COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

FINAL YEAR PROJECT SUBMITTED TO WOLKITE UNIVERSITY, DEPARTMENT OF CHEMICAL ENGINEERING IN PARTIAL FULFILMENT OF THE REQUIRMENT FOR THE DEGREE OF BACHELOR SCEINCE IN CHEMICAL ENGINEERING

TITLE: PRODUCTION AND CHARACTERIZATION OF POTASSIUM CARBONATE FROM BANANA PEELS

PREPARED BY:

NAME	ID NO
ARARSO NUGUSE	ENGR/0125/10
AYANA KASSA	ENGR/0145/10
DAWIT OLIKA	ENGR/0276/10
SOFIA JEMAL	ENGR/0818/10
TIGIST TIBEBU	ENGR/0879/10

ADVISOR: Mr. GETU WEYYA

JUNE 13,2022

WOLKITE, ETHIOPIA

DECLARATION

This is to declare that the work which is being presented in this thesis entitled production and characterization of Potassium Carbonate from Banana peels is modified by ourselves, and that all sources of materials used for the thesis have been duly acknowledged.

Set by: Signature

1. Ararso Nuguse ______________
2. Ayana Kassa ______________
3. Dawit Olika ______________
4. Sofia Jemal ______________
5. Tigist Tibebu ______________

Approved by:

Mr. Getu W. ___________ ____________

Examiners:	Signature	Date
1. _________________________	_________	________________
2. _________________________	_________	________________
3. _________________________	_________	________________

ACKNOWLEDGMENT

Beyond all we thank our almighty God who allows us to do this project and helped us to accomplish our BSc. Degree successfully. Then we would like to express our profound gratitude and sincerest appreciation to our advisor Mr. Getu W. for his encouragement, invaluable constructive ideas and suggestions on our thesis work.

It is our greatest pleasure to thank to all the Department of chemical Engineering lab technicians for their excellent assistance and guidance during our experiments. We are grateful for their friendly advices, technical assistances and encouragement that they have offered for the group throughout the work.

Last but not the least, we would like to express our gratitude to all respondents of our final year project thesis, whom they share us their valuable time and knowledge. Finally, we would like to thank our beloved families.

Table of Contents

List of Tables

Page

List of Figures

Page

List of Acronyms

WC – working capital

PEC- purchased equipment cost

FCI- fixed capital investment

DC- Direct cost

IC- insulation cost

ICIC- instrumentation and controls installed cost

PC- piping cost

EC- Electrical Cost

BPAC- Building Process and Auxiliary cost

SFC-Serves Facilities Cost

LC- Land Cost

IC-Indirect Cost

ESC- Engineering and Supervision Cost

CECC- Construction Expense and Contractors Cost

CC- Contingency Cost

DPC- Direct Production Cost

POC- Plant Overhead Cost

MC- Manufacturing Cost

AC- Administrative Cost

DSC- Distribution and Selling Cost

RDC –Research and Development Cost

FC- Financing Cost

GI- Gross Annual Earning

DC- Deprecations Cost

GP- Gross Profit

NP- Net profit

Aj- Annual cash flow

ROI- Return on Investment

PBP-Payback Period

NPw- Net Present worth

EXECUTIVE SUMMARY

In Ethiopia, agriculture is a way of life for which agricultural land is an indispensable resource up on which the welfare of the society built in; though, our environment is facing challenges from waste disposals. From those wastes, banana peels are playing their own contribution due to huge consumption. Hence, the main aim of this project was to produce potassium carbonate from those wastes by pyrolysis. The ash method was chosen from other alternative methods since it is preferable to extract K_2CO_3 from the banana peels by converting to ash. Several studies show that some fruit peels like banana peel contain alkali metals such as, potassium, sodium, calcium and magnesium with a high constituent of potassium which is a source for production of potassium carbonate. These metals are present in the form of various salts. When the plant matter or fruit peel is subjected to heat, burnt in presence of air, the metals are oxidized to metal oxides. Carbon dioxide produced during burning of banana peel, combines with potassium oxide to produce potassium carbonate. Potassium carbonates have various uses in flat glass, chemicals, and soap, pulp and paper production sectors. During the experiment the raw material was characterized by its moisture content to be 87.2% and also the ash content became 13.64%. After characterization of the peels the samples were burnt in a furnace at different temperatures to see its effect and resulted with 30g of ash which is then filtered, and evaporated for 5hours finally ended with a yield of 15.6g of potassium carbonate. Finally, the produced potassium carbonate was characterized by observing its reactivity, solubility, alkaline property, color.

Key words: ash method, banana peel, alkali metals, potassium carbonate.

CHAPTER ONE

INTRODUCTION

1.1 Background

Potassium carbonate (K_2CO_3) is a white, deliquescent inorganic salt, soluble in water (insoluble in alcohol), which forms a strongly alkaline solution. Potassium carbonate is one of the most important inorganic compounds used in industry even though it is as old as recorded history. Potassium Carbonate scientifically known us Potash. Potash has gained a world-wide domestic and commercial use in the flat glass, chemical, pulp and paper sectors [1]. It is also used for production of local soap, and traditionally used as a cleansing agent and as a source of raw material for potash-based industries [2]. Potash is found in various plant. The potash yield depends on the type of plant material, the nature of soil where the plants grow and the efficiency of extraction technology used [3]. The potash content in the peels of some varieties of plantain and banana ranged from 69.0 to 81.9% (of ash) and 4.7 to 9.6% of dry peel [4]. Bananas and plantains have been said to be the fourth largest fruit crop of the world. The world production is estimated to be 139 million tons, in which tropical Africa alone produces about 17 million tons of bananas annually [5].

Ethiopia is the country which produces, banana annually 898,355 tons and from this around 359,342 tones are the waste or banana peels. The peel of banana represents about 40% of the total weight of fresh banana and has been underutilized. This means around 40% of produced banana is wasted [6]. This abundant quantity of banana peel residues produced worldwide has been identified as a serious agricultural bio-waste and is a great challenge to waste management.

Potassium carbonate can be produced using Ash method, Lv Bulan method, Electrolysis Method, and Ion-exchange method. However, ash method is the most common method that is used in the extraction of potassium carbonate from banana peel. This method is easy to use, have less power consumption, economically feasible and good product quality. Therefore, the ash method is more preferable for our project.

Generally, this study focuses on the production and characterization of potassium carbonate from waste banana peels. The obtained potash was characterized by parameters like, odor, color, reaction with HCl, PH, taste and solubility etc.

1.2 Statement of the Problem

Ethiopia is the country which produces, banana annually 898355 tons and from this around 359,342 tones are the waste or banana peel. From this waste our country is not benefited. Currently, in Ethiopia there is shortage of potassium carbonate. Due to the problem of this shortage, the potassium carbonate is still imported from another country and also it is very expensive. If potassium carbonate is produced locally, we believe strongly that, it will reduce foreign currency used for importing potassium carbonate.

After the banana pulp has been used, the peels are normally disposed inappropriately. The generated waste (peel) has given rise to the problem of solid-waste management and has become a serious issue. Disposal methods like landfills generate greenhouse gas like methane and the burning method also results in the release of carbon dioxide which is a major public health and environmental problem. The finding of different scholars revealed the possibility of converting waste banana peels into the valuable product like potassium carbonate. So, the production of banana peel-based potassium carbonate by the ash method is incomparable remedy for environmental pollution able to occur due to peel humus.

1.3 Objectives

1.3.1 General objective

The aim of this research is to produce and characterize potassium carbonate from banana peels.

1.3.2 Specific objectives

The specific objectives of this thesis are:

❖ To determine the physical and chemical characteristics of the potassium carbonate produced

❖ To estimate the amount of potassium carbonate that can be produced from banana peels

❖ To determine the effect of moisture and temperature on potassium carbonate production

1.4 Significance of the study

The production of potassium carbonate produced from banana peels have variety of significances.

❖ Providing a remedy for the bottlenecked problems of environmental pollution due to the discarded of the waste banana peel.

❖ In addition to that it also brings economic effects by minimize the cost of importing.

❖ To increase the potassium carbonate supply in order to meet the market need or demand.

❖ To utilize banana product into a wide range of uses.

1.5 Scope of the study

The production of this Potassium Carbonate has followed a series of steps or Procedures starting from raw material collection from around Gubrie city then drying, crushing, burning in a furnace, mixing (homogenizing), filtration, evaporation, and undergo separation process. Finally; the recrystallized potash collected and stored. This project also covers characterization of the banana peel sample such as moisture content and potassium carbonate produced like reaction with HCl, PH and finally economic feasibility was done.

Research question

❖ Does the locally produced potassium carbonate, from the banana peel, have the same property as the one which is imported?

❖ How much percent of potassium carbonate can we get from banana peel ash?

❖ In what temperature does the banana peel change to ash?

CHAPTER TWO

LITERATURE REVIEW

2.1 Banana

The term "banana" is also used as the common name for the plants which produce the fruit. This can extend to other members of the genus Musa like the scarlet banana (Musa coccinea) and pink banana (Musa velutina). It can also refer to members of the genus Ensete, like the snow banana and the economically important false banana. Both genera are classified under the banana family, Musaceae [7]. Banana agricultural waste is one of the potential lignocellulosic substrates which are mostly unutilized but sufficiently available in many parts of the world [8].

The recycling and utilization of solid wastes are currently major issues for environmental research. The treatment of solid waste goes as far back as the 18th century, when burying the waste was the best option for waste management. Inadequate municipal and industrial solid waste collection and disposal creates a range of environmental problems in Ethiopia. A considerable amount of waste ends up in open dumps or drainage systems, which threatens both surface water and ground water quality and causes serious environmental and health problems. The open air burning of waste, spontaneous combustion in landfills and incinerating plants lacking effective treatment for gas emissions are all causing air pollution [9], [110]. The adverse effects of inadequate solid waste service create significant issues for productivity and economic development. Solid wastes, such as fruit peels, are largely obtained as a byproduct from food processing industries, juice processing plants, hotels and restaurants. These types of waste can cause serious environmental problems unless they are converted into a useful product or disposed of properly [11].

In this study, waste of banana peel is used as a source of potassium carbonate (K_2CO_3). The banana fruit is abundantly available in the world as it is the superb fruit that can give us energy, make us feel full and provide our body with essential nutrients (proteins, carbohydrates, phosphorus, vitamin A, iron, and potassium) and high amount of fibers [12]. As such, the more banana consumption, the more peels will dump to the landslide. Therefore, the banana peel is plentiful enough to be used [13].

