor was placed on a heated source. For each sample, the temperature and reaction time was noted, to enable the determination of temperature and time at which highest yield of wax was obtained. Bee wax was melted along with the wax obtained from used water sachets. The two waxes were properly mixed and then stearic acid was added and stirred .Thereafter, Olive oil was introduced while still stirred to ensure a proper mix .The mixture was allowed to cool to 41°C and poured into a container for storage. The polish was allowed to set.

3.2.4.2. Shoe Polish Formulations and their Mixing Ratio

Three different formulations of polish were prepared and labeled samples A (100°C), B (150°C) and C (200°C), the three samples were also compared with the standard polishes labeled D (Kiwi). The densities, melting points and viscosities of shoe polishes produced and that of control (Kiwi) polishes were determined using ASTM standard methods.

Table 3.1 Shoe Polish Formulations

Ingredients	Sample A (%)	Sample B (%)	Sample C (%)
Sachet wax	20	33	25
Bee wax	25	15	30
Fragrance	12	12	8
Olive oil	43	50	37

3.2.5. Proximate analysis of used water sachets

3.2.5.1. Ash content determination

The nearest 0.1mg of 1gm sufficient dry used water sachets was measured, and the nearest 0.1mg empty crucible was weighed. The sample was put into a crucible and the crucible was ignited in the muffle furnace at 725°C for 1 hour 30 minutes and then the crucible was, placed in the desiccators. Finally, the sample was cooled to a room temperature, and weighed to the nearest 0.1 mg.

The ash content A_c is given in % by:

Calculate the percentage of ash content (weight basis) as follows

$$\% \text{ ASC} = \frac{\text{mass of empty crucible} - \text{mass of crucible plus dried sample}}{\text{mass of crucible plus dried sample} - \text{mass of empty crucible}} * 100 \quad (3.1)$$

3.2.5.2. Volatile Matter Content determination

The temperature of the muffle furnace was adjusted to 800°C and the steady temperature condition in the furnace was maintained. The weight of crucible was measured. About 1g of the sample was weighed; the sample was putted into crucible and after placed the lids on the crucible and was transferred into the muffle furnace and leaved exactly for 8 min at 800°C. Finally, it was allowed to cool by placed the crucible in the desiccators to room temperature and weighed to the nearest 0.1mg.

The volatile matter content on dry basis, VD in% is given by:

$$VD = [(100 * (B - F) - M_c (B - G)) * (B - G) (100 - M_c)] * 100 \quad (3.2)$$

Where B =mass in g of the crucible and sample before heating, F = mass in g of the crucible and contents after heating, G = mass in g of the empty crucible, M_c = % of moisture content

3.2.5.3. Fixed Carbon Content determination

The fixed carbon content, was determined by subtracted the sum of percentage compositions of moisture content, volatile matter content, and ash content from 100.

3.2.6. Characterization of Polyethylene wax

3.2.6.1. Standard Test Method for Melting Point of Polyethylene Wax

A quantity of wax was put in a dish and placed on an electric heater. A thermometer was placed in a dish to monitor the temperature.

The air bath was supported in its proper position in the water bath, filled the water bath to within 13 mm (1/2 in.) of the top with water at a temperature of 16 to 28°C (60 to 80°F). The bath temperature is kept within these limits throughout the test. The wax sample was heated to at least 8°C (15°F) above its expected melting point (70 °C - 90 °C). To heat the wax sample use a suitable container in an oven or water bath which is held at a temperature not exceeding 93°C (200°F). Avoid the use of direct heat such as flame or hot plate. Do not keep the sample in the molten state longer than 1 h. Fill the test tube to a height of 51 mm (2 in.) with the melted sample. Insert the melting point thermometer through the center of a cork so that the 79-mm (31/8-in.) immersion line is at the lower surface of the cork. The cork was inserted into the test tube so that the bottom of the thermometer bulb was 10 mm (3/8 in.) from the bottom of the test tube. The test tube was supported assembled in the water bath as shown in Figure 3.6 while the temperature of the molted wax was still at least 8°C (15°F) above its expected melting point.

The melting point of bee wax recorded by thermometer at every 15 s. Record each reading to the nearest estimated 0.05°C (0.1°F). The progressed reported result was used to determine the appearance of the plateau. Identify the plateau as the first five consecutive readings all of which agree within 0.1°C (0.2°F).Discontinued the test after obtained these five plateau readings.

3.2.6.2. Density determination of Polyethylene wax by Measuring Cylinder

A quantity of wax was put in to a beaker and weighed. The sample was weighed out to the nearest 0.1 gram and then the sample, transferred in to a suitable graduated cylinder. The base of the cylinder was gentled taped on a slightly resilient surface, such as a rubber pad or book, until the height of the sample in the cylinder is at a minimum, and the sample height does not reduce with further tapped. Finally reading volume of a sample in cc (ml) was recorded. The change in volume was noted and recorded.

3.2.7. Characterization of shoe polish

3.2.7.1. Viscosity Determination by Rotary Viscometer Method

In this test method, the shoe polish was placed in a glass tube, housed in an insulated block at a fixed temperature. A metal spindle is then rotated in the shoe polish at a fixed rpm (10 rpm), and the torque required to rotate the spindle is measured. Based on the internal resistance to rotation provided by the shear stress of the shoe polish, the shoe polish absolute viscosity can be determined. Absolute viscosity is reported in centipoises (CP),

equivalent to Pa*s in SI units. This method is commonly referred to as the Brookfield method and is described in ASTM D2983.

3.3. Evaluation of the Performance of Shoe Polish& Compared with Commercial Product

The polished and shined leather samples were tested on some physical parameters as follows:

3.3.1. Luster/Gloss

The polished samples were examined for their gloss/luster by comparing them with one another (Sample A, Sample B, Sample C . with commercial product sample D).

3.3.2. Rub Resistance

The polished leather samples were rubbed with white and clean cotton material for about 40 times. The change in hue and level of staining were examined.

3.3.3 Fading Resistance

The polished leather samples were tested for fading resistance by exposing them to the sun for 74hrs. Finally, change in hue and gloss was used to assess the parameter.

3.3.4. Dust Absorption Resistance

The polished leather samples were exposed to an open environment, where dust can get easy access to them for 24hrs. The level of dust adsorption was examined.

3.3.5. Wrinkle/Crease Resistance

The polished leather samples were each held at both end and creased as if washed garment to see if the polish was peeled off the leather.

3.4. Optimization of process Parameters

The formulated shoe polish with three parameters with three factors (A, B, C) and three levels (1, 2, and 3) were selected to build a proper experimented was optimized by using experimental design expert.

3.5. Techno-Economic Feasibility Study

The techno-economic feasible study for shoe polishes production for major unit operations. Assumptions were made based on literature review. Cost estimation for solid processing plant using percentage of delivered equipment cost and estimation of total production cost.

Chapter Four

4. RESULT AND DISCUSION

4.1. Formulated polyethylene wax from used water Sachets

Table 4.1 .Reaction temperature, time and Yield of Polyethylene wax

SN.	Pyrolysis Temperature(°C)	Pyrolysis time(min)	Yield of sachet wax (%)
1	100	30	31.64
2	100	45	35.4
3	100	60	32.9
4	150	30	29.4
5	150	45	23.7
6	150	60	19.6
7	200	30	16
8	200	45	12
9	200	60	8

4.1.1Design Expert Output (yield)

4.1.1.1. Response output of yield

Design Expert Output

ANOVA for Selected Factorial Model

Table 4.2 Analysis of variance table [Partial sum of squares]

Source	Sum of Square	DF	Mean Square	F value	Prob>F(Significant)
Model	730.39	4	182.60	18.77	0.0074
A	685.55	2	342.78	35.24	0.0029
B	44.84	2	22.42	2.30	0.2158
Residual	38.91	4	9.73		
Cor Total	769.30	8			

The Model F-value of 18.77 implies the model is significant. There is only a 0.74% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve the model. Both factors, Temperature (A) and Time (B) are significant.

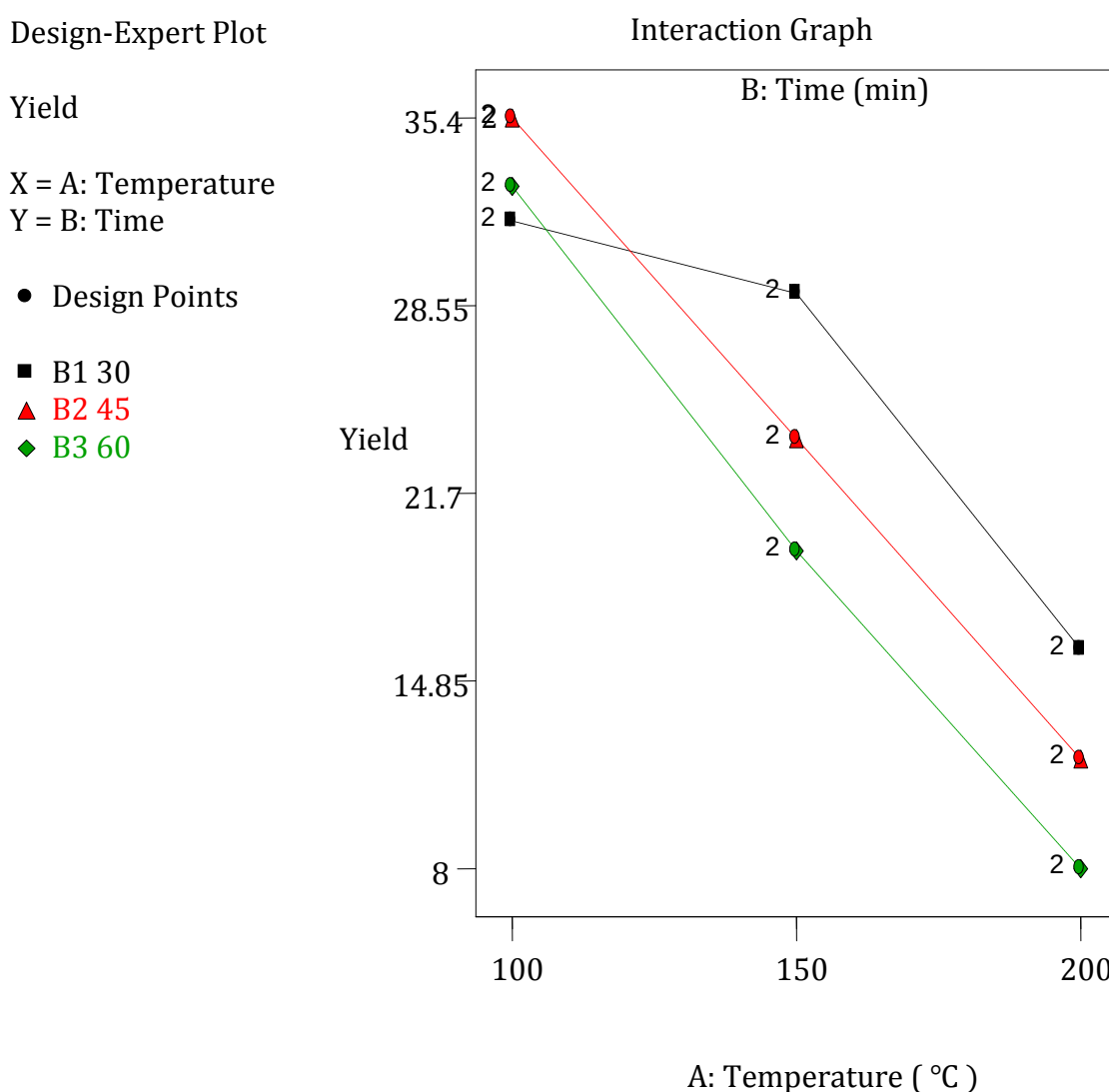


Figure 4.1 interaction graph of yield

The effect of pyrolysis temperature and time on the yield of polyethylene (sachet) wax is shown in Figure 4.1. At high pyrolysis temperature, the decrease in wax yield is very obvious. It can be seen from Figure 4.1 that, the yield is 8-35.4 % at the pyrolysis

temperature range of 100°C-200°C, when the polyethylene waste (pure water sachet) was pyrolysed to polyethylene wax, above 200°C , the sachets melted into fuel oil.