Banana peel has absorption capabilities for some elements and ions in liquid or solution. Banana peel has absorption capacities to remove chromium from wastewater [14], copper, and also some dyes [15]. Unfortunately, the benefits of banana peels are not popular as many people still do not realize about. Banana peels are readily available, low cost, and environment friendly bio-material. These agricultural wastes are also inexhaustible, cheap and non-hazardous, and are specifically selective for heavy metals and can be easily disposed by incineration. The main banana residue is the fruit peel, which accounts for 40% of the total fruit weight.

Banana peel has been selected to perform the present study due to its high content in carbohydrates, which is due to their organic nature that are easily metabolized by microorganisms, as it has the physical integrity to serve as a supporting material. There are few industrial for uses banana peels and they are a major agricultural waste in different regions of the planet [16].

2.1.1 Different stages of maturation

As the banana develops, the peel acts as housing for chlorophyll that is manufactured as a result of the direct sunlight required to grow the fruit. Banana and plantain are consumed or locally processed at various stages of maturation which have been classified from stage 1, green skin, to stage 7, yellow skin with black spots [17]. Mature green banana especially plantain is very rich in starch and is one of the promising substitutes for the starch industry. The fruit is then delivered for consumption. The ripening classification defines 7 stages by color index. At stages 1 to 3, banana is not usually eaten like fruit because it is green, very hard, astringent and rich in starch. At stage 7, banana is overripe and muddy [18].

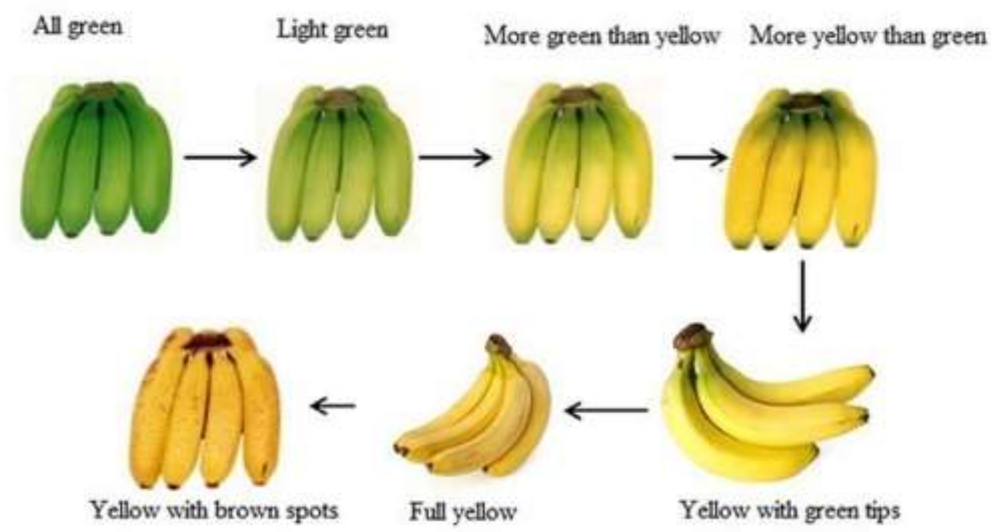


Figure 2.1: Stages of banana maturation
(Source: www.semanticsscholar.com).

As the interior fruit reaches peak condition, the green peel that had been absorbing all that sunlight begins to undergo a chemical change that helps to mellow the fruit. As a result, the interior of the peel releases nutrients into the fruit that enhance the sweetness. At the same time, the peel begins to lose chlorophyll content and changes from green to yellow. During this transformation, the peel itself begins to deteriorate, leaving behind only a thin covering that can be peeled away from the mature fruit with ease. Since bananas ripen quickly, it does not take long to go from a bitter green banana to a sweet yellow banana [19].

According to the desired use, banana and plantain are consumed or locally processed at various stages of maturation which have been classified from stage 1, green skin, to stage 7, yellow skin with black spots [20]. According to literature, green banana is very rich in starch and its flour may contain (61.3 to 76.5) g/100 g of starch (dry basis) and also has a fiber content of (6.3 to 15.5) g/100 (dry basis). Moreover, a great part of the starch found in the green banana flour is the resistant starch type 2 from (52.7 to 54.2) g/100 g dry basis) [20].

Banana fruit at different maturity stages presents significant difference ($p < 0.01$) on physic-chemical characteristics and fruit firmness. The soluble solids increase from early stages until the end of maturity, while fruit firmness diminishes during ripening, due to the action of polygalacturonase and pectin methyl esterase enzymes involved in pectin degradation in the cell wall and middle lamella [20].

Mature green banana especially plantain is very rich in starch and is one of the promising substitutes for the starch industry. Ripening determines the essential appearance and taste qualities of dessert bananas when consumed fresh with bright yellow-colored skin, flavors, consistency of pulp and starch-sugar transition. Ethylene is used as a catalyst for triggering a climacteric change [20].

The biochemical composition of banana fruits depends on the cultivar, abiotic factors such as climate, cultivation method and nature of the soil. The banana fruit contains relatively high levels of potassium [21].

2.1.2 Banana production in Ethiopia

In Ethiopia, the major banana producing regions are Southern (SNNPE), Oromia and the Amhara regions. During the 2010/2011 production season about 31,885.86 hectares of land has been covered with banana and the estimated annual production was about 270571.516 tones and the potential yield of banana is highly increasing at research level. It is the most important cash crop in some parts of Southern Ethiopia, especially in Arbaminch Gamo-Gofa zone. But, banana production is also familiar in Gedeo Zone of Southern Ethiopia [22].

Cavendish Banana Varieties

The most common banana variety found in grocery stores is the Cavendish variety. Within this group, there are many different cultivars, such as the “Dwarf Cavendish” and the “Giant Cavendish.” The “Giant Cavendish” is a hardy plant of unknown origin. The “Giant Cavendish” has largely replaced the “Dwarf Cavendish,” a smaller plant that stands between 1.22 and 2.13meter in height. The fruit of the “Dwarf Cavendish” are smaller and thin-skinned. These fruits bruise easily, which is problematic during shipping [22].

Small Varieties

Small banana varieties, also called baby bananas, are recognized by their miniature size; the fruit is only about10.2 to 12.7 centimeters in length with thin, yellow skin. They have and intensely sweet flavor when they are allowed to reach optimal ripeness. These small varieties include “Lady Finger” bananas, sometimes called “Orito”. This hearty, drought resistant plant is native to Malaysia. It is able to ward off most common banana pests and diseases, such as Panama disease and black weevils. However, leaf spot disease does pose a problem for “Lady Finger” plants [22].

Cooking Bananas

Most banana varieties, including the Cavendish, are classified as dessert bananas and are peeled and eaten raw once they have reached optimal ripeness. However, some banana varieties are cooked before they are consumed, such as plantains. Plantains are a staple crop in many Latin American cultures. The fruit is fried or sautéed until it is crispy around the edges. Plantains only have a hint of sweetness and a mild, starchy flavor. They are implemented in meals as a side dish the same way that people use rice or potatoes [22].

2.2 Banana peel

Banana peels are agricultural waste that discarded all over the as useless material. They cause waste management problems although they have some compost and cosmetics potentiality [23]. Banana peels also contain high potassium and phosphorus, which prove to be helpful in the compost.

The substance could be used for medicine as well as personal care and known for anti-fungal and antibiotic properties, loaded with lot of vitamins, minerals and fibber that benefit for skin care and for healing the wound [24].

Besides that, banana peels have absorbent potentiality [23]. It is very useful for purification and refining processes. Banana peel has absorption capabilities for some elements and ions in liquid or solution. Banana peel has absorption capacities to remove chromium from wastewater [25], copper, and also some dyes [26]. Unfortunately, the benefits of banana peels are not popular as many people still do not realize about. Banana peels are readily available, low cost, and environment friendly bio-material. These agricultural wastes are also inexhaustible, cheap and non-hazardous, and are specifically selective for heavy metals and can be easily disposed by incineration [27]. The main banana residue is the fruit peel, which accounts for 30 to 40% of the total fruit weight.

There are few industrial uses for banana peels and a major agricultural waste in different region of the planet. Attempts at the practical utilization of banana peels have included the production of protein, ethanol, methane, pectin, extracts and enzymes. Banana peels have also been used as food for livestock and as a bio sorbent for heavy metals, dyes and the removal of phenolic 13 compounds [28]. Banana peel has been selected to perform the present study due to its high content in carbohydrates, which is due to their organic nature that are easily metabolized by microorganisms, as it has the physical integrity to serve as a supporting material.

In addition, its content in ascorbic acid exerts an inhibitory effect against bacteria. Moreover, the banana processing industry generates a huge amount of solid wastes, which are dumped in landfills, rivers, oceans and unregulated dumping grounds. Therefore, their reutilization would help to diminish the pollution problems caused by their disposal [29].

Accumulating evidence has revealed that both banana pulp and peel contain various antioxidants, for instance vitamins (A. B, C and E), β-carotene and phenolic compounds such as catechin, epicatechin, lignin's and tannins and antho-cyanine's. Several reports indicated that banana peels possess higher phenolic compounds and antioxidant properties as well as mineral content than banana pulps [30].

2.3 Potassium carbonate and its properties

Potash is the common name for various mined and manufactured salts that contain potassium in water-soluble form. In some rare cases, potash can be formed with traces of organic materials such as plant remains, and this was the major historical source for it before the industrial era. The name derives from "pot ash," which refers to plant ashes soaked in water in a pot [31].

Potassium derives its name from potash, and was first derived by electrolysis of caustic potash, in 1808.Potash (especially potassium carbonate) has been used from the dawn of history in bleaching textiles, making glass, and, from about A.D. 500, in making soap. Potash was principally obtained by leaching the ashes of land and sea plants. Potash was one of the most important industrial chemicals and it was refined from the ashes of broadleaved trees. Potassium carbonate serves a wide range of end use markets. The potassium carbonate market is quite diverse since it is utilized in numerous applications. The functionality characteristics of this chemical allow it to be used in major area such as specialty glass, ceramics, potassium silicate, pharmaceuticals, food, detergents and cleaners, photographic chemicals, agricultural, gas purification, rubber additives, polymer catalysts, potassium bicarbonate, cement, and textiles [32].

2.3.1 Physical properties

Some of the physical properties of potassium carbonate are: Melting point, Solubility, density, Boiling point and PH.

Table 2.1: Physical property of potassium carbonate

Physical Property	Standard values
Bulk density	1,202-1,346.3Kg/m3 (granular, varies by grade); 16.78 Kg/m3 (extra fine)
Melting point	$891^{0}C$
Solubility in water	112 grams in 100ml water at $20^{0}C$
Appearance	White, granular, free-flowing, hygroscopic
Boiling point	decomposes
PH	11-12
Taste	Alkaline taste
Solubility	Very soluble in H_2O, insoluble in ethanol 112g/100ml ($20^{o}C$), 156g/100ml ($100^{o}C$), 3.11g/100ml ($25^{o}C$)

2.3.2. Chemical property

Table 2.2: Chemical properties of potassium carbonate

Chemical property	Changes occur
Reaction with acid	Neutralizes acids exothermally to form salts plus water
Reaction with water	Water easily from air and it dissolves in water
Reaction with metal	Reacts with certain metals (such as aluminum and zinc) to form oxides or hydroxides of the metal and generate gaseous hydrogen
Flammability	May generate flammable and/or toxic gases with ammonia salts, nitrides,

	halogenated organics, various metals, peroxides. And hydro peroxides
Combustion	non-combustible, substance itself does not burn but may decompose upon heating
Reaction with catalyst	May serve as a catalyst. React when heated above about 840 c with aqueous solution of reducing sugars other than sucrose, to evolve toxic level of carbon monoxide
Reaction with organic compounds	May initiate polymerization reactions in polymerizable organic compounds, especially epoxides

2.4 Potassium carbonate production method

Potassium carbonate can be produced using the following four methods [18,21].

Ash method

Ash method is the method that is suitable for a variety of plants (such as banana peel, cotton seed, tea seed shell, sunflower shell) firing the ash extract. This method is easy due to product quality, economically feasible, simple used and less power.

Lv Bulan method: - is the method that is suitable to extract K_2CO_3 from coal. This method is long due process and other reasons have been replaced by other methods.

Electrolysis method: - is obtained by electrolysis of potassium chloride solution of potassium hydroxide, carbon dioxide in the carbonation tower but requires more power.

Ion-exchange method: - Using cation exchange resin is exchanged with potassium chloride. Potassium bicarbonate, ammonium bicarbonate and then eluted into a dilute solution, the multi effect evaporation, carbonation, crystallization, separation, calcination the products. This method is the product of good quality, short process for small-scale production.

2.5 Potash Mining Methods

Conventional, solution, and cut-and-fill stope mining are methods used in extracting ore for potash [33].

Conventional Mining

Conventional mining includes a number of steps. First, the miners travel to the extraction site. They are lowered into the ground and, then, transported to the mining face. They, then, undercut, drill, charge, and blast the ore. A continuous mining machine mines the mine seam.

These machines can mine up to 882 tonnes per hour, making paths of up to 7.9 meters wide and 2.4meter high. These machines also have the potential to be automated. Conveyor belts, next, carry the ore to underground bins where it is stored until it is hoisted up by skips at speeds of 550-1,100 meters per minute.

Solution Mining

When conventional underground mines become flooded and unworkable, potash can be extracted using solution mining. Water is injected as a brine or salt and water solution. It is then circulated throughout the mine workings to dissolve potash and salt from the original pillars and walls. The brine is pumped to an evaporation pond.

Submersible pumps are used, each pumping about 9,000 liters per minute.as the liquid cools, the potash and salt crystals settle to the bottom of the pond. The cool brine is then heated and reinjected into the mine to start dissolving potash again. The remaining potash in the ponds is removed with floating dredges and pumped to the mil.

Cut-and-Fill Stope mining

Cut-and-fill stope mining is an underground process that uses continuous mining machines to excavate the ore in a step-like manor. It uses the fresh tailings to create a new floor for further mining. This method involves transporting personnel and ore the same way as conventional mining.

Commercial Production method

Potassium carbonate is manufactured in a fluidized bed reactor. This results in a product that is anhydrous, making it unnecessary to perform any further processing to eliminate hydrated water (calcining). The process starts with potassium chloride and through an electrolytic conversion of the KCl salt, potassium hydroxide (caustic potash, KOH), chlorine (Cl_2) and hydrogen (H_2) are produced. The hydrogen is a fuel source while the chlorine has numerous important and varied applications.

Liquid caustic potash and carbon dioxide are the only raw materials required for producing potassium carbonate. The dry potassium carbonate can easily be dissolved in water to form a liquid solution. Typically, a 47% solution is recommended as this capitalizes on the highest concentration with the lowest freezing point (3°F). This minimizes handling problems during colder weather [33]. The reactions are:

$2KCl + 2H_2O \rightarrow 2KOH + Cl_2 + H_2$

$2KOH + CO_2 \rightarrow K_2CO_3 + H_2O$

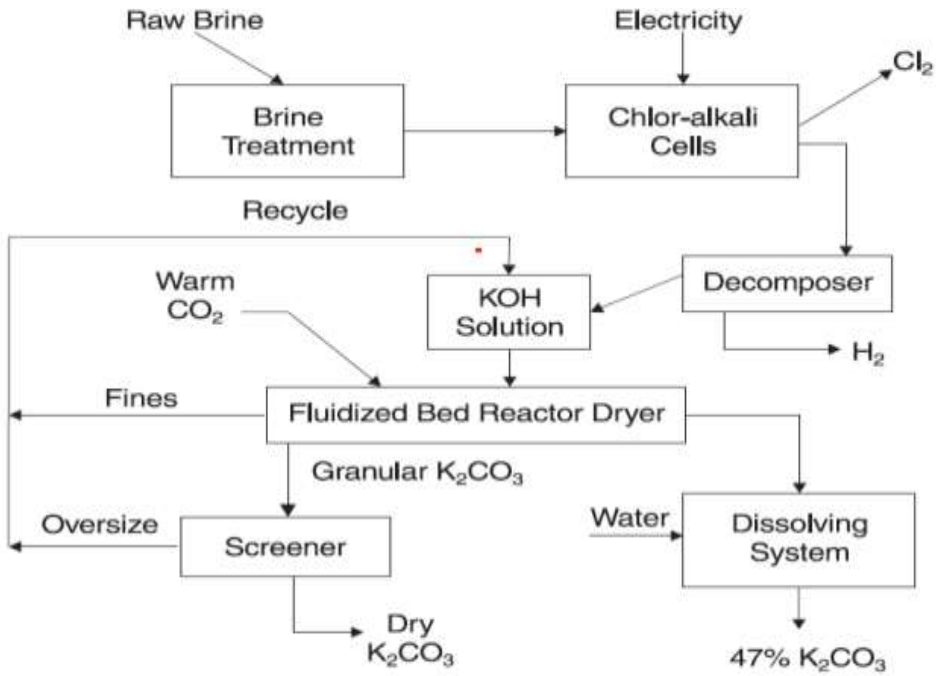


Figure 2.2 Flow chart of manufacturing process

2.6 Factors affecting potassium carbonate production

The factors that affect production of potassium carbonates are [34,35]:

Temperature: temperature has great role in production of potassium carbonate; for example, in the drier when the temperature is below 110°C the moisture contents are not completely removed. As a result, they remove gases to the environment during the burning process in the furnace. In the furnace if the temperature is above 600°C the property of potassium carbonate leads to denature.

PH: -It affects alkaline property of the product.

Nature of banana fruit: From the different types of banana species the most suitable banana type in production of potassium carbonate is Cavendish banana varieties.

Type of soil: Mostly the type of soil affects to banana fruit to its size, and if the size is so small the amount of potassium carbonate per peel is so little and more for large peel. Small Varieties of banana are small in size but disease and drought resistance.

Water: The amount of water used during mixing process affects for production of potassium carbonate. Using high amount of water affects filtration process to consume more time. In addition to that using lower amount of water than the ash content is not advisable during production process but it must be proportioned well with ash content.

2.7 Application of Potassium Carbonate

Potassium carbonate is used in the production of soap and glass. The potassium carbonate market is divided between the glass industry and other numerous applications [36].

1. Potassium carbonate is used to make specialty glasses, such as television screens, cathode ray tubes, and optical lenses. Video and television screens account for 44% of potassium carbonate usage, while specialty glass and ceramics use 10%. The main reason that relatively expensive potassium carbonate is used in place of soda ash in glass applications is that it is more compatible with the required lead, barium and strontium oxides. These specialty glasses possess the improved properties of greater electrical resistivity, higher index of refraction, greater brilliance or luster, lower softening point and a wide temperature working range. In addition, potassium carbonate allows improved behavior of many colorants in glass**. 3**
2. Potassium carbonate is use as fertilizer, provides plants with the potassium they need to stay healthy and grow.
3. Potassium carbonate is used in the chemical industry, where it is used as a raw material to make other chemical compounds, potassium silicate being the most common. It may be used as a mild drying agent where other drying agents, such as calcium chloride and magnesium sulfate, may be incompatible. It is mixed with distilled water to make a safer

electrolyte for oxyhydrogen production than potassium hydroxide, the more commonly used electrolyte.

4. Smaller amounts of potassium carbonate are still used for what was once its major application: the manufacture of soap. Potassium soaps (made from potassium carbonate) have some characteristics different from more common sodium soaps (made from sodium carbonate). They tend to be softer or even liquid and better able to create suds in water that contains a high concentration of minerals.
5. Potassium carbonate is used for glazes in the making of pottery.
6. It is used in the manufacture of pigments and printing inks.
7. It is used as an additive in certain food products, chocolate being one example.
8. Potassium carbonate softens hard water. Aqueous potassium carbonate is also used as a toxin-free cleaning agent and is also called electrolyzed or "engineered" water. The water softening properties of the potassium carbonate add to water's natural ability to remove dirt and sanitize areas.
9. Potassium carbonate is sometimes used as a buffering agent in the production of mead or wine.
10. It may also be used to dry some ketones, alcohols, and amines prior to distillation.
11. Potassium carbonate was often used to harden rosin in varnish recipes, especially for use on musical instruments. It is also used to emulsify wax to make Punic wax.
12. It is used for the tanning and finishing of leather and the dyeing, washing, and finishing of wool; and
13. It is an ingredient in welding fluxes, and in the flux coating on arc-welding rods.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 Raw materials and chemicals

In this study, waste banana peel was used as raw material. Distilled water and Hydrochloric acid were used for production and characterization of K_2CO_3, respectively.

3.1.2 Equipment

The major equipment's and apparatuses those used in this thesis incorporate Plastic bags, Knife, Digital Oven, Crushers, Shaker, Weighing Balances, Filter papers, furnace, Flask (funnel), beaker, Cylinder measurement and PH meter.

3.2 Preparation of Banana Peels

The banana peels were collected from Gubrie using plastic bags. The collected samples were separated from unwanted materials manually. The prepared banana peels (1643g) was dried at sun for two days and later oven-dried at a temperature of 110^0C for three hours to ensure adequate removal of moisture from the sample and reduce the size in uniform way.