Similar trend was observed by Jixinget *al.*, (2003) while pyrolysing waste plastics to produced polyethylene wax. Therefore 100°C and 45 min are the optimal temperature and the optimal reaction times in other to produce wax with high yield i.e., over 30%. But these optimal temperatures and optimal reaction times will only be acceptable, the melting point of wax produced are within ASTM standard wax.

It was also observed that when the polyethylene wastes water sachet was pyrolysed at temperature 100°C, the yield decreases sharply from 31.4 % to 8 % as the pyrolysis time was changed from 30 to 60 minutes. At the same reaction time with an increase in pyrolysis temperature, the yield decreases. This is a very significant trend.

Conditions would operated this process at a temperature set at 100 °C and Time 45 min at the high level give the highest yield.

At the same reaction time with an increase in pyrolysis temperature, the yield decreases. This is a very significant trend.

There are two reasons for the decrease in yield, one is the pyrolysis of wax to more gaseous products as the temperature increases; the other reason is the vaporization of wax when pouring from the reactor into the mould.

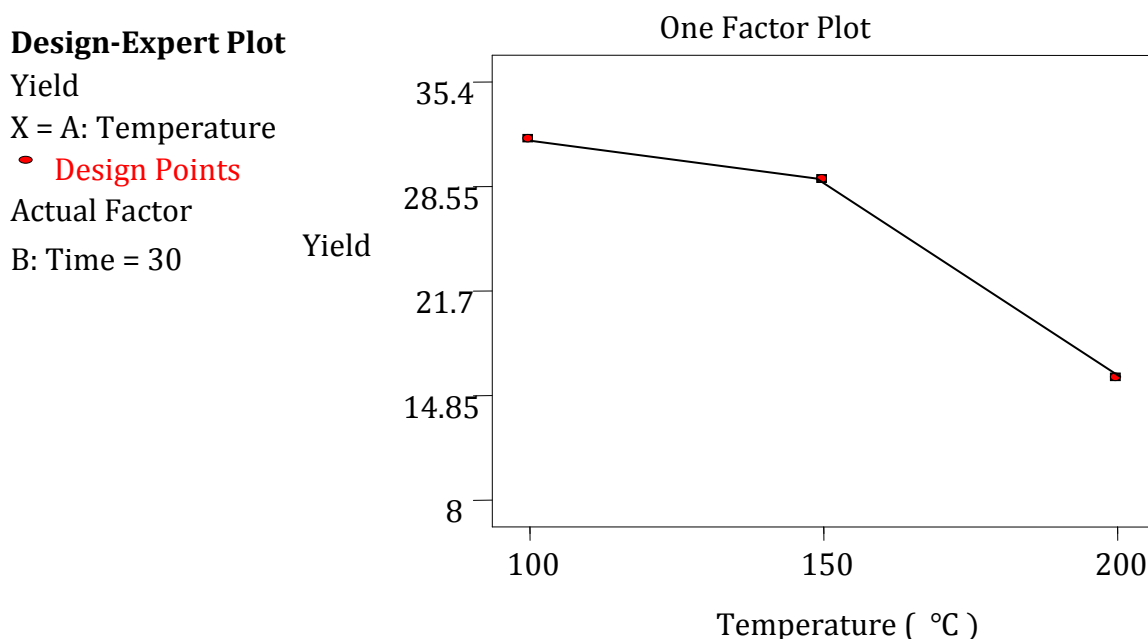


Figure 4.2 One Factor Plot of Yield vs. Temperature

It was observed that, at the same pyrolysis temperature, the yield decreased with the increase of pyrolysis time.

Design-Expert Plot

Yield

X = B: Time

• Design Points

Actual Factor

A: Temperature = 100

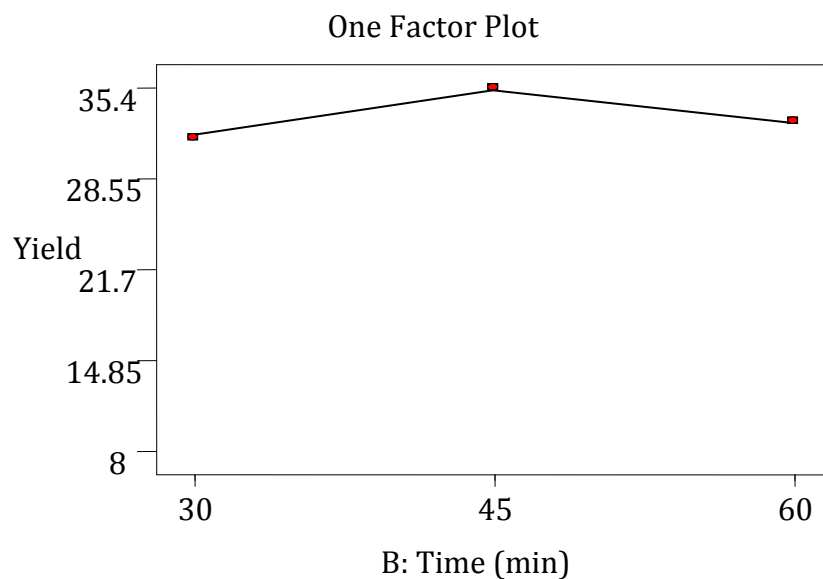


Figure 4.3 One Factor Plot of Yield vs. Time

Conditions would operated this process at a temperature set at 100 °C and Time 45 min at the high level give the highest yield.35.4

Table 4.3 Constraints and optimaization

Parameter	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight
Temperature	is in range	100	200	1	1
Time	is in range	30	60	1	1
Yield	Maximize	8	35.4	1	1

Table 4.4. No of available Solutions & their Desirability

SN	Temperature (°C)	Time (min)	Yeild	Desirability
1	100	45	35.4	1
2	100	60	32.9	0.909
3	100	30	31.64	0.863
4	150	30	29	0.766
5	150	45	23.7	0.573
6	150	60	19.6	0.423
7	200	30	16	0.292
8	200	45	12	0.146

4.2. Characterization Results

4.2.1. Proximate Analysis of a Raw Material

The Proximate Analysis result of used water sachet determines the distribution of its contents. It may be noted that the volatile matter present, in used water sachets, contributes maximum to its contents. The moisture content present in the sample can also be considered as water vapor when it is heated to high temperatures. Hence, about 92.5 % was volatile matter and almost negligible moisture content. The values from the Table 4.1 indicates that the ash content of the sample was 0.5 %.This gives an overview about the properties and components of used water sachet.

Table.4.5. Proximate Analysis of used water sachet

Used water sachet content (components)	Composition (%)
Ash Content	0.5
Moisture Content	0
Volatile Matter	99.5
Fixed carbon Content	0

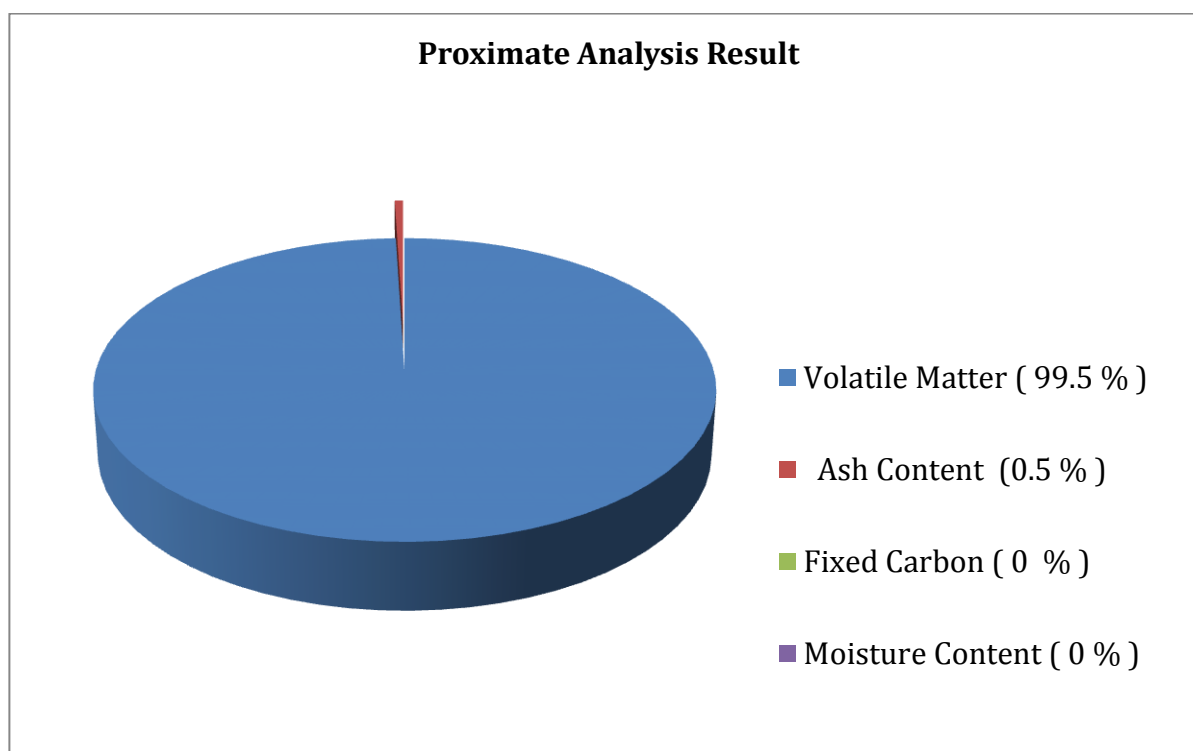


Figure 4.8 Proximate analysis results

4.2.2. Melting point

The melting point of wax at different pyrolysis temperature and time was shown in Table 4.6 below.

Table 4.6 Melting point result at different temperature and time

SN.	Temperature (°C)	Pyrolysis time(min)	Melting point (°C)
1	100	30	125
2	100	45	112
3	100	60	111
4	150	30	120
5	150	45	88
6	150	60	76
7	200	30	80
8	200	45	72
9	200	60	65

The properties of the wax produced from used water sachets before it was used to formulate polish after pyrolysis is shown in Table 4.7. These parameters were measure before additives (like Olive oil, stearic acids etc) were added to the shoe polish. The wax produced at pyrolysis temperature 100°C was used to produce the polish. The melting point of the wax is 76°C, while the density is 0.741g/ml.

Table 4.7 Properties of sachet Wax Produced from waste water sachets

Process Parameters	Optimum Values
Pyrolysis temperature	100°C
Melting Point	76 °C
Density @ room temperature	0.741 g/ml

4.2.2.1. Response output of Melting Point

Response :-Melting Point

Anova for selected Factorial Model

Table 4.8 Analysis of variance table [Partial sum of squares]of melting point

Source	Sum of Squares	DF	Mean Square	F value	Prob>F Significant
Model	3809.33	4	952.33	11.88	0.0171
A	2860.67	2	1430.33	17.84	0.0102
B	948.67	2	474.33	5.92	0.0638
Residual	320.67	4	80.17		
Cor Total	4130.00	8			

The Model F-value of 11.88 implies the model is significant. There is only a 1.71% chance that a "Model F-Value" this large could occur due to noise. values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A is significant model terms.

If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model. Both factors, Temperature (*A*) and Time (*B*) are significant.

Design-Expert Plot

Melting Point

X = A: Temperature

Y = B: Time

• Design Points

■ B1 30

▲ B2 45

◆ B3 60

Melting Point (°C)

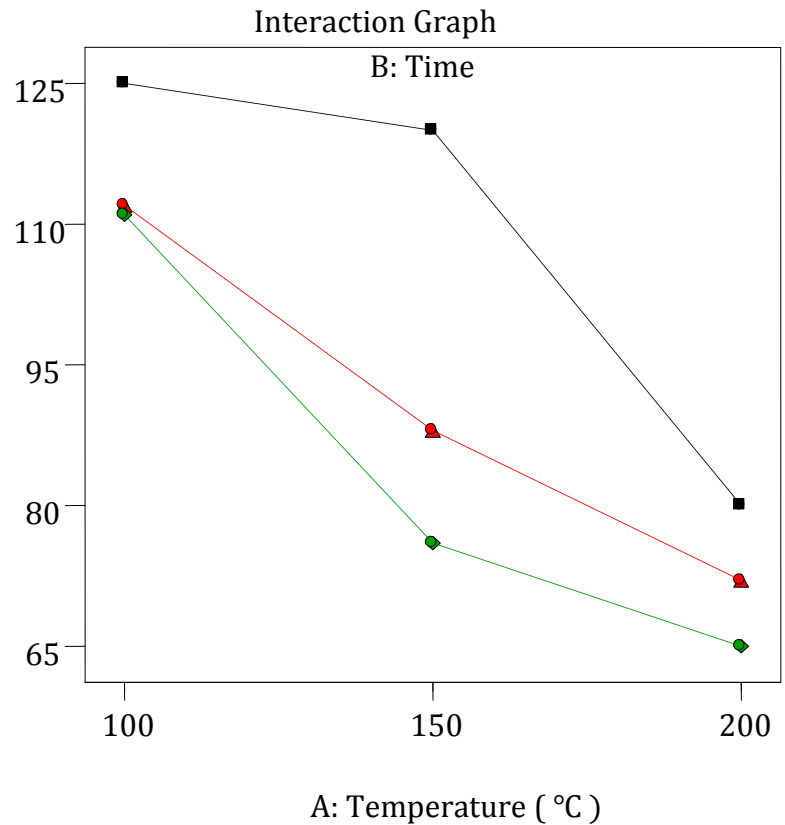


Figure 4.9 interaction graph of melting point

The melting point of polyethylene wax was determined by its molecular weight range and the extent of the pyrolysis of polyethylene, The deeper the pyrolysis, the lower the molecular weight range, the lower the melting point.

Figure 4.9 shows that with an increase in pyrolysis time, the melting point of polyethylene wax decreases. It can be seen that if polyethylene waste water sachet was pyrolysed at the temperature range 100°C to 200°C, the melting point of polyethylene wax varies from 65°C to 125°C. At 100°C the waste sachets were not fully pyrolysed to wax so the melting point was not determined at this temperature. At a temperature of 150°C the melting point decreases sharply with a sudden decrease in slope after 30 minutes as shown in Figure-6.

In this study polyethylene wax with melting point of 125-65°C was obtained at 100°C to 200°C waste from the waste sachets, Jixinget *al.*, (2003) obtained a melting point of 144°C-104°C while pyrolyzing waste plastics. Standard wax property requires that the melting point of wax should be between 60-93°C for microcrystalline wax (Wax properties, 2010). Conditions would operated this process at a temperature set at 100 °C and Time 30 min at the high level give the highest melting point.

Design-expert Plot
Melting Point
X = A: Temperature
• Design Points
Actual Factor

B: Time = 30

Melting Point (°C)

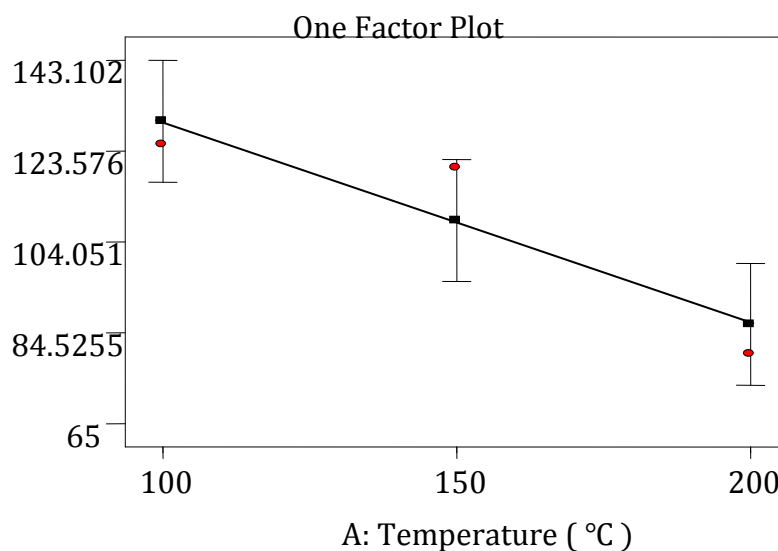


Figure 4.10 One Factor Plot of melting point vs. Temperature

At a temperature of 150°C the melting point decreases sharply with a sudden decrease in slope after 30 minutes as shown in Figure 4.10.

Design-Expert Plot
Melting Point
X = B: Time
• Design Points
Actual Factor

A: Temperature = 100

Melting Point(°C)

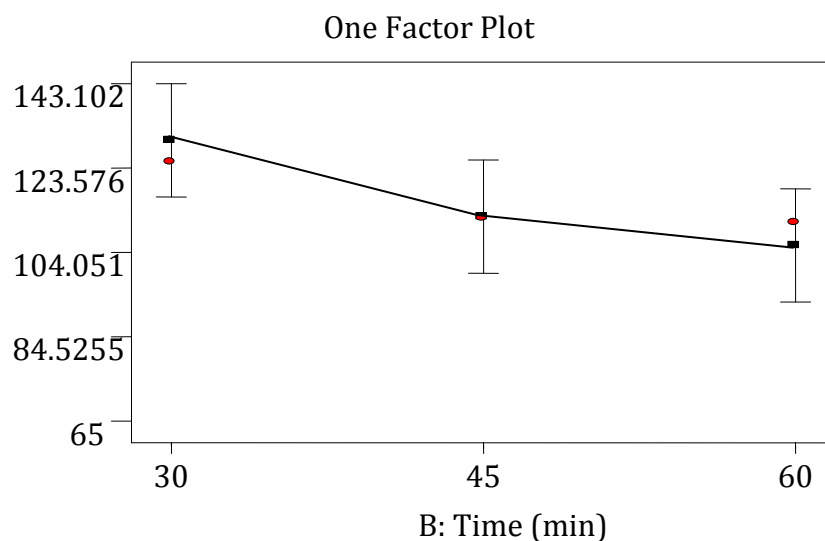


Figure 4.11 One Factor Plot of melting point vs. Time

The increase in pyrolysis time, the melting point of polyethylene wax decreases. It can be seen that if polyethylene waste water sachet was pyrolysed at the temperature range 100 - 200°C.

4.3. Thermo physical Properties of Shoe Polish

4.3.1. Melting Point of shoe polish

Figure 4.16 shows the thermo physical properties of polishes produced from waste water sachet wax and other known standard polish. Samples A, B and C were prepared using the formulated shoe polish discussed earlier while sample D is the control samples which are Kiwi. The melting point of sample D which is Kiwi control polish was the highest followed by sample A which contains only 20 % wax produced from waste sachets. In the analysis, sample D (Kiwi polish) had the highest melting point followed A and then B and C which had the highest melting point. Sample B & C has the highest melting point and contains more waste polyethylene sachet wax of about 33 and 25 % respectively. This shows that the percentage of waste sachet wax required for formulated shoe polish should not exceed 33%.

Table 4.9 Melting Point of shoe Polish

SN.	Formulated& Controlled Shoe Polish	Response Melting Point (°C)
1	A	24
2	B	65
3	C	60
4	D	30

Design-Expert Plot

Melting Point

X = A: p

● Design Points

Melting Point (°C)

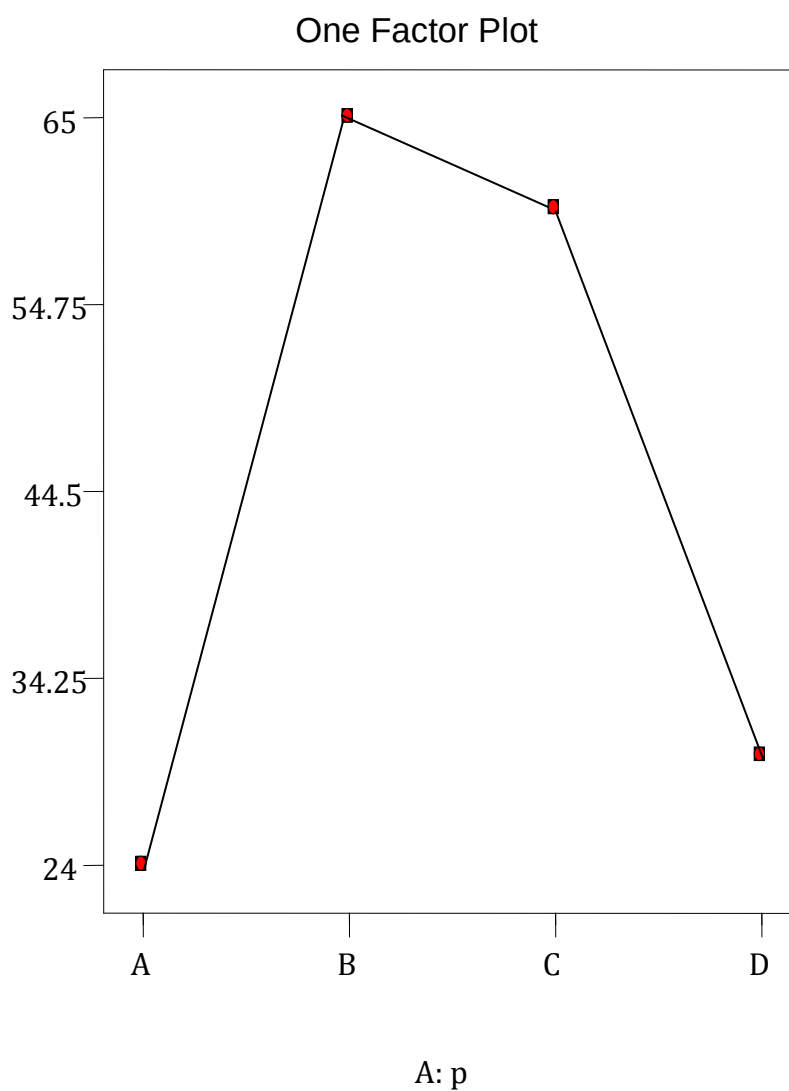


Figure 4.16. Melting point of formulated & controlled shoe polish

4.3.2. Density of Shoe Polish

Table 4.10 Density of shoe polish

SN.	Formulated & Controlled Shoe Polish	Response Density (g/ml)
1	A	0.54
2	B	0.67
3	C	0.59
4	D (KIWI)	0.61

Design-Expert Plot

Density

X = A: Sample type

• Design Points

Density (g/ml)