3.3 Proximate Analysis of Sample

Moisture content (MC)

A known weight of banana peels was dried by sunlight for two days and later by oven that operates at temperature of 110℃ for three hours. The moisture content was determined using the method suggested by Miroslav and Vladimir (1999).

$$\text{Moisture content (MC)} = \frac{\text{initial Wight of sample} - \text{weight of sample after oven drying}}{\text{Initial Wight of sample}} * 100$$

Dry moisture content (DMC)

Initially known weight of fresh banana peel and weight of peel charcoal taken to calculate dry moisture content of our sample. Dry moisture content is the ratio of weight of peel charcoal to weight of fresh banana peels and expressed in percent.

$$\text{Dry moisture content (DMC)} = \frac{\text{weight of sample after oven drying}}{\text{Initial Wight of sample}} * 100$$

Ash Content (AC)

A known weight of each oven-dried sample was placed in a porcelain crucible and ash in muffle furnace set at 400℃ for 4 hours; it was cooled in desiccator, and the final weight of ashes was determined using electronic balance. Ash content was calculated using the formula below;

$$\text{Ash Content (AC)} = \frac{\text{Final weight ashes}}{\text{weight of oven dried sample}} * 100$$

Volatile matter

A known weight of each oven-dried sample was placed in a porcelain crucible and ash in muffle furnace it was cooled in desiccators for 10 minutes then weight of ash (weight after volatile matter) was measured using electronic balance. Volatile matter is determined the amount of volatile substance released due to the effects of high temperature.

$$\textbf{Volatile matter} = \frac{\text{weight of sample after oven} - \text{weight after volatile matter}}{\text{Weight of sample after over drying}} * 100$$

3.4 Extraction of potassium carbonate

A well crushed banana peel was burnt in furnace at 400ºC for 4hours and subsequently was turned into ashes. The formed ash was placed in desiccator for 10 minutes to cool down. Later 30g ash was placed in a 2liter round bottom flask and 1000milliliter of distilled water was added. The Ash mixed with distilled water and dissolved by shaking for 5minutes, then filtered the solution first by sieve then by using filter paper to remove insoluble solids and chemicals such as elemental Carbon and Group 2 carbonates. Then filtrate was taken by beaker and placed on evaporator and boiled continuously to about 100℃ for 5hours then solid residue had been obtained. The extracted alkali was purified by subjecting it to series of crystallization procedure by entering it in to an oven. Finally, the condensed products were collected and named potassium carbonate.

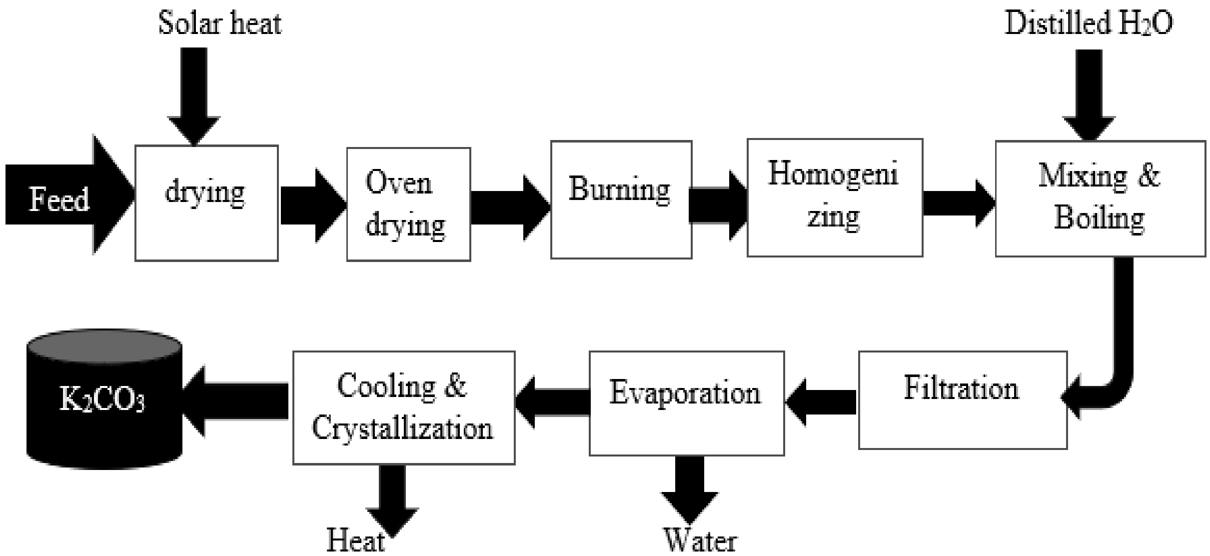


Figure 3.1: Block flow diagram of potassium carbonate production

3.5 Characterization of potassium carbonate

3.5.1 Chemical property:

To characterize the produced potassium carbonate from banana peels we have performed different tasks.

Reaction of potassium carbonate with HCl

0.5 g of the sample ash of potassium carbonate was mixed with 3.5ml of the distilled water in the beaker, 2 ml of the dilute hydrochloric acid was added into beaker and dissolved by shaking, hence potassium carbonate react with Hydrochloric acid gives salt, carbon dioxide and water.

Alkalinity

Alkalinity test was done by measuring its PH. Alkalinity test of potassium carbonate was done by taking 0.5 g of the sample ash of potassium carbonate and mixed with 3.5ml of the distilled water in the beaker. Then the PH meter was used to knew its value.

3.5.2 Physical property

The obtained potassium carbonate was also characterized by its physical property. The product was characterized by properties like; solubility, color, odor, taste and phase.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Result Calculation

Moisture content (MC)

Initially 1643g of banana was dried and 214g of peel charcoal was gained. Therefore, using the results, the moisture content calculated as below;

Moisture content (MC) = $\frac{\text{initial Weight of sample} - \text{weight of sample after drying}}{\text{Initial Wight of sample}}$ *100

$$MC_1 = \frac{1643 - 214}{1643} * 100\% = 86.9\%$$

$$MC_2 = \frac{1643 - 209}{1643} 100\% = 87.2\%$$

$$MC_3 = \frac{1643 - 201}{1643} * 100\% = 87.7\%$$

According to (Hamid, H., 2016) the moisture content of the banana peel at initial stage have to be 87% - 92.5%, when the banana peels are inserted in the oven the moisture content varies with temperature. So mostly according to Hamid moisture contents of ash was ranged between 87% to 92.5% and our experiment result also found in this range. High moisture contents are the best feed stock for reducing time needed and amount of energy consumed during conversion of peel charcoal to ashes. Lower moisture content which is ranged below 86%, needs long time and higher amounts of energy to be converted to potash. According to experiment done by Ankrah in 1974, the result shows that moisture content of the sample was between 80.9% to 86%. This experiment shows that, the peel charcoal to be converted to ash takes around 6hours and 30minutes under the furnace that operate with 600℃. Our experiments result (86.9%, 87.2% and 87.7%) are found in the range determined by Hamid and the experiment takes 4hours under the furnace that operate with temperature of 400℃.

Dry moisture content (DMC) = $\frac{\text{weight of sample after drying}}{\text{Initial Wight of sample}}$ *100

$$DMC_1 = \frac{214}{1643} * 100\% = 13.02\%$$

$$DMC_2 = \frac{209}{1643} * 100\% = 12.7\%$$

$$DMC_3=\frac{201}{1643}*100\% = 12.23\%$$

Ash Content (AC) = $\frac{\text{Final weight ashes}}{\text{weight of oven dried sample}}*100$

$$AC_1=\frac{30}{214}*100 = 14.02\%$$

$$AC_2=\frac{29.2}{214}*100 = 13.64\%$$

$$AC_3=\frac{28.8}{153.5}*100 = 13.46\%$$

Ash content is one of the important parameters to good quality potash. Ash can be determined as total mineral content in the peels. It was remained in the ash of the burned waste banana peel at high temperature to remove any volatile organic compounds (VOC). According to Hoffman (2005), the normal ash content for banana peel was approximately 5 % to 15%. Low ash and high volatile matter content biomasses are the best feed stock for bio-energy conversion including pyrolysis and gasification processes among others and the equation is given as (Kabenge *etal*., 2018).

Density of sample (DS) = $\frac{weight\ of\ sample\ after\ drying\ in\ gm}{volume\ of\ sample\ in\ litter}$

$$DS_1=\frac{214}{1000\ \text{ml}} = 0.214\text{g/ml}$$

$$DS_2=\frac{209}{1000\text{ml}} = 0.209\text{g/ml}$$

$$DS_3=\frac{201}{1000\text{ml}} = 0.201\text{g/ml}$$

4.2 Raw material characterization

Based on data from oven

Fresh banana peels were collected from juice houses, 1643 g of banana peels were dried for 2 days and supplied to oven with weight of 280.26g and oven temperature of 110 for 3hours and 214g was obtained. Therefore, using the results the moisture content was calculated to be 86.9%.

Table 4.1: Data of moisture content after oven drying

Temperature (℃)	Try no	Weight after oven dried (g)	Moisture content (%)
110	Try 1	214	86.9
	Try 2	216	86.85
115	Try 1	209	87.2
	Try 2	211	87.15
120	Try 1	201	87.7
	Try 2	204	87.58

By adjusting the temperature of the oven at different level with constant time, varies weight of dried sample (banana peel) was obtained. As the heating temperature level of the oven increase the amount of water to be left the sample (moisture content) was also increase.

Table 4.2: Data of temperature, and potassium carbonate product, depending on the result of furnace

Temperature ℃	Try no	Ash content (g)	K_2CO_3 product (g)
400	Try 1	30	15.6
	Try 2	30.22	15.8
450	Try 1	29.2	14.7
	Try 2	29.14	14.3
500	Try 1	28.8	14.3
	Try 2	29.1	14.45

The ash obtained at those temperatures was blackish in color, indicating incomplete combustion due to unburned carbon. At higher temperatures more and more of carbon is oxidized to carbon dioxide. Reduction in mass is also due to disintegration of solid compounds, alkali metal salts, into gaseous components.

When the ashes were put in water, potassium and sodium were dissolved but magnesium and calcium doesn’t dissolve. This is because the elements belong to group I in the periodic table and one major property of group I elements is the formation of soluble salts and bases. Hence, the hydroxides and carbonates of potassium and sodium are soluble in water. The rest insoluble elements are removed by filtration using filter paper. The supposition that the ash-alkali extract is alkali hydroxide could have been brought about by the explanation that K_2CO_3 is formed during the combustion of a banana peel and these dissolve in water during extraction to form hydroxides.

At low temperature (dissolve)

$$K_2CO_{3(s)} + H_2O \longrightarrow 2K^+_{(aq)} + CO^{2-}_{3(aq)}$$

At high temperature (reaction)

$$K_2CO_3 + H_2O \longleftrightarrow 2KOH_{(aq)} + CO_{2\ (g)}$$

At these temperatures', blackish potassium carbonate product was obtained, because of complete combustion was performed.

4.3 Extraction of potassium carbonate

After the combustion of 214g of banana peel charcoal 30g of ash was obtained and this ash was mixed with 1000ml of distilled water. The solution of water and ash was subjected to heating stove that work at temperature of 100℃ for 1hour and 30minute, until it boils. Later we have filtered out the boiled solution and then the filtrate was taken into 1liter beaker and heated for evaporation purpose for five hours, which resulted to produce 15.6g of potassium carbonate.

4.4 Product characterization

4.4.1 Reaction with hydrochloric acid

Since one way to characterize a given product is to know its behavior of reactivity. Therefore, for this purpose 0.5g of Potassium carbonate was taken to react with 2ml of hydrochloric acid to make salt of potassium chloride. During the reaction bubbles of carbon dioxide was formed which is an example of carbonate- acid which also informs the presence of carbonate.

$K_2CO_3 + 2HCl \rightarrow 2KCl + CO_2 + H_2O$

4.4.2 Alkaline test of potassium carbonate

By ionization method

In order to measure PH of potash 0.5 g of the sample of potassium carbonate was mixed with 3.5ml of the distilled water in the beaker. Potassium belong to group I in the periodic table of elements and one major property of group I elements is the formation of soluble salts and bases. Hence, the hydroxides and carbonates of K and Na are soluble in water. Self-ionization of water produces equal number of OH^- and H^+ ions. When potash is introduced, it also ionizes into K^+ and CO_3^{2-} ions. The CO_3^{2-} ion attract H^+ ion from water, resulting in a decrease in H^+ ion but an increase in OH^- ion, which leads to increase in PH (alkaline condition). From our experiment the PH meter reads 11.32 of hydrogen ion concentration.

Determination of alkali content

The alkali content of potash consists of the potassium carbonates. It was reported in some literatures to be hydroxide of K. Usually this is determined by acid-base titrimetric, using methyl orange and/or phenolphthalein indicator. Some weight of the crude potash is dissolved with distilled water in volumetric flask and made up to mark. An aliquot is titrated with HCl. If total alkali content is of interest, methyl orange is used as the indicator and if only the hydroxide content is of interest, phenolphthalein indicator is used. The individual hydroxide and carbonate contents may be determined by using the double-indicator (phenolphthalein and methyl orange) method. The phenolphthalein indicator is first added to the aliquot and the point of change in color indicates the neutralization of the whole of hydroxides and half of the carbonates a weighed amount of ash was reacted with dilute HCl the reaction:

$K_2CO_3 + 2HCl \rightarrow 2KCl + CO_2 + H_2O$

4.4.3 Physical property

The produced potassium carbonate was completely soluble in water, insoluble in ethanol, and had approximately blue-black color due to the complete combustion of carbon in addition the product was granular in size with low deliquescent property due to the carbon content, it is also odorless.

CHAPTER FIVE

MATERIAL AND ENERGY BALANCE

5.1. Material Balance

The knowledge of material balance is a useful tool in determining the quantity of raw material required and the products produced. Material balance is also used to study the operation of plant, identification of sources of materials loss (Peters *etal*., 2003).

The general conservation equation for any process system is written as:

$$Input + Generation = Output + Accumulation + Consumption$$

For a process with no generation or consumption of material within the system, equation

$$Input - Output = Accumulation$$

In a steady state process, the accumulation term is zero. Mass is neither generated nor consumed but if a chemical reaction occurs; particular chemical specie may be formed or consumed in the process. The steady state balance reduces to

$$Input - Output = 0$$

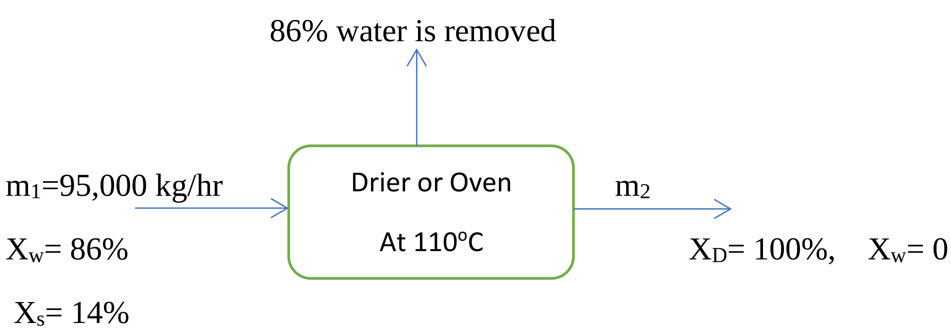
Assumptions:

200 tone/day peel processed

18hr working per day

315 working days

1. **Drier**



The amount of water removed from drier is

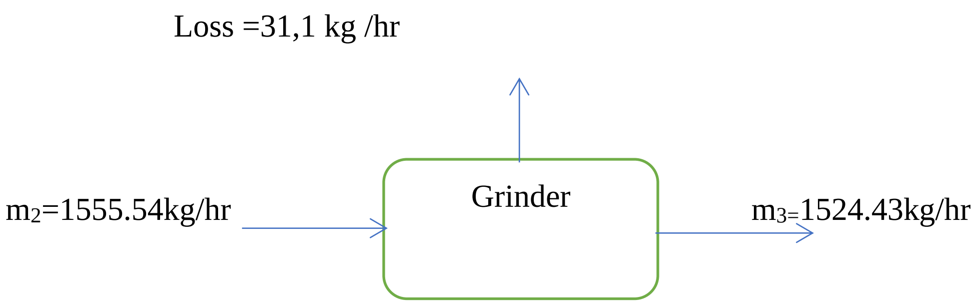
$$m\ H2O\ removed = m1 * xw = 11111\ kg/hr * 0.86 = 9555.46\ kg\ /hr$$

Since there is no reaction; $Input = output = m1 = mH2O + m\ 2$

$$mfp\ XS = md\ XD$$

$$11111\ kg/hr * 0.14 = md = 1555.54 kg\ /\ hr$$

2. Grinder



Let assume the grinder has ability or efficiency of grinding is 98%. Since there is no reaction,

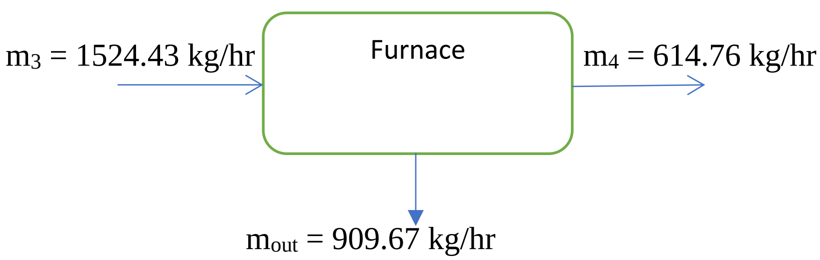
Input =output; but the efficiency of grinder is 98 %

Input efficiency = output = m3

1555,54kg/hr * 0.98 = 1524.43 kg/hr

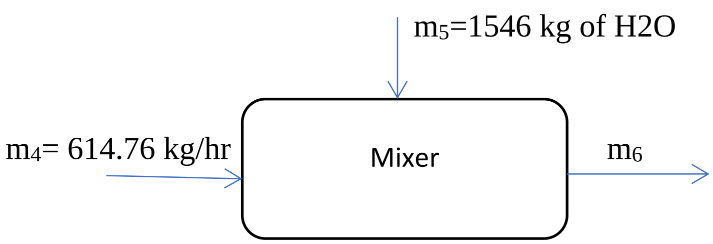
Therefore; the grinded banana peel removed from grinder is = 31.1 kg/hr

3. Furnace



4. Mixing

In mixer unit in industrial scale, we get 614.76kg/hr of ashes then add 1546L distilled water. Therefore:
let, m_5= distilled H2O = 1546 kg of H2O = 1546 L



At steady sate, $input = output$

$$m6 = m5 + m4 = 614,76\ kg/hr. + 1546L$$

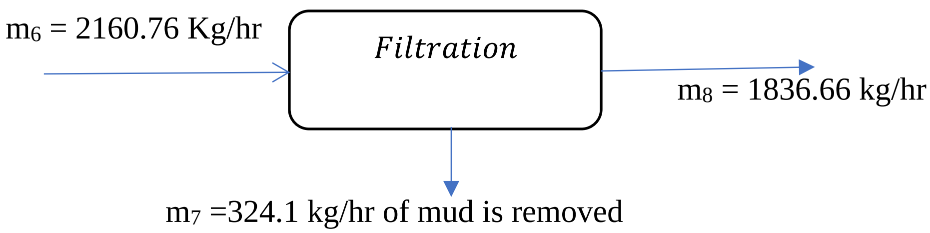
$$= 2160.76\ Kg/hr$$

5. Filtration

In Filtration unit in lab scale, we have get 1000 gm of leachate (distilled water + ashes) and 150 gm of mud. Therefore, amount of mud removed from filtration unit is