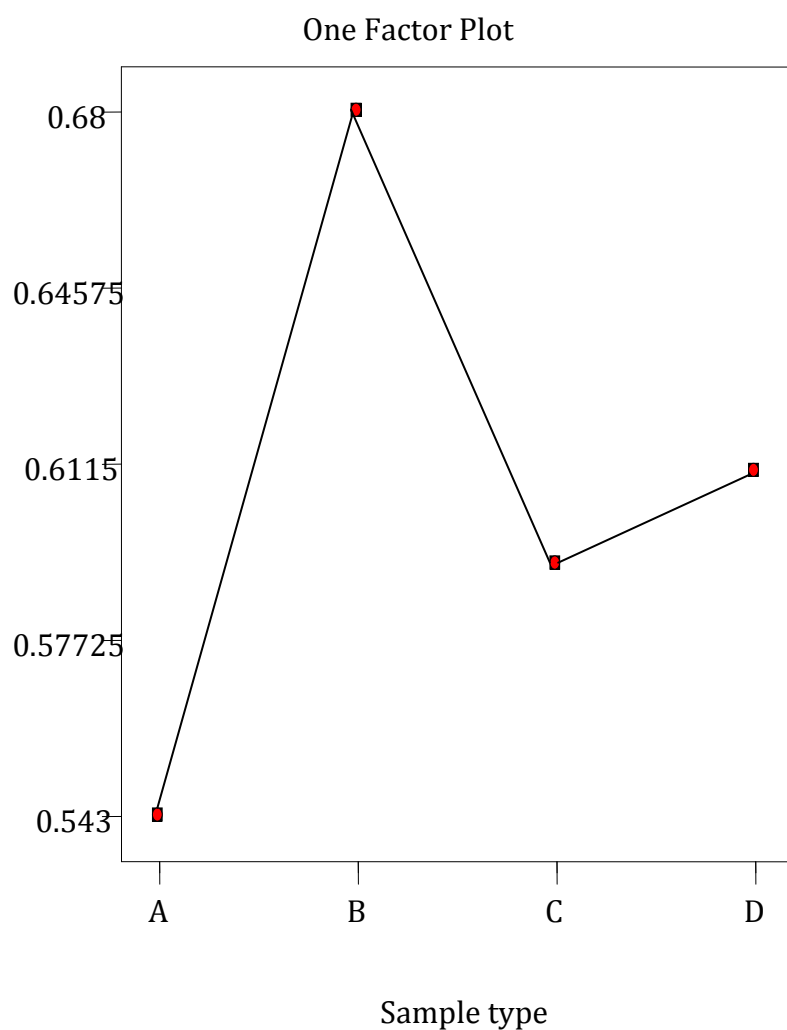


Figure 4.17 Density of formulated and controlled shoe polish

The density of shoe polish sample B and C are compared favorably with that of samples D (control polishes) than sample A. Sample B had more dense than sample A and C.

4.3.3. Viscosity of Shoe Polish at Different Temperatures

Table 4.11 Viscosity of shoe polishes at different temperature

Temperature (°C)	Viscosity of Formulated and Control polish			
	A	B	C	D
40	2.2	6.45	0.88	8.23
50	2.01	3.15	0.62	3.66
60	0.63	1.34	0.2	3.13

Design-Expert Plot

Viscosity

X = A: Temperature

• Design Points

Actual Factor

B: formulated and control

Shoe polish = A

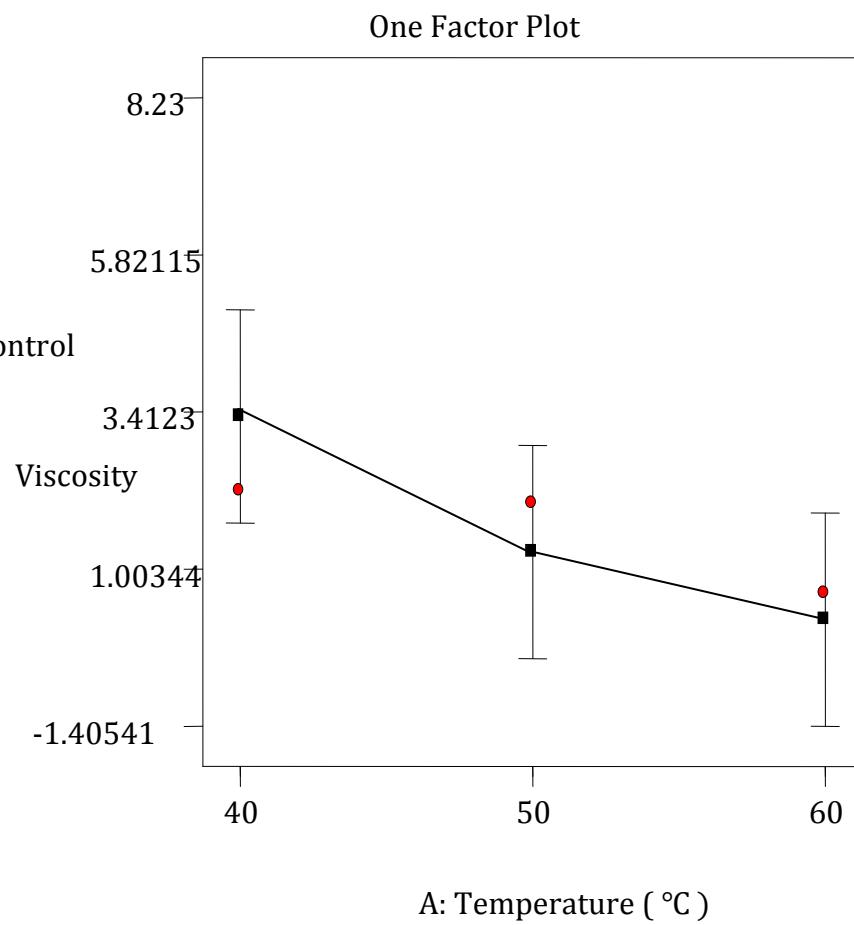


Figure 4.18 Model graph one factor plot of viscosity vs. Temperature

Design-Expert Plot

Viscosity

X = B: formulated shoe

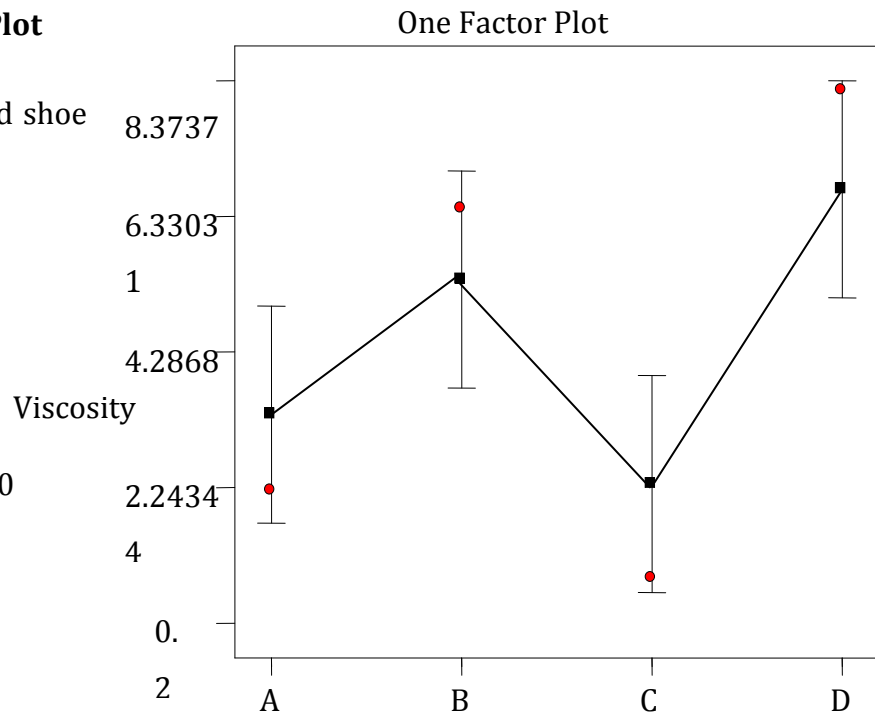
polish

Design Points

Actual Factor

A:

Temperature = 40



B: formulated and control shoe
polish

Figure 4.19 Model graph one factor plot of viscosity vs. formulated Shoe polish

From the Figure 4.19 shows, the viscosity of shoe polishes formulated A, B, C & the control polishes D at different temperatures. The increase in temperature affects the viscosity of the samples. Viscosity value decreased with increase in temperature for all samples, polishes labeled sample B formulated using 33 % water sachets was hard compared with sample A and C at 40-60°C. Generally viscosity of the polishes decreases with temperature. Viscosity of polish produced using sample B compared favorably with control polish sample D than sample A and C at 50°C.

4.4. Performance of Shoe polish& Compared with Commercial Product

Table 4.12 Physical tested of shoe polish

Physical Property	Formulated Shoe Polish			Kiwi (D)
	A	B	C	
Luster / gloss	Good	Very Good	Good	Very Good
Rub Resistance	Very Good	Good	Good	Very Good
Fading Resistance	Very Good	Very Good	Very Good	Excellent
Dust Absorption Resistance	Good	Very Good	Good	Excellent
Wrinkle / Crease Resistance	Good	Very Good	Good	Very Good

From the resulted in table 4.12 it is observed that, Sample B and commercial shoe polishes exhibited, a very good gloss. Which comparably shown by the polish from polyethylene sachet wax. This is due to the tinting strength of polythene and its excellent interaction with solvent, oil (Turner, 1993and Morgans, 1990). Shoe polish from polythene showed good rubbing resistance, which is inferior to sample A and commercial (D) shoe polishes, but the same with sample C shoe polish. The fading resistance of the formulated shoe polish (Sample B) showed almost the same with that sample A and C shoe polish but inferior to that of Commercial shoe polish. This is due to smooth texture and tinting strength of the polythene. (Gumel, 2006).

Polyethylene (Sample B) exhibited a very good resistance to dust similar to that commercial shoe polish (D), but Superior to that of carbon Sample A and polishes. This was attributed to the small particle size and smooth texture of the polythene (Christie, 1993). The shoe polish produced from polyethylene wax (Sample B) showed a very good wrinkle resistance, which the same was in compared with that of Commercial, but superior to that of sample A and Sample C. This is due to the excellent interaction of the polyethylene wax with the reagents used and adhesion of the polish to the finished leather (Guthrie and Lin, 1994).

Chapter Five

5. MATERIAL AND ENERGY BALANCE

5.1. Heat and Mass Balance Analogies

Matter is transformed to energy when C-C and C-H chains break on heating at high temperature, forming various inflammable monomers, active molecular groups and other smaller molecules which are burned.

Table 5.1 an analogy of heat and mass transfer

Nature		Heat transfer	Mass transfer
		Transfer of Thermal energy within a single phase	Transfer of chemical components from a donor to host phase within a phase
Mechanisms	Molecular movement in closed systems	Heat conduction in metal and transfer of hot gas stream	Diffusion and transfer of hot gases involving phase changes
	Radiation	Thermal radiation	No mass radiation
	Macroscopic movement (gases)	Convective and conductive heat Transfer	Convective mass transfer (molecules)
Technical meaning		Favoring Heat transfer (temperature gradient) Prevention of heat transfer by insulation and isolation	Cracking of polymer plastics, transfer Of pyrolysis-synthesis gases to combustion chamber and burning
Transport equation		Heat and material flow rates and driving forces (temperature, concentration and pressure)	
Transport area		Heat transfer surface	Mass of hot gases
Driving Forces and intensive variables		Temperature difference	Concentration, composition, phase change and pressure differences
Examples		Heat conduction, radiation and convection (free and forced)	Drying and dissolving of solids, absorption of gases and distillation

This process involves a dynamic mass and heat transfer system ensuring effective resource recovery from waste. A careful evaluation of the energy and mass balance analysis of the simplified process is absolutely necessary to ascertain the environmental friendliness of the technology.