$$m7 = \frac{0.150 \text{ kg} * 2160.76\text{kg/hr}}{1000 \text{ kg}}$$

$$= 324{,}14\ kg/hr\ of\ mud\ is\ removed$$



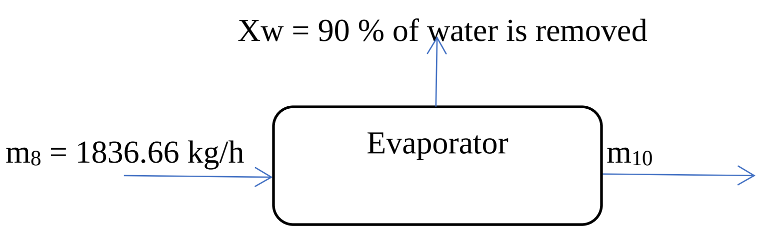
At steady sate, input= output

$$m6 = m7 + m8$$

$$m8 = m6 - m7 = 2160.76 - 324.1 = 1836.66\ kg/hr$$

6. Evaporation

Assume that the efficiency of evaporator is 90%



At steady sate, $input = output$

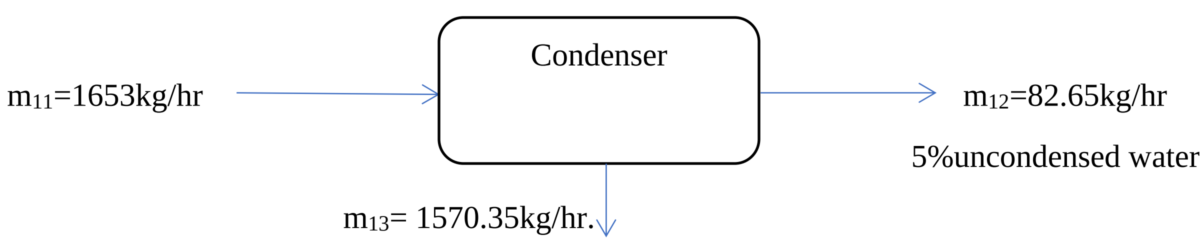
$$m8 = m10 + m9$$

$$But;\ m9 = 0.90 * m8 = 0.90 * 1836.66\ kg/hr = 1653\ kg/hr$$

$$m10 = m8 - m9 = 1836{,}66\ kg/hr - 1653\ kg/hr = 183.66\ kg/hr$$

7. Condensation

Assume that the efficiency of the condeser is 95%



95 % of condensate water is removed

m13 = Water removed = 0.95 * 1653 kg/hr= 1570.35 kg/hr

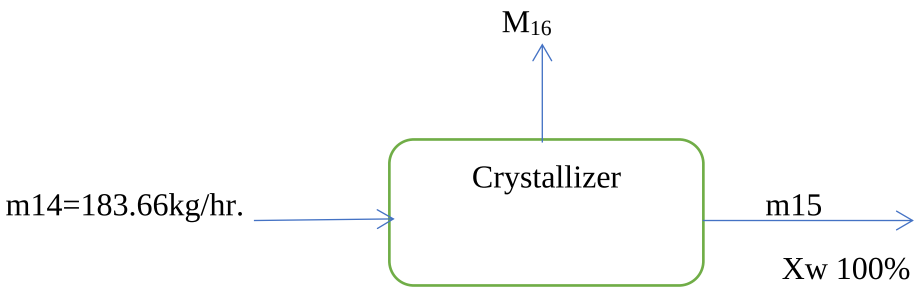
At steady sate, input= output

m11 = m12 + m13

$m_{12}=m_{11}-m_{13}$=1653-1570.35=82.65kg/hr

M uncondensed water = 0.05 * 1653 = 82.65 kg/hr

7. **Crystallization**



Assume that the efficiency of the crystallizer is 98%,

m15 = 0.98 * 183.66 = 180 kg/hr.

So that the company has the capacity to produce 180 Kg of Potassium carbonate per hour.

m16 = m15 – m14 = 3.66 kg/hr

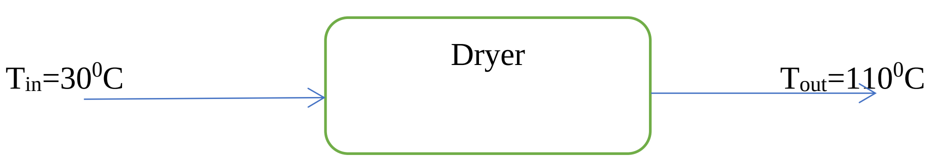
5.2 Energy Balance

1. Dryer

The oven dries the sample by 110°C from 40°C.

The energy required is $Q = mCp\Delta T$

Where m is mass of wet fruit peel



Cp is specific heat of wet fruit peel

$$\Delta T = Tf - Ti$$

The specific heat capacity of banana peel is 2.03KJ/Kg*K

The specific heat capacity of water is = 4,185.5 J/ (Kg·K) = 4.1855KJ/Kg*K

Mass of fruit peel from material balance is = 11111 kg/hr

$$Cp = Cpb * Xb + Cpw * Xw$$

$$= 2.03\ kJ/(kg * K) * 0.14 + 4.1855\ kJ/(kg \cdot K) * 0.86$$

$$= 3.88kJ/(kg \cdot K)$$

$$Q = m\ Cp\ \Delta T$$

$$= 11111\ kg/hr * 3.88 * (110 - 30)$$

$$= 3{,}448{,}854.88\ kJ/hr$$

2. Furnace

$$Q = m\ Cp\ \Delta T$$

$$= 1524.43\ kg/hr * 2.03\ kJ/(kg * K) * (400 - 60) = 1052161.586\ kJ/hr$$

3. Evaporator

Cp = 0.1KJ/kg.k

m = 846.9kg/hr

$T_{ref} = 25^0C$

$T = 35^0C$

$\Delta Hf = H_{35} - H_{25}$

$$= 1{,}008.36 - 1{,}888.6$$

$$= -819.76 \frac{KJ}{Kg.K}$$

$$\Delta H_p = H_{110} - H_{35}$$

$$=mCp\Delta T - 1{,}008.36$$

$$=183.66 * 0.1 * (100 - 35) - 1{,}008.36$$

$$= 1193.79 - 1{,}008.36$$

$$=185.43 \ \frac{KJ}{Kg.K}$$

ΔHv = 461.42KJ/Kg.K

ΔHf +ΔHs =ΔHv + ΔHp

ΔHs = 461.42 +185.43+ 819.76

$$\Delta Hs = 1466.61 \frac{KJ}{Kg.K}$$

4. Condenser

Assume the efficiency of our condenser is 98%

Q = m Cp ΔT +mhfg

=183.66 kg/hr * 4.1855 * (80- 30) +183.66Kg/hr*2.033KJ/Kg

=<u>38062.06 KJ/hr</u>

CHAPTER SIX

FEASIBILITY ANALYSIS

6.1 Equipment Sizing

1. Sizing of drier

$$\mathrm{v} = \frac{\text{flow rate of fees}}{\text{density of feed}}$$

$$= \frac{11111}{1381.5} = 8.04\ \mathrm{m^3/hr}$$

The residence time of drier is 4hr

$$\text{Therefore volume of drier} = 8.04\frac{\mathrm{m3}}{\mathrm{hr}} * 4\mathrm{hr}$$

$$\mathrm{v} = 32.17\mathrm{m^3}$$

The drier is filled 60% of its capacity

$$\mathrm{v} = 32.17/0.6 = 53.62\mathrm{m^3}$$

2. Sizing of furnace

$$\mathrm{v} = \frac{\text{flowrate}}{\text{density}}$$

$$= \frac{1524.43}{1381.5} = 1.1\mathrm{m^3/hr}$$

The residence time of furnace is 8hr.

Therefore volume of the furnace is $\mathrm{v} = \frac{1.1\mathrm{m3}}{\mathrm{hr}} * \mathrm{hr} = 8.83\mathrm{m^3}$

The furnace is filled 75% of its capacity

$$v = \frac{8.83}{0.75} = 11.77\mathrm{m^3}$$

3. Equipment sizing on mixer

The residence time of the mixer is 5hr

$$\mathrm{v} = \frac{\text{flowrate of water}}{\text{density of water}} + \frac{\text{flowrate of ash}}{\text{density of ash}}$$

$$= \frac{1546}{1000} + \frac{614.76}{2130}$$

$$= 1.546 + 0.2886$$

$$= 1.83\mathrm{m^3/hr}$$

The residence time of the mixer is 5hr

$$v = \frac{1.83m3}{hr} * 5hr = 9.17\text{m}^3$$

The mixer is filled 80% of its capacity

$$\text{Therefore Vmixer } = \frac{9.17}{0.8} = 11.46\text{m}^3$$

4. **Sizing of storage tank**

$$\text{v} = \frac{\text{flowrate of K2CO3}}{\text{density of K2CO3}}$$

$$= \frac{183.66}{2830} = 0.065\text{m}^3/\text{hr}$$

The residence time of storage is 7hr

Therefore volume of the final storage tank is $\text{v} = \frac{0.065\text{m3}}{\text{hr}} * 7\text{hr} = 0.455\text{m}^3$

The storage is filled 75% of its capacity

$$\text{v} = \frac{0.455}{0.75} = 0.6\text{m}^3$$

6.2 Cost Analysis

6.2.1 Purchased Equipment Cost

For the cost estimation of the equipment of this plant design exchange rate is assumed i.e., 1US Dollar =51birr

Table 6.1: Purchased equipment cost

Equipment name	Quantity	Actual capacity (m3)	USD	ETB
Oven(dryer)	1	53.62	12,305	627,555
Crusher	1	-	1442	73,542
Furnace	1	11.77	13170	671,670
Mixer	1	11.46	3268	166,668
Filtration	2	-	4662	23,776
Filtration tank	1	-	70	3570
Evaporator	1	-	4806	245,106
Pump	2	-	672.9	34,317.9
Final storage tank	1	0.6	4662	237,762
Packing machine	1	-	4806.6	245,136.6

Cost of equipment: Source: hhttps://www.alibaba.com

Therefore, the Purchased equipment cost

$$\text{PEC} = 627{,}555 + 73{,}542 + 671{,}670 + 166{,}668 + 23{,}776 + 3570 + 245{,}106 + 34{,}317.9 + 237{,}762 + 245{,}136.6 = 2{,}329{,}103.5$$

PEC=2,329,103.5 birr

6.2.2 Estimation of Fixed Capital Investment

A) Direct Cost (DC)

Material and labor involved in actual installation of complete facility. It involves Equipment, installation, piping, electrical, insulation and painting (Peters M.,*etal*., 2003).

- Installation including insulation and painting (25-55%) of purchased equipment cost IPC=Assumed %* (PEC).
- Instrumentation and controls installed (6-30%) purchased equipment cost
  ICIC=Assumed %* (PEC)
- Piping installed (10-80%) of purchased equipment cost
  PC = assumed %* (PEC)
- Electrical installed (10-40%) of purchased equipment cost
  EC=assumed %* (PEC)
- Buildings, process, and auxiliary (10-70%) of purchased equipment cost
  BPAC=assumed %* (PEC)
- Service facilities and yard improvements (40-100%) of purchased equipment cost
  SFC=assumed %* (PEC)
- Land (4-8%) purchased equipment cost
  LC= assumed % *(PEC)

$$\text{DC} = \text{PEC} + \text{IPC} + \text{ICIC} + \text{PC} + \text{EC} + \text{BPAC} + \text{SFC} + \text{LC}$$

B) Indirect cost

Indirect Cost (IC): expenses which are not directly involved with material and labor of actual installation of complete facility (Peters M.,*etal*., 2003)

- Engineering and supervision (5-30%) of purchased equipment cost ESC =17.5% PEC
- construction expense and contractors fee (6-30%) of purchased equipment cost CECC=18%of PEC
- contingency (5-15%) of Purchased equipment cost CC=10%of PEC

$$IC = ESC + CECC + CC$$

Table 6.2: Estimated cost of fixed capital investment

Component	Range%	Selected %	Estimated Cost
Purchase equipment	-		2,329,103.5
Piping	10-80	45	1090745.55
Electrical	10-40	25	605968.25
Instrumentation and construction	6-30	18	436298.22
Building	10-70	40	969551.6
Service facility and Yard improvement	40-100	70	1696715.3
Land	4-6	6	145432.74
Engineering & supervision	5-30	17.5	424178.825
Construction expanded & Constructor's fee	6-30	18	436298.22
Contingency	5-15	10	242387.9
Total			8,376,680.1

$$\text{Fixed Capital Investment} = \text{Direct Cost} + \text{Indirect Cost} = 8{,}376{,}680.1$$

$$\text{working capital} = (10-20)\% * \text{TCI} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .1$$

$$\text{TCI} = \text{FCI} + \text{WC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

$$\text{TCI} = \text{FCI} + 15\%\text{TCI} \ldots \text{by taking average } 15\%$$

$$\text{TCI} - 0.15\text{TCI} = \text{FCI}$$

$$\text{TCI}(1-0.15) = \text{FCI}$$

$$\text{TCI} = \frac{\text{FCI}}{1-0.15}$$

$$\text{TCI} = \frac{8{,}376{,}680.1}{0.85} = 9{,}854{,}917.76$$

From this working capital,

$$\text{WC} = 0.15 * \text{TCI} = 1{,}478{,}237.66$$

6.2.3 Estimation of Total Production Cost

The production cost divide into manufacturing costs and general expenses cost.