5.1.1. Energy and Mass Input and Output in a Process

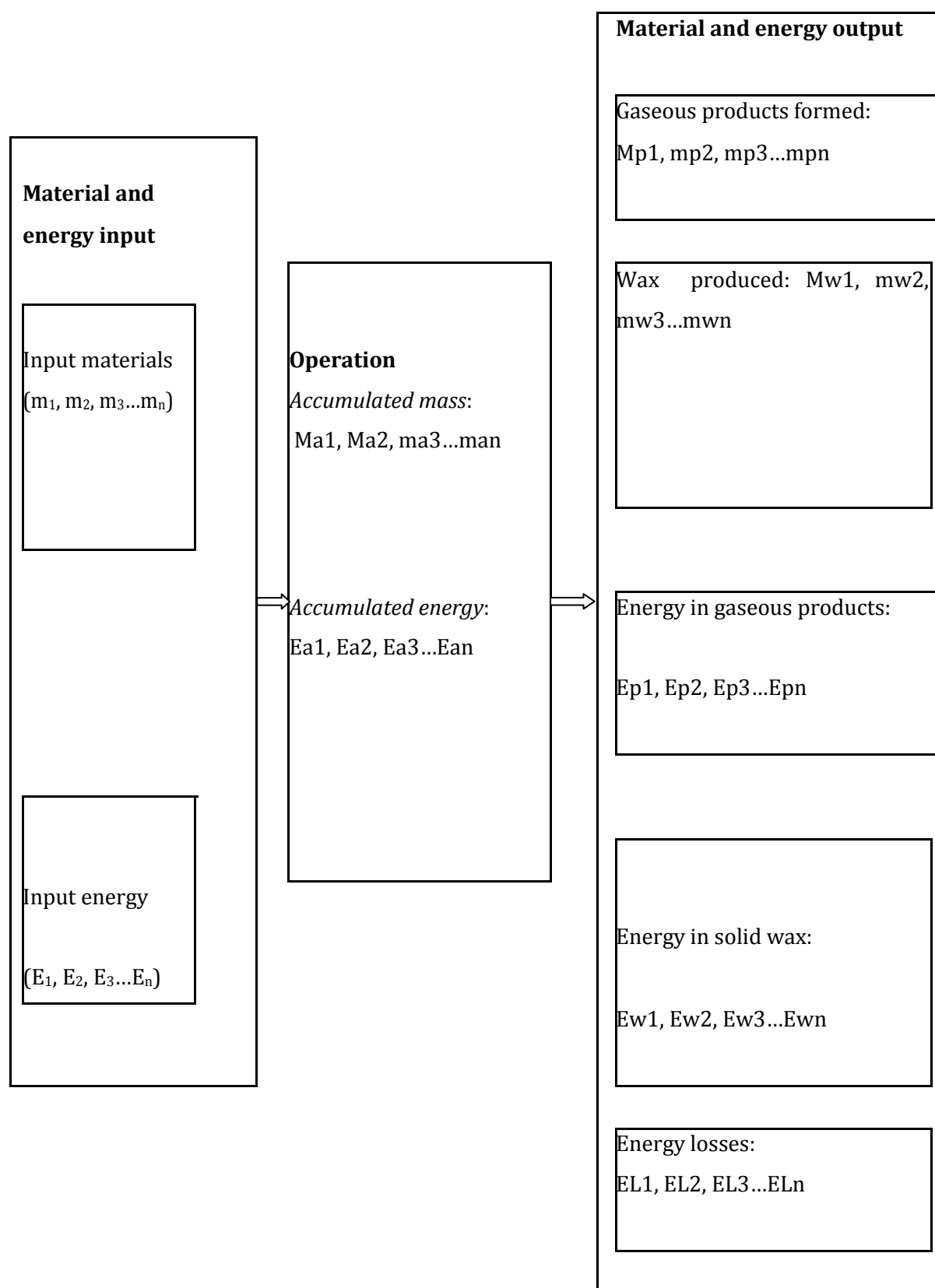


Figure 5.1 modeling the energy and mass calculations

This open system governed by the law of conservation of matter and energy. Hence, various material and energy inputs undergo conversions that lead to accumulations and

output. The mass and energy analysis mainly involve the transformation of mass (wax, and gaseous) through cracking and burning liberating various energy forms, exhaust gases and residue ash.

5.1.2. Mass Balance within the Process

The law conservation of mass or energy states that in every chemical and physical process, matter can neither be created nor destroyed but can be transformed from one form (mass or energy) to another (Eq. 5.1).

$$\sum Q + \sum W = 0 \quad (5.1)$$

Applying the non-flow conservation of energy law to the process involves an integrated of physical and chemical changes sustained by net heat transformation (Q) involving internal energy (U) and work (W) changes (Eq. 5.2).

$$U_2 - U_1 = \sum_1^2 dQ + \sum_1^2 dw \quad (5.2)$$

Applying the law of conservation of mass using [M_i (mass in), M_o (mass out), M_g (mass generated) and M_a (mass accumulated)] gives equation 5.3.

$$M_i - M_o + M_i = M_g \quad (5.3)$$

The application of this principle is necessary for quantifying solid.

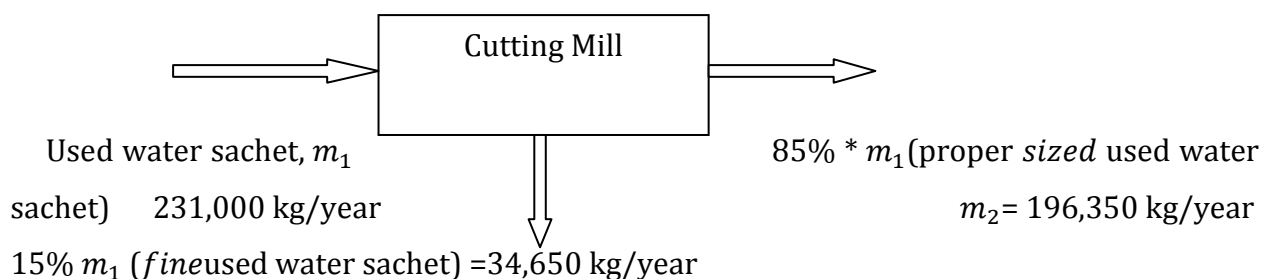
5.2. Material Balance

From Formulated shoe polish (33 % of sachet wax, 15 % of Bee wax, 12 % of Fragrance, and 50 % of Olive oil) was needed.

1. Cutting Mill

Assumption: - used water sachet was sufficiently dried

- From projected demand 700,000 kg/year was specified, 231,000 kg/year of used water sachet, 105,000 kg/year of Bee wax, 84,000 kg/year of Fragrance, 350,000 kg/year of Olive oil.

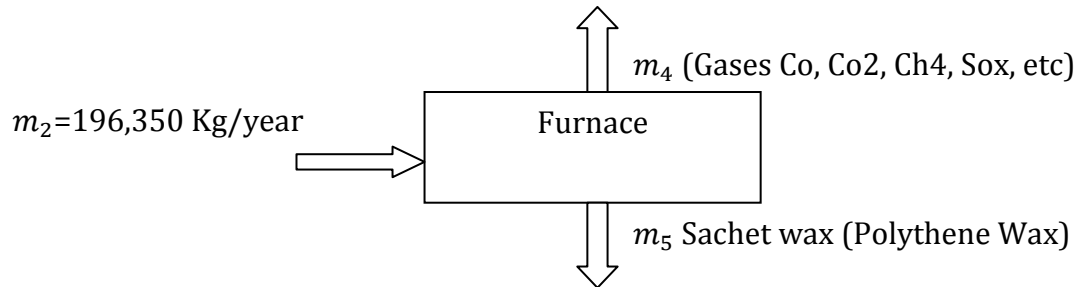


Assumption: - 85% of proper used water sachet was obtained; the remaining 15% was fined used water sachet.

$$m_2 = 0.85 * m_1 = 0.85 * 231,000 \text{ kg/year} = 196,350 \text{ kg/year}$$

$$m_3 = 0.15 * m_1 = 0.15 * 12,000 \text{ kg/day} = 34,650 \text{ kg/year}$$

2. Carbonization unit



In the lab scale, 100 g of used water sachet was pyrolyzed and 59 g of sachet wax was obtained.

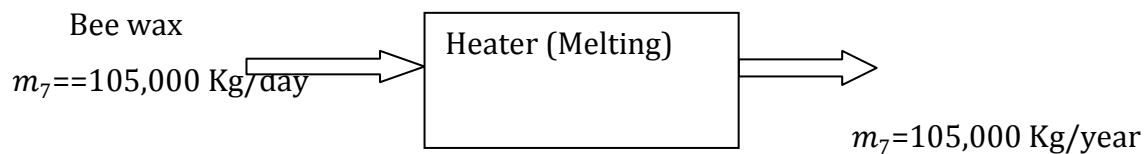
$$m_5 = 196,350 \text{ Kg/year} * 59/100 = 115,846 \text{ Kg/year}$$

$$\text{And } m_{in} = m_{out} = m_4 = m_2 - m_5 = 196,350 \text{ Kg/year} - 115,846 \text{ Kg/year} = 80,503 \text{ Kg/year}$$

3. Cooling unit



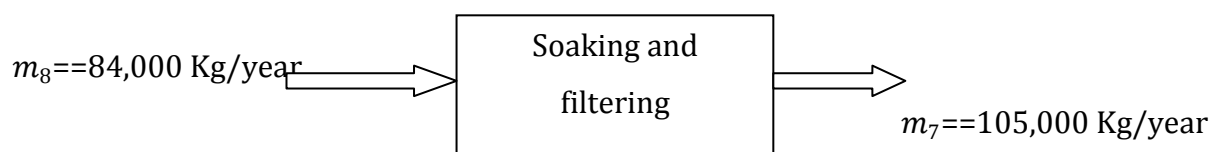
4. Melting



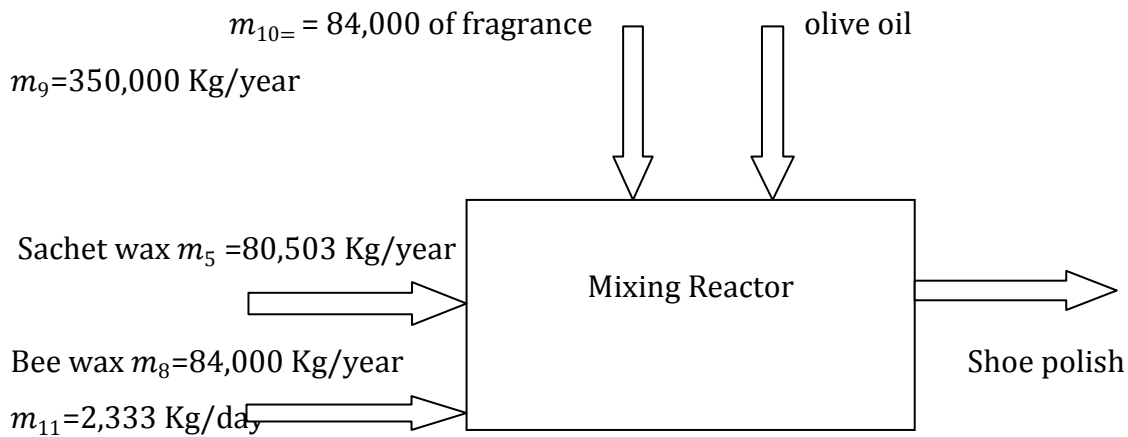
5. Soaking and Filtering

From lab result 100 g of bee wax was filtered 80 g of bee wax

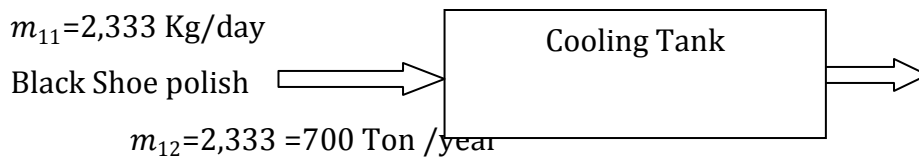
$$m_8 = 105,000 \text{ Kg/year} * 80/100 = 84,000 \text{ kg/year}$$