Total production cost = manufacturing cost + general expenses (Peters M.,etal., 2003)

1. **Manufacturing cost**

$$\mathrm{MC} = \text{Direct manufacturing cost(DMC)} + \text{Fixed manufacturig cost(FMC)} + \text{Plant overhead cost(POC)}$$

A) Direct production cost (DMC)

Direct production costs are calculated and equal the sum of the following items as specified within the processes: Raw materials, operating Labor, direct supervisor and clerical labor, Laboratory, Utilities, and operating supplies (Peters M., *etal.*, 2003).

i. **Raw materials (RMC):**

Two different raw materials are examined in the Potassium Carbonate production process in this project for economic purposes banana peel and water. In chemical plants, raw material costs are usually in the range of 10 to 60 percent of the total product cost.

Take: 30% of TPC

=0.3*TPC

ii. **Utilities (UTC)**

One utility is examined in the Potassium carbonate production process in this project for economic purposes: electricity, furnace, dryer (oven) and evaporator.

As a rough approximation, utility costs for ordinary chemical processes amount to 10 to 20 percent of the total product cost.

Take: 15%of TPC

=0.15*TPC

iii. **Operating Labor (OLC)**

Assumption: The plant requires 35 workers, and their annual expenditure, is estimated at Birr 642,960

Table 6.3: Manpower requirement and annual labor cost

No	**Description**	**Required number**	**Salary monthly**	**Salary annually**
1	Plant manager	1	5000	60000
2	Secretary	1	1500	18000
3	Accountant	1	3000	36000
4	Clerk	1	1200	14400

5	Production head	1	4500	54000
6	Operator	8	5500	66000
7	assistance operator	8	3600	43200
8	Mechanic	2	3500	45600
9	Electrician	2	3800	45600
10	Storekeeper	1	900	10800
11	Purchaser	1	3200	38400
12	Seal’s man	1	2500	30000
13	Personnel	1	1250	15000
14	Timekeeper	1	900	10800
15	Cashier	1	1200	14400
16	Driver	1	1500	18000
17	Guard	2	700	8400
18	Cleaner	1	600	7200
19	Sub-total	35	44650	535800
20	Employee benefit (20% BS)			107160
21	Total			642960birr

iv. Direct supervisor and clerical labor (SCC):

The cost for direct supervisor and clerical labor averages about 10 percent of the cost for operating labor.

$$SCC = 0.1 * 642960birr = 64{,}296birr$$

v. Maintenance and repairs (MC)

In the process industries, the total plant cost per year for maintenance and repairs ranges from 2 to 10 percent of the fixed capital investment.

Take 9%of FCI

$=0.09 * 8{,}376{,}680.1 = 753{,}901.2birr$

vi. Operating supplies (OSC)

The annual cost for these types of supplies is about 20 percent of the total cost for maintenance and repairs.

$$0.2 * 753{,}901.2 = 150{,}780.24birr$$

vii. Laboratory charges (LCC)

For quick estimates, this cost may be taken as 10 to 20 percent of the operating labor.

Take 15%of OSC

$$0.15 * 150{,}780.24 = 22{,}617.04 birr$$

viii. Patents and royalties (PRC)

A rough approximation of patent and royalty costs for patented processes is 0 to 6 percent of the total product cost

$$\text{PRC} = 4\% \text{ of TPC} = 0.04 * \text{TPC}$$

B) Indirect Production Cost

1. Fixed Production Cost

This costs the sum of depreciation, insurance, and taxes

I. Depreciation

In economic studies in which the time value of money is not to be considered, it is acceptable to use a constant yearly depreciation rate for a fixed period but by assuming take 10%of FCI.

$$\text{DC} = 0.1 * 8{,}376{,}680.1 = 837{,}668.01\text{birr}$$

II. Local taxes (TC)

The magnitude of local property taxes depends on the locality of the plant and the regional laws. Annual property taxes for plants in highly populated areas are ordinary in the range of 2 to 4 percent of the fixed- capital investment.

Take: 3% of FCI

$$0.03 * \ 8{,}376{,}680.1 = 251{,}300.4$$

III. Insurance (IC)

Insurance rate amount is about 2 percent of the fixed capital investment per year.

$$0.02 * 8{,}376{,}680.1 = 167{,}533.6 birr$$

IV. Rent (RC)

Annual cost for rented land and buildings amount to about 8 to 12 percent of the value of the rented property, in preliminary estimates, rent is usually not included.

2. Plant overhead cost

Costs are for hospital and medical services; general plant maintenance and overhead; safety services; payroll overhead including pensions, vacation allowances, social security, and life insurance; packaging, restaurant and recreation facilities, salvage services, control laboratories, property protection, plant superintendence, warehouse and storage facilities, and special employee benefits.

The plant overhead cost for chemical plants is about 50 to 70 percent of the total expenses for operating labor, supervision, and maintenance.

Take 60% of (OLC+SC+MC)

$$= 0.6(167{,}533.6 + 251{,}300.4 + 837{,}668.01) = 753{,}901.2 birr$$

C) General expense (Peters M., *et al*., 2003).

$$\textbf{General expenses} = \text{administrative costs} + \text{distribution and selling costs} + \text{research and development costs}$$

Administration costs (ADC)

May be approximated as 15 to 25 percent of operating labor

Take 22%of OLC

$$ADC = 0.22 * 642{,}960 = 141{,}451.2 birr$$

Distribution and selling costs (DSC)

These costs for most chemical plants are in the range of 2 to 20 percent of the total product cost.

Take 7%of TPC

$$\text{DSC} = 0.05 * \text{TPC}$$

Research and development cost (RDC)

In chemical industry, these costs amount to about 2 to 5 percent of every sales dollar, or about 4 percent of total product cost.

Take 3% of TPC

$$= 0.03 * \text{TPC}$$

There for total product cost is

$$\text{TPC} = \text{MC} + \text{GE} = (\text{DMC} + \text{FMC} + \text{POC}) + (\text{AC} + \text{OC})$$

$$\text{TPC} = \text{CRM} + \text{CUT} + 1.33\ \text{COL} + 0.03\ \text{TPC} + 0.069\ \text{FCI} + 0.032\ \text{FCI} + \text{CDEP} + 0.708\ \text{COL} + 0.032\ \text{FCI} + 0.177\ \text{COL} + 0.009\text{FCI} + 0.16\ \text{TPC}$$

$$\text{TPC} = 1.24(\text{CRM} + \text{CUT} + \text{CDEP}) + 2.74\ \text{COL} + 0.23\ \text{FCI}$$

$$= 1.24 * (2{,}523{,}004\text{birr} + 1{,}256{,}502\ \text{birr} + 418{,}834\ \text{birr}) + 2.74 * 141{,}451.2\ \text{birr} + 0.23 * 8{,}376{,}680.1\ \text{birr}$$

$$= 7{,}520{,}154.3\ \text{birr}$$

6.3 Unit Analysis Cost

Assumption

- 200 tone/day peel processed
- 18hr working per day
- 315 working days
- 6batch/day
- 3hr/batch

The unit costs for potassium carbonate production are calculated as the annual operating cost divided by the annual production rate (Peters M., *etal.*, 2003).

$$\text{Unit cost (birr/kg)} = \frac{\text{total product cost}}{\text{annual production(kg)}}$$

$$=\frac{200\text{ton}}{\text{day}} * \frac{315\text{day}}{\text{year}} * \frac{1000\text{kg}}{\text{ton}} = 63{,}000{,}000\text{kg/year peel process}$$

By scaling up the sample approximately 377142.85kg/year annual production rate

$$\text{Unit cost} = \frac{7{,}520{,}154.3}{377{,}142.85} = 19.94\text{birr/kg}$$

6.4 Potassium Carbonate Selling Price

To conduct the profitability analysis, the selling price for Potassium carbonate must be first identified. The current lower selling price for white granule Potassium Carbonate is US$ 2000-2500/1000Kg. For profitability let it will sell with current local market value 51$ (127.5birr/Kg).

6.5 Profitability Analysis

According to the project income statement, the project will start generating profit in the first year of operation. Important ratios such as profit to total sales, net profit to equity (Return on equity) and net profit plus interest on total investment (return on total investment) show an increasing trend during the lifetime of the project. To calculate the gross profit let calculate the sales value per annual.

i. Sales (Sales Revenue)

$$\text{Sales} = \text{unit cost} * \text{annual capacity}$$

$$= 50\text{birr/kg} * 377142.85\text{kg/year}$$

$$=18{,}857{,}142.5 \text{ birr/year}$$

ii. Gross profit (GP)

$$\text{Gross profit (GP)} = \text{Sales} - \text{TPC}$$
$$= 18{,}857{,}142.5 - 7{,}520{,}154.3$$
$$= 11{,}336{,}988.2 \text{ birr}$$

iii. Net profit (NP)

$$\text{Net profit} = \text{Gp} - (\text{sales} - \text{TPC}) * \text{tax rate},$$
$$\text{Taking taxes of } 30\%$$
$$= \text{Gp} - \text{Gp} * 0.3 = \text{Gp}\,[1 - 0.3]$$
$$= 11{,}336{,}988.2 * (1 - 0.3)$$
$$= 7{,}935{,}891.74 \text{ birr/year}$$

iv. Turnover Ratio

Turnover ratio is defined as the ratio of gross annual sales to the fixed-capital investment where the product of the annual production rate and the average selling price of the commodities are the gross annual sales figures. The reciprocal of the turnover ratio is sometimes defined as the capital ratio or the investment ratio. Turnover ratios of 0.2 up to 5 are common for some business establishments and some are as low as 0.2.

$$\text{Turnover} = \frac{\text{Gross annual sales}}{\text{fixed capital investment}}$$
$$= \frac{18{,}857{,}142.5}{8{,}376{,}680.1} = 2.25$$

So, our project acceptable to establishment since turn ratio between the maximum and minimum range (0.2-5)

6.6 Payback Period

The payback period is a simple indicator measuring how long it takes to recover the initial investment in the potassium carbonate production plants. When choosing among a few mutually exclusive projects, the project with the quickest payback is preferred. The payback period is calculated as the quotient of the total capital investment divided by the net profit as shown in equation below.

$$\text{payback period} = \frac{\text{total capital investment}}{\text{net profit}}$$
$$= \frac{10{,}968{,}666.12}{2{,}169{,}886.73} = 5.05 \text{ years}$$

Internal Rate of Return (ROI)

Rate of rate before tax

$$\text{ROI} = \frac{\text{anuual gross profit}}{\text{total capital investment}} * 100$$

$$= \frac{3{,}338{,}287.27}{10{,}968{,}666.12} * 100\% = 30.43\%$$

Rate of rate after tax

$$\text{ROI} = \frac{\text{annual netprofit}}{\text{total capital investment}} * 100$$

$$= \frac{2{,}169{,}886.73}{10968666.12} * 100 = 19.78\%$$

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATION

7.1 Conclusion

Potassium carbonate is an important chemical substance for the use not only in industry but also in pharmaceutical and agricultural sector. There is practically no source of potassium carbonate in nature except very minor source in African lakes and Dead Sea. Generally, it is industrially produced from potassium chloride which is expensive and energy consuming process.