6. Mixing Reactor



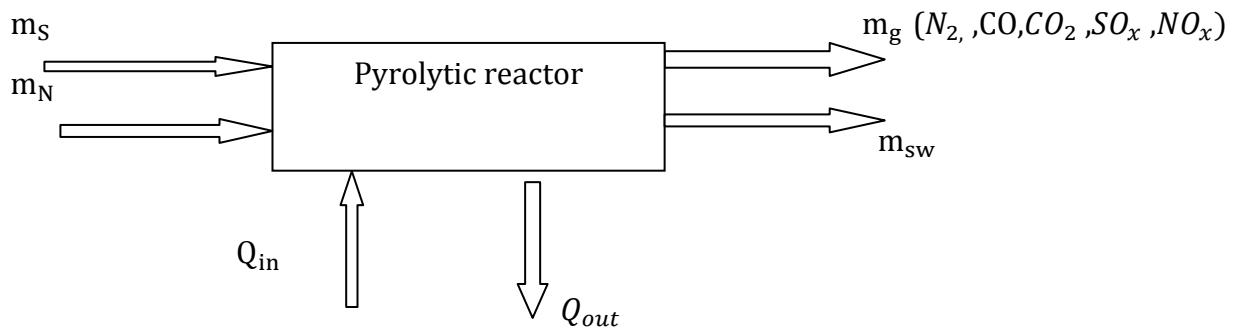
7. Cooling



5.3. Energy Balance Calculation

The reactor is designed with a used water sachet flow rate of $5,000$ kg/h. The nitrogen (N_2) flow rate inside the reactor is determined by Carbolite characteristics. The N_2 gas velocity required for 2mm particles inside the horizontal tubular reactor is in the region of 0.3 m/s (Yanik et al. 2007). Assuming a maximum linear velocity flow was taken as 5 kg/h to increase the robustness of the design. For practical operation the N_2 flow rate should be in the region of $2 - 3$ kg/h.

The energy balance of the system can be viewed as the separate combination of N_2 gas and used water sachet and pyrolysis products. N_2 gas does not undergo phase change or reaction and it therefore requires heating and cooling to the design temperatures. Used water sachet requires heating, and then undergoes a reaction resulting in phase change. The pyrolysis product requires cooling and condensation.



Where m_s = mass flow rate of used water sachet; m_g = mass flow rates of gases; m_{sw} = mass flow rate sachet wax; m_N = mass flow rate of nitrogen

$$E_{out} = E_{in} + E_{generated} - E_{consumed} - E_{accumulated} + E_{losses} \quad (5.4)$$

At steady state the accumulation of energy is zero. Pyrolysis heat requirements between 200 and 400 J/g were reported for various biomasses by Van de Velden et al. (2010). Therefore at a used water sachet flow rate of 463 g/s approximately 138.9 KJ/s could be required. During pyrolysis energy is required in the form of heat, to create the reactive conditions.

5.3.1. Thermodynamic properties for the energy balance

The enthalpy of evaporation and specific heat capacity for water and nitrogen were obtained from Cengel (2003). The bio-gas specific heat capacity was estimated from CO and CO₂ be close to 1 kJ/kg*K (www.engineeringtoolbox.com, 2009). To account for variation and increase the robustness of the design the value was slightly increased to (1.5 kJ/kg*K). Average Cp values were used over the temperature range 25 – 500°C.

From the references for thermodynamic properties are given:

$$Q_{in} = \Delta E = \Delta E_{heating} + \Delta E_{evap} + \Delta E_{rxn} \dots \dots \dots 5.5$$

Table 5.2 Energy balance on Carbolite reactor

Species	M*kg/h	Cp (ave),kJ/kg	$\Delta T, k$	Q, kW
Biomass heating	5,000	1.2	475	791.7
Nitrogen heating	5	1.1	475	0.73
Total				792.43

5.4. Equipment Design and Selection

Equipment design for this preliminary process evaluation involves determining the size of the equipment in terms of the volume, flow per unit time, or surface area. Some of the

calculations are presented in the following to indicate the extent of the calculations which are sometimes adequate for a preliminary design.

5.4.1. Reactor Volume

Assume a 4-h cycle and operation of the mixing reactor at constant temperature and pressure of 115°F and 1 atm, respectively. The volume of reactants per day (with a 10% safety factor)

Equipment Sizing

Provide olive oil and sachet wax storage

Volume of sachet wax Tank = (3,982) * (6) = 23,892 gal

Volume of olive oil Tank = (4500) * (6) = 27,000 gal

Select a 24,000-gal carbon steel tank for sachet wax storage and a 27,000-gal carbon steel tank for olive oil storage

5.4.2. Equipment specifications

Table 5.3 Equipment specification and sizing

NR	Item & description	Size	Materials of Construction
1	Storage tank For wax	24,000 gal	Carbon steel
2	Storage tank for used water sachet	27,000 gal	Carbon steel
3	Mixing reactor	1,300 gal	Stainless steel
4	pump (centrifugal) for melted wax transfer	70 psi (up to 50 psi)	Carbon steel
5.	pump (screw) for sachet transfer	50 psi(up to 50 psi)	Carbon steel

Chapter Six

6. Economical Feasibility Study

6.1. Plant Location & Site Location

The geographical location of the final plant can have strong influence on the success of the industrial venture. Considerable care must be exercised in selecting the plant site, and many different factors must be considered. Primarily the plant must be located where the minimum cost of production and distribution can be obtained but other factors such as room for expansion and safe living conditions for plant operation as well as the surrounding community are also important. The location of the plant can also have a crucial effect on the profitability of a project.

The choice of the final site should first be based on a complete survey of the advantages and disadvantages of various geographical areas and ultimately, on the advantages and disadvantages of the available real estate. The various principal factors that must be considered while selecting a suitable plant site are briefly discussed in this section. The factors to be considered are raw material availability, location (with respect to the marketing area), availability of suitable land, transport facilities, availability of labors, availability of utilities (Water, Electricity), environmental impact and effluent disposal, local community considerations, climate, Political strategic considerations, taxations and legal restrictions

a) Raw Materials Availability

The source of raw materials is one of the most important factors influencing the selection of a plant site. This is particularly true for the shoe polish plant because a large volume of used water sachet is consumed in the process, which will result in the reduction of the transportation and storage charges. Attention should be given to the purchased price of the raw materials, distance from the source of supply, freight and transportation expenses, availability and reliability of supply, purity of raw materials and storage requirements.

b) Location

The location of markets or intermediate distribution centers affects the cost of product distribution and time required for shipping. Proximity to the major markets is an important consideration in the selection of the plant site, because the buyer usually finds advantageous to purchase from near-by sources.

c) Transport

The transport of materials and products to and from plant will be an overriding consideration in site selection. If practicable, a site should be selected so that it is close to at least two major forms of transport: road, rail way. Road transport is being increasingly used, and is suitable for local distribution from a central warehouse.

Rail transport will be cheaper for the long-distance transport. If possible the plant site should have access to all three types of transportation. There is usually need for convenient rail and air transportation facilities between the plant and the main company headquarters, and the effective transportation facilities for the plant personnel are necessary.

d) Availability of Labors

Labors will be needed for construction of the plant and its operation. Skilled construction workers will usually be brought in from outside the site, but there should be an adequate pool of unskilled labors available locally; and labors suitable for training to operate the plant. Skilled tradesmen will be needed for plant maintenance. Local trade union customs and restrictive practices will have to be considered when assessing the availability and suitability of the labors for recruitment and training.

e) Availability of Utilities

The word “utilities” is generally used for the ancillary services needed in the operation of any production process. These services will normally be supplied from a central facility and includes Water, Fuel and Electricity.

f) Local Community Considerations

The proposed plant must fit in with and be acceptable to the local community. Full consideration must be given to the safe location of the plant so that it does not impose a significant additional risk to the community.

6.2. Market Study & Plant Capacity

6.2.1. Past Supply and Present Demand

The demand for polishes largely met through import. Ethiopia imported a variety of polishes and creams used in different applications. The data source for import statistics i.e.

Ethiopian Revenue and Customs Authority classifies imported of polishes and creams under the following headings.

34051000 – Polishes, creams and similar preparations for foot wear or leather;

34052000 – Polishes, creams and similar preparations for maintenance of wood work; and

34053000 –polishes, creams and similar preparations for coachwork

Among the above three types of polishes and creams imported during the period 2000-2001 , only the first two types , which are intended for use in footwear and wood are considered in the analysis of past supply and present demand . The quantity and value of the two types of polishes and creams imported in the past 12 years covering the period 2000-2011 is presented in the Table 6.1

Table 6.1 past supply data of shoe polish

Year	Amount of Shoe Polish [Ton]	Cost in (000) Birr
2000	382.2	9776
2001	478.8	12,959
2002	393.7	10,825
2003	345	8,642
2004	473.4	12,495
2005	586.2	15,312
2006	587.5	19,159
2007	672.3	20,441
2008	661.1	23,482
2009	495	25,095
2010	568	37,991
2011	442.1	33,313

Source: - Ethiopian Revenues and Customs Authority.

Table 6.1 reveals that import of polishes and creams during the period 2000-2007/08 has been modestly rising. The annual average level of import which was 400 tons during the period 2000 – 2003 has increased to annual average of 580 tons during the years 2004-2007/08. However, during the last recent three years i.e. 2009 – 2011 the mean figure has slightly declined to about 540 tons. Hence, by looking to the historical data the present demand is estimated at about 600 tons.

6.2.2. Projected Demand

The factors that affect the demand for shoe and floor polishes are urbanization and urban population growth, and income rise of the urban population. Footwear and floors that require polishing are basically found in the urban areas. Hence, an annual average growth rate of 4% is taken in forecasting the future demand by linking with urbanization and urban population growth (see Table 6.2).

Table 6.2 projected demand for polish (TONS)

Year	Projected Demand of Shoe Polish [Ton]
2013	624
2014	649
2015	675
2016	702
2017	730
2018	759
2019	790
2020	821
2021	854
2022	888
2023	924

The product is a consumer item which is to be demanded by most people. Hence, the product has to reach the final consumer through a two step channel i.e. distributors and retailers.

6.3. Plant Capacity and Production Program

6.3.1. Plant Capacity

The market study shows that demand for shoe polish increases from 624 tons in the year 2013 to 924 tons in the year 2023. Based on the market study and period required to implement the project and market penetration and technical skill development, the envisaged plant capacity is 700 tons per annum on a single shifts of 8 hours per day and 300 working days per year.