Banana plant may be a good source of potassium carbonate. Considerable amount of potassium carbonate can be isolated from banana pseudo-stem fiber ash. Burning of fiber in open air is the most effective process from where maximum quantity of carbonate can be isolated. The source of carbonate might be the oxalate content in plant's cell. In plants, oxalates occur as metabolic end products of the oxaloacetate, glycolate and glyoxalate pathways. The resulted blackish-colored Potassium carbonate is due to the presence of large amount of uncombusted carbon particles.

Besides, the use of banana peel waste for caustic potash production; it also helps to solve disposal problems of banana peel. Instead of indiscriminate dumping; it would be exploited for potassium carbonate production thus, converting waste to useful product.

In addition, potassium carbonate production from banana peel is safe and improved method to build indigenous capabilities with attendant reduction of unemployment hence, has the ability to generate income for the Ethiopian economy.

7.2 Recommendation

Since potassium carbonates have many applications for the country; we recommend that the investors can invest on potassium carbonate production to become profitable and as solution maker for the country economy.

During our work the color of K_2CO_3 became blue-black rather than white color, this is due to the lower operating temperature of the furnace for combustion. So, we want to recommend that researchers who have interest in this work have to use a furnace having higher operating temperature for complete combustion to occur.

REFERENCES

[1]. Onyegbado CO, Iyagba ET, Offor OJ (2002): Solid soap production using plantain peels ash as source of alkali. J. Appl. Sci. Environ. Manag 6:73-77.

[2]. Babayemi JO, Adewuyi GO, Dauda KT, Kayode AAA (2011). The Ancient alkali production technology and the modern improvement: A Review. Asian J. Appl. Sci. 4:22-29.

[3]. Taiwo, O.E. and F.A.O. Osinowo, 2001. Evaluation of various agro-wastes for traditional soap production. Bioresource. Technol., 79: 95-97.

[4]. Kevin, M.D., 2003. Caveman Chemistry: 28 Projects, from the Creation of Fire to the Production of Plastics. Universal Publisher, Australia, ISBN-13: 978-1581125665, 428.

[5]. Onyegbado CO, Iyagba ET, Offor OJ (2002): Solid soap production using plantain peels ash as source of alkali. J. Appl. Sci. Environ. Manag.

[6]. Central statistics of Ethiopia. Agri. in 2019

[7]. Auroreet al., 2009 Bananas, raw materials for making processed food products. Trends Food Sci Technol. 2009;20(2):78–91.

[8]. waste management, Volume 34, Issue 2, February 2014, Pages 498-503.

[9]. X. Pan, D. Xie, Y.W. Yu, the bioconversion of mountain pine beetle-killed Lodgepole pine to fuel ethanol using the organosolv process Biotechnol. Bioeng., 101 (2008), pp. 39-48

[10]. M.J. Taherzadeh, K. Karimi Pretreatment of lignocellulosic wastes to improve ethanol and biogas production: a review Int. J. Mol. Sci., 9 (2008), pp. 1621-1651

[11]. H. Tibolla, F.M. Pelissari, F.C. Menegalli Cellulose nanofibers produced from banana peel by chemical and enzymatic treatment LWT-Food Sci. Technol., 59 (2) (2014), pp. 1311-1318

[12]. Sapuan et al., 2018. mixed domestic-waste catalysts for methyl ester production of soybean oil. Maejo International Journal of Energy and Environmental Communication,2019

[13]. Tan et al., 2015. Mixed domestic-waste catalysts for methyl ester production of soybean oil. Maejo International Journal of Energy and Environmental Communication,2019

[14]. Barre, A., W.J., Menu-Bouaouiche, L., Van Damme, E.J.L., May, G.D., Herrera, A.F., Van Leuven F., Rouge, P. (2000). Purification and structural analysis of an abundant thaumatin-like protein from ripe bananas. Planta 791-799.

[15]. Peumans, W.J., Zhang, W., Barre, A., Astoul, C.H., Balint-Kurti, P.J., Rovira, P. Rouge, P., May, G.D., Van Leuven, F., Truffa-Bachi, P., Van Damme, E.J.M. (2000). Fruit specific lectins from banana and plantain. Planta 211:

[16]. The journal of supercritical Fluids Volume 58, Issue 3, October 2011, Pages 343-351.

[17]. Del Mar Verde Mendez, C., Forster, M.K., Rodriguez-Delgado, M.A., Rodriguez, E.M., Romero, C.D. (2003). Content of free phenolic compounds in bananas from Tenerife (Canary Islands) and Ecuador. European Food Research and Technology 217: 287-290.

[18]. Juliana W. Sauls. Home Fruit Production--Banana. Retrieved on 25th October 2010.

[19]. Kevin, M.D., 2003. Caveman Chemistry: 28 Projects, from the Creation of Fire to the Production of Plastics. Universal Publisher, Australia, ISBN-13: 978-1581125665, 428.

[20]. Emagaet al., 2010 T.H. Emaga, R.H. Andrianaivo, B. Wathelet, J.T. Tchango, M. Paquot Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. Food Chemistry, 103 (2007), pp. 590–600

[21]. Del Mar Verde Mendez, C., Forster, M.K., Rodriguez-Delgado, M.A., Rodriguez, E.M., Romero, C.D. (2003). Content of free phenolic compounds in bananas from Tenerife

[22]. Auroreet al., 2009Bananas, raw materials for making processed food products. Trends Food Sci Technol. 2009;20(2):78–91.

[23]. Moller, M., Kayma, M., Vieluf, D., Paschke, A., Steinhart, H. (1998). Determinationand characterisation of cross-reacting allergens in latex, avocado, banana and kiwifruit.Allergy 53: 289-296

[24]. Sanchez-Monge, R., Blanco, D., Collada, C., Aragoncillo, S. (1999). Isolation andcharacterization of major banana allergens: identification as fruit class I chitinases.Clinical & Experimental Allergy 29: 673-680.

[25]. Barre, A., Peumans, W.J., Menu-Bouaouiche, L., Van Damme, E.J.L., May, G.D.,Herrera, A.F., Van Leuven F., Rouge, P. (2000). Purification and structural ananalysisof an abundant thaumatin-like protein from ripe bananas.Planta 791-799.

[26]. Peumans, W.J., Zhang, W., Barre, A., Astoul, C.H., Balint-Kurti, P.J., Rovira, P.,Rouge, P., May, G.D., Van Leuven, F., Truffa-Bachi, P., Van Damme, E.J.M. (2000).Fruit-specific lectins from banana and plantain.Planta 211: 546-554.

[27]. Koshte, V.L., van Dijk, W., van der Stelt, M.E., Aalberse, R.C. (1990). Isolation andcharacterization of BanLec-1, a mannoside-binding lectin from Musa paradisiaca(banana). Biochemistry Journal272: 721-726.

[28]. Whelton, P.K., He, J., Cutler, J.A., Brancati, F.L., Appel, L.J., Follmann, D., Klag,M.J. (1997). Effects of oral potassium on blood pressure. Meta-analysis ofrandomized controlled clinical trials.JAMA: The Journal of the American MedicalAssociation277: 1624-1632.

[29]. Kanazawa, K., Sakakibara, H. (2000). High content of dopamine, a strong antioxidant,in Cavendish banana.Journal of Food Chemistry 48: 844-848.

[30]. MacNaughton, W.K., Wallace, J.L. (1989). A role for dopamine as an endogenousprotective factor in the rat stomach.Gastroenterology 96: 972-980.

[31]. Englberger, L., Darton-Hill, I., Coyne, T., Fitzgerald, M.H., Marks, G.C. (2003). Caretoid-rich bananas: A potential food source for alleviating vitamin A deficiency. Food and Nutrition Bulletin24: 303-318.

[32]. Emagaet al., 2010 T.H. Emaga, R.H. Andriana Ivo, B. Wathelet, J.T. Tchango, M. Paquot Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. Food Chemistry, 103 (2007), pp. 590–600

[33]. Englberger, L., Darton-Hill, I., Coyne, T., Fitzgerald, M.H., Marks, G.C. (2003).Caretoid-rich bananas: A potential food source for alleviating vitamin A deficiency.Food and Nutrition Bulletin24: 303-318.

[34]. Peumans, W.J., Zhang, W., Barre, A., Astoul, C.H., Balint-Kurti, P.J., Rovira, P. Rouge, P., May, G.D., Van Leuven, F., Truffa-Bachi, P., Van Damme, E.J.M. (2000). Fruit specific lectins from banana and plantain. Planta 211: 546-554

[35]. Kanazawa, K., Sakakibara, H. (2000). High content of dopamine, a strong antioxidant, in Cavendish banana. Journal of Food Chemistry

[36]. Leonard J, Lygo B, Procter G (1998) "Advanced Practical Organic Chemistry", Stanley Thomas Publishers Ltd.

APPENDIX

Raw material gathering

raw material sun drying

after sun drying

After oven drying

burning by furnace

after burning

Ash formed

mixing with distilled H_2O

Filtration

Filtration residue

Evaporation

after evaporation K_2CO_3

Crystal K_2CO_3

reaction with HCl

K_2CO_3 solubility in water

K_2CO_3 solubility in Ethanol