6.4. Economical Estimation

6.4.1. Estimated Capital Costs For Shoe polish Production

Table 6.3 Purchased Equipment cost

Type of Equipment	Quantity	Equipment Cost (\$)
Cutting Mill	1	14,000
Screen	1	7,000
Elevator	1	6,500
Heater	1	70,000
Storage tank	3	220,000
Filter tank	1	63,000
Soaking tank	1	45,000
Packaging machine	1	86,000
Mixing reactor	1	120,000
Rotary Cooler	1	100,000
Centrifugal pump	1	2300
Screw pump	1	2,200

Total purchased equipment cost= Total processing equipment=1,448,000\$

6.4.1.1 Estimation of Total Capital Investment

Table.6.4. Estimation of FCI and TCI

Item	Solid Processing Plant	Cost (\$)
Purchased Equipment – Delivered	45 %	1,448,000
Purchased-equipment installation	45%	651,600
Instrumentation and controls (installed)	9%	130,320
Piping (installed)	16%	231,680
Electrical(installed)	10%	144,800
Buildings(including services)	25%	362,000
Yard improvements	13%	188,240
Service facilities(installed	40%	5,79,200
Land	6%	86,880
Total direct plant cost		3,822,720
Engineering and Supervision	33 %	477,840
Construction expenses	39%	564,720
Indirect costs		1,042,560
Total direct and indirect plant costs		4,865,280
Contractor's fee (about 5% of direct and indirect		243,264
Contingency(about 10%(D+I)		486528
Fixed- capital investment		5,595,072
Working Capital (About 15 % of TCI)		

Capital costs based on different percentages of the total equipment cost according to Peters and Timmerhaus (1991).

$$\text{Total capital investment}(TCI) = FCI + WC \quad (6.1)$$

$$WC = 15\% * TCI \quad (6.2)$$

Insert Eq 6.2 in to Eq 6.1 we get,

$$TCI = FCI / 0.85 = 5,595,072 / 0.85 = 6,582,438 \$$$

6.4.2. Estimation of Total Product Cost

6.4.2.1. Estimation of Manufacturing Cost

Manufacturing Cost = Direct production cost + Fixed charges + Plant overhead cost.

a) Fixed Charges: (10-20% total product cost)

i. Depreciation: (depends on life period, salvage value and method of calculation-about 10% of FCI for machinery and equipment and 2-3% for Buildings) and Consider depreciation = 10% of FCI for machinery and equipment and 2.5% for Building Value for Buildings).

ii. Local Taxes: (1-4% of fixed capital investment) Consider the local taxes = 2.5% of fixed capital investment.

iii. Insurances: (0.4-1% of fixed capital investment) Consider the Insurance

iv. Rent: (8-12% of value of rented land and buildings)

$$\text{Total Fixed Charges} = \text{Depreciation} + \text{Local Taxes} + \text{Insurances} + \text{Rent} = 291,062.3 \$$$

b) Direct Production Cost: (about 60% of total product cost)

Now we have Fixed charges = 10-20% of total product cost – (given); Consider the Fixed charges = 15% of total product cost.

$$\text{Total product cost} = \text{Total fixed charges} / 0.15 \text{ Total product cost}$$

i. Raw Materials: (10-50% of total product cost); Consider the cost of raw materials = 30% of total product cost *Raw material cost*.

ii. Operating Labor (OL): (10-20% of total product cost); Consider the cost of operating labor = 15% of total product cost.

iii. Direct Supervisory and Clerical Labor (DS & CL): (10-25% of OL); Consider the cost for Direct supervisory and clerical labor = 17.5% * OL

iv. Utilities: (10-20% of total product cost); Consider the cost of Utilities = 15% of total product cost

v. Maintenance and repairs (M & R): (2-10% of fixed capital investment); consider the maintenance and repair cost = 6% of fixed capital investment.

vi. Operating Supplies: (10-20% of M & R or 0.5-1% of FCI); consider the cost of Operating supplies = 15% of M & R.

vii. Laboratory Charges: (10-20% of OL); consider the Laboratory charges = 15% * OL

Laboratory charges = 15% * 291,062.3\$ = 43,659.3\$

c) Plant overhead Costs

(50-70% of Operating labor, supervision, and maintenance or 5-15% of total product cost); includes for the following: general plant upkeep and overhead, payroll overhead, packaging, medical services, safety and protection, restaurants, recreation, salvage, laboratories, and storage facilities.

Consider the plant overhead cost = 10% of Total Product Cost; *Plantoverheadcost* = 10% * 1,940,415.3\$ = 194,041.5\$

Thus, Manufacturing cost = Direct production cost + Fixed charges + Plant overhead costs

Manufacturecost = (1,644,884.3\$) + (291,062.3\$) + (194,041.5\$) = 2,129,988.1\$

6.4.2.2. Estimation of General Expenses Cost

General Expenses = Administrative costs + distribution and selling costs + research and development costs.

I. Administrative costs : (2-6% of total product cost); Consider the Administrative costs = 4% of total product cost.

ii. Distribution and Selling costs: (2-20% of total product cost); includes costs for sales offices, salesmen, shipping, and advertising. Consider the Distribution and selling costs = 11% of total product cost *Distributionandsellingcosts*

iii. Research and Development costs: (about 5% of total product cost)

Consider the Research and development costs = 5% of total product cost *Researchandfinancing* (interest): (0-10% of total capital investment), Thus, Total General Expenses = 717,204.9\$.

Total Product cost = Manufacture cost + General Expenses

Total Product cost = (2,129,988.1\$) + (717,204.9\$) = 2,847,193\$

6.4.3 .Production Program

In order to develop the operators' skill in production and quality control, it is vital to have a gradual capacity buildup. In addition to this, a period is required to penetrate to the market. Hence, it is assumed that the plant will go into full capacity operation in four years' time starting with 70% capacity in the first year and progressively developing to 85%, 95% and 100% in the second, third and fourth year and then after, respectively. The production program of the envisaged plant is given in Table 6.5.

Table 6.5 Production Program

No.	Item Description	1 st year	2 nd year	3 rd year	4 th -6 th
1	Shoe polish (tons)	490	550	660	700
2	Capacity Utilization	70	85	95	100

6.4.4. Financial Evaluation

6.4.4.1. Profitability

Based on the projected profit, the project will generate a profit throughout its operation life. Annual net profit after tax ranges from Birr 4.75 million to Birr 5.99 million during the life of the project. Moreover, at the end of the project life the accumulated net cash flow amounts to Birr 60.27 million.

6.4.4.2. Break-even Analysis

The break-even analysis establishes a relationship between operation costs and revenues. It indicates the level at which costs and revenue are in equilibrium. To this end, the break-even point for capacity utilization and sales value estimated by using income statement projection are computed as followed.

$$BEC = [F / (TSR - TPC)] * 100 \quad (6.3)$$

$$\text{Break -Even Sales Value} = \frac{\text{Fixed Cost} + \text{Financial Cost}}{\text{Variable Margin ratio (\%)}} \quad (6.4)$$

$$\text{Break -Even Sales Value} = 26,583,480 \text{ birr}$$

$$\text{Break -Even Point} = 30 \% \quad (6.5)$$

6.4.4.3. Pay-back Period

$$\text{Payback period} = FCI / \text{Netcashaccrual} \quad (6.6)$$

The pay- back period, also called pay – off period is defined as the period required for recovering the original investment outlay through the accumulated net cash flows earned by the project. Accordingly, based on the projected cash flow it is estimated that the project's initial investment will be fully recovered within 3 years.

6.4.4.4. Internal Rate of Return

The internal rate of return (IRR) is the annualized effective compounded return rate that can be earned on the invested capital, i.e., the yield on the investment. Put another way, the internal rate of return for an investment is the discount rate that makes the net present value of the investment's income stream total to zero. It is an indicator of the efficiency or quality of an investment. A project is a good investment proposition if its IRR is greater than the rate of return. That could be earned by alternate investments or putting the money in a bank account. Accordingly, the IRR of this project is computed to be 30.37% indicating the viability of the project.

$$\text{Rate of Investment (ROI or ROR)} = \text{Net Profit} / \text{TCI} \quad (6.7)$$

ROR= 30.5 %

6.4.4.5. Net Present Value

Net present value (NPV) is defined as the total present (discounted) value of a time series of cash flows. NPV aggregates cash flows that occur during different periods of time during the life of a project in to a common measuring unit i.e. present value. It is a standard method for using the time value of money to appraise long-term projects. NPV is an indicator of how much value an investment or project adds to the capital invested. In principle, a project is accepted if the NPV is non-negative.

Accordingly, the net present value of the project at 10% discount rate is found to be Birr 25.90 million which is acceptable.

6.5. Economic & Social Benefits

The project can create employment for 30 persons. The project will generate Birr 16.44 million in terms of tax revenue. The establishment of such factory will have a foreign exchange saving effect to the country by substituting the current imports. The project will also generate income for the Government in terms of payroll tax.

Chapter Seven

7. Conclusion & Recommendation

Used water sachets have become uncontrollable nuisance in Ethiopia. Most places are littered with the polymer made materials which are continuously dumped indiscriminately. In fact a considerable portion of the Ethiopia land mass has been occupied by varieties of waste. This research work thesis tends to look at the used water sachets as blessing by converting them to a more useful product. The effective management of the polyethylene waste through conversion into further usable products turns the littered surrounding to an environmentally friendly one by preventing outspread of disease and simultaneously creating employment for both skilled and unskilled labor.

Polyethylene wax was found to form a good and compatible formula in the production of shoe polish. Its shoe polish exhibited soft texture, dark hue, and very good wrinkle resistance compared with commercial shoe polish.

The use of polythene wax in the Production shoe polish was hereby recommended as it was reduce extensively, the level of pollution, which arises as a result of indiscriminate disposal of “used water sachet” in our environment.

The properties of Shoe Polish formulated from wax produced from used water sachet were studied. Pyrolysis temperatures between 100°C -200°C is required to produced sachet wax from used water sachets for formulated shoe polish. The melting point, density and viscosity of one of shoe polish formulated using 33% sachet wax compared favorably with standard commercial polish. One of the economic advantages of this research thesis work was the use of 33 % sachet wax which was a waste product, in addition to bee wax to produce the shoe polish. The other economic advantage of this project is that wealth generation and employment opportunity can be created.

The conversion of low density polyethylene i.e. LDPE (used water sachet) was demonstrated in this research. Efforts will be conduct in converting other polyethylene such as ;ultra high molecular weight polyethylene (UHMWP),ultra low molecular weight polyethylene (ULMWPE or PE-WAX),High molecular weight polyethylene (HMWPE),high density polyethylene(HDPE),high density cross- linked polyethylene (HDXLPE),cross-linked polyethylene (PEX or XLPE),medium density polyethylene (MDPE),linear low density polyethylene (LLDPE), and ,Very low density polyethylene (VLDPE) to polyethylene wax for further conversion into further usable products.

References

- Ababio, O.Y (1990) "New School Chemistry" 3rd Edition. African FEP. Publishers, Nigeria pp 108-113.
- Aboulkas et al (2007) Pyrolysis kinetics of polypropylene Morocco oil shale and their mixture. Journal of thermal analysis and calorimetry, 89: 203-209.
- Achankeng E (2003) Globalization, urbanization and municipal solid waste management in Africa. African studies association of Australasia and the pacific 2003 conference proceedings.
- Akpovi, S. V ;(1993) Provision of environmental sanitation: The problem of refuse disposal in Benin City. Paper presented at the CENCER seminar series, university of Benin, Benin City (1981).
- Angyal A, Miskolczi N, Bartha L (2007) Petrochemical feedstock by cracking of plastic waste. Journal of analytical and applied pyrolysis, vol. 79, Issues 1-2: 409-414 [Pyrolysis 2006: Papers presented at the 17th international symposium on analytical & applied pyrolysis, Budapest, Hungary].
- Aquado J, Serrano, DP, Escola JM (2006) Catalytic upgrading of plastic wastes: In: Scheirs J, Kaminsky W (Eds), Feedstock recycling and pyrolysis of waste plastics: Converting waste plastics into diesel and other fuels, John Wiley & Sons, Ltd, UK.
- Aziegbe, F.I ;(2004) Sediment sources, redistribution and management in Ekpoma, Edo State, Nigeria Journal of Human Ecology (in press).
- Bayer, A.G. (1986) "Tanning, Dyeing and Finishing" 4th Edition GeschäftsbereichFarben, 5090 Levertkusenpp 24-30.
- Berger, P.S, Clark, R.M and Reasoner D.J ;(1993). Water, Drinking. In: Encyclopedia of Microbiology. Vol. 4:385-398.
- Bhandare PS, Lee BK, Krishman K (1997) Study of pyrolysis and incineration of disposable plastics using combined TG/FT-IR technique. Journal of thermal analysis, vol. 49: 361-366. Akademiai Kladó. Budapest.
- Biniecka M, Campana P, Tarola AM (2005) Thermo-valorisation integrated waste management. XI Italian Hungarian Symposium on Spectrochemistry, MicrochemicalJournal, vol. 79, issues 1-2: 319-324.
- Blasi DC (1997) Linear pyrolysis of cellulosic and plastic waste. J. of Analytical and Applied pyrolysis. Vol. 40-41:463-479, pyrolysis "96.
- Blazsó M (1997) Recent trends in analytical and applied pyrolysis of polymers. Journal of analytical and applied pyrolysis, 39: 1-25.

Bockhorn H et al. (1999) Dehydrochlorination of plastic mixtures. Journal of analytical and applied pyrolysis, 49: 97-106.

Boer DE, Boer DJ & Jager J (Eds) (2005) Waste management planning and optimisation: Handbook for municipal waste prognosis and sustainability assessment of waste management systems, Ibidem-verlag, Stuttgart.

Bos U, Makishi C, Fischer M (2007) Life cycle assessment of common used agricultural plastic products in the EU (abstract), ISHS Acta Horticulturae 801: International Symposium on High Technology for Greenhouse System Management: Greensys2007.

Characklis, W.G, and Marshall K.S ;(1990). Biofilms: a basis for an interdisciplinary approach. pp. 3-15.

Cheremisinoff NP (2003) Handbook of solid waste management and waste minimisation technologies. Butterworth Heinemann, New York.

Christie R.M (1993) "Surface Coating Reviews in Pigment Structures, Properties and Synthesis Procedure" Oil and Color Chemist Association, U.K P 10-11.

Costa PA, Pinto FJ, Ramos AM, Gulyurtlu IK, Cabrita IA, Bernardo MS (2007) Kinetic Evaluation of the Pyrolysis of Polyethylene Waste, *Energy & Fuels* 21: 2489-249.

Edraw max Software

Egwari, L., Aboaba, O; (2002). Environmental impact on the bacteriological quality of domestic water supplies in Lagos, Nigeria. Rev. Saúde Pública. 36 (4): 513-520.

Encinar M, González JF (2008) Pyrolysis of synthetic polymers and plastic wastes. Kinetic study. Fuel Processing Technology, Vol. 89, issue 7: 678-686.

Ferrara I, Missios P (2005) Recycling and waste diversion effectiveness: Evidence from Canada. Environmental & Resource Economics, 30: 221-238.

Foley G, Kerkhof P, Madougou D (2002) A review of the rural firewood market strategy in West Africa. Africa region working paper series, No. 35.

Gadgil, A., Derby, E., (2003). Providing Safe Drinking Water to 1.1 Billion Unserved People. Paper # 70492.

<http://www.academia.com>

<http://www.academia.com>

<http://www.aiche.com>

J.H De Bussy: "Materials and Technology -Natural Organic Materials Related Synthetic Products ". Longman, London, UK, vol. v, pp 317-381, 1976.

L .Jixing Shuyuan, Xuan Wang and L Xian yang. Study on the Conversion Technology of waste Polyethylene Plastic to Polyethylene Wax, Energy Sources vol 25, pp 77 -83. 2003.

L. Chalmers," Household and Industrial Chemical specialties ". Chemical Publishing Co. Inc., New York, NY, USA, 1979.

LeChevallier, M.W; (1999). Biofilms in drinking water distribution systems: significance and control, identifying future drinking water contaminants. National Academy Press. Washington, DC.

Mustapha, S., Adam, E.A., (1991). Discussion on Water Problems in Nigeria: Focus on Bauchi State. Natl. Water Res. Inst.

Odemerho (Eds.). Ibadan, Evans Brothers Publishing Company Limited P 77-87
Onokerhoraye, A. G ;(1984) Perspectives on the urban environmental quality and public policy in Nigeria. Paper presented at the Department Seminar Series, Department of Geography and Regional Planning, University of Benin, Benin City.

Omuta, G. E. D ;(1988) urban solid waste generation and management: Towards an environmental sanitation policy. In: Environmental Issues and Management in Nigeria Development. P. O. Sada and F. O.

Owolabi, R.U., Kareem, S.A., (2010) Dechlorination/On set of microbial growth in water storage tank, Journal of Applied Sciences Research, 6(6): 589-593.

Oyinlade, O. O ;(1991)Urban Solid Waste Management in Nigeria: Case Study of Akure, Ondo State: Unpublished M.Sc. Thesis, Department of Geography and Regional Planning, University of Benin,Benin City.

Peters, M., and Timmerhaus, K., 1991. Plant Design and Economics for Chemical Engineers. McGraw-Hill, Inc., New York.

R.H. Perry; and C.H Chilton," Chemical Engineers Handbook ", McGraw-Hill, New York, NY, USA, 2008.

Ramasasthy, C. V ;(1988) Estimation of solid wastes in Bendel State Nigeria. In: Environmental Issues and Management in Nigeria Development. P. O. Sada and F. O. Odemerho (Eds.). Ibadan, Evans Brothers Publishing Company Limited.

Secchi, A.R., Bolson, A., (2005), Analysis and Optimization OfLDPE Production.

US EPA ;(2002) Health Risks from Microbial Growth and Biofilms in Drinking Water Distribution Systems.

Van der Wende, E., and Characklis,W.G (1990). Biofilms in potable water distribution systems. p. Drinking Water Microbiology.McFeters,GA (Ed.). pp. 249-268. Springer-Verlag. New York, NY.

Appendices

Financial Analysis Supporting Tables

Appendix I: Income Statement (in 000 Birr)

Item	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11
Sales revenue	44,306	53,800	60,129	63,294	63,294	63,294	63,294	63,294	63,294	63,294
Less variable costs	38,060	46,216	51,653	54,371	54,371	54,371	54,371	54,371	54,371	54,371
VARIABLE MARGIN	6,246	7,584	8,476	8,923	8,923	8,923	8,923	8,923	8,923	8,923
in % of sales revenue	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10
Less fixed costs	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079
OPERATIONAL MARGIN	5,167	6,506	7,398	7,844	7,837	8,561	8,561	8,561	8,561	8,561
in % of sales revenue	11.66	12.09	12.30	12.39	12.38	13.53	13.53	13.53	13.53	13.53
in % of sales revenue		1,408	1,232	1,056	880	704	528	352	176	0
GROSS PROFIT	5,167	5,097	6,165	6,788	6,957	7,857	8,033	8,209	8,385	8,561
in % of sales revenue	11.66	9.47	10.25	10.72	10.99	12.41	12.69	12.97	13.25	13.25
Income (corporate) tax	0	0	0	2,036	2,087	2,357	2,410	2,463	2,515	2,568
NET PROFIT	5,167	5,097	6,165	4,751	4,870	5,500	5,623	5,746	5,869	5,992
in % of sales revenue	11.66	9.47	10.25	7.51	7.69	8.69	8.88	9.08	9.27	9.47

Appendix II: Cash Flow for Financial Management

Item	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 10	Year 11
Total Cash Flow	5,889	58,021	53,807	60,134	63,294	63,294	63,294	63,294	63,294
Inflow funds	5,889	13,715	7	5	0	0	0	0	0
Inflow operation	0	44,306	53,800	60,129	63,294	63,294	63,294	63,294	63,294
Other income	0	0	0	0	0	0	0	0	0
TOTAL CASH OUTFLOW	5,889	52,025	52,295	56,669	60,361	59,357	59,450	59,080	57,197
Increase in fixed assets	5,889	0	0	0	0	0	0	0	0
Increase in current assets	0	12,435	2,660	1,773	887	1	0	0	0
Operating costs	0	38,060	46,216	51,653	54,371	54,378	54,378	54,378	54,378
Marketing and Distribution cost	0	250	250	250	250	250	250	250	250
Income tax	0	0	0	0	2,036	2,087	2,357	2,515	2,568
Financial costs	0	1,280	1,408	1,232	1,056	880	704	176	0
Loan repayment	0	0	1,761	1,761	1,761	1,761	1,761	1,761	0
SURPLUS (DEFICIT)	0	5,996	1,512	3,464	2,933	3,937	3,844	4,214	6,097
CUMULATIVE CASH BALANCE	0	5,996	7,508	10,973	13,905	17,842	21,687	33,958	40,056

Appendix I I I: Discounted Cash Flow (in 000 Birr)

Item	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Total Cash Inflow	0	44,306	53,800	60,129	63,294	63,294	63,294	63,294	63,294	63,294
Inflow operation	0	44,306	53,800	60,129	63,294	63,294	63,294	63,294	63,294	63,294
Other income	0	0	0	0	0	0	0	0	0	0
Total Cash Out Flow	18,291	40,963	48,235	52,787	56,658	56,715	56,985	57,038	57,144	57,197
Increase in fixed assets	5,889	0	0	0	0	0	0	0	0	0
Increase in net working capital	12,402	2,653	1,769	884	1	0	0	0	0	0
Operating costs	0	38,060	46,216	51,653	54,371	54,378	54,378	54,378	54,378	54,378
Marketing and Distribution cost	0	250	250	250	250	250	250	250	250	250
Income (corporate) tax	0	0	0	0	2,036	2,087	2,357	2,410	2,515	2,568
NET CASH FLOW	-18,291	3,343	5,565	7,342	6,636	6,579	6,309	6,256	6,150	6,097
CUMULATIVE NET CASH FLOW	-18,291	14,948	-9,383	-2,041	4,594	11,173	17,482	23,738	36,091	42,189
Net present value	-18,291	3,039	4,600	5,516	4,532	4,085	3,561	3,210	2,608	2,351
Cumulative net present value	-18,291	15,252	-10,653	-5,137	-604	3,480	7,041	10,252	15,754	18,105

Net Present Value = 25,897

Rate of Return = 30.7 %

Pay Back Period = 3 years

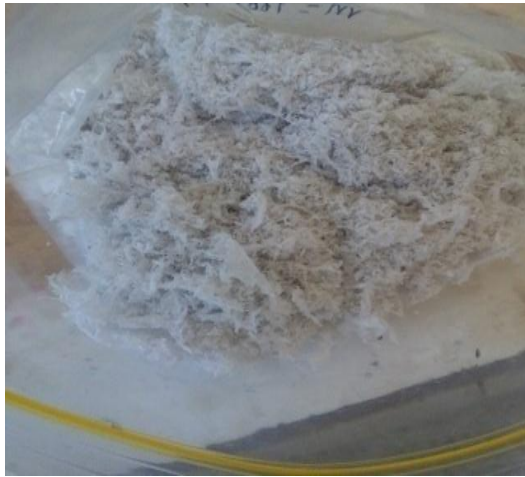
Appendix IV: Pictures of Plastic disposal and Laboratory Equipments



A: Dominance of plastic waste in landfills and impacts on the environment



B: Basic Equipments used to produce shoe polish



C: Shoe Polish Product from Bee wax and Used Water Sachets

