WOLKITE UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

Extraction of Pectin from Lemon Peel

By;

Name	ID. No.
1. Abduba Gelo	**……ENGR/015/09**
2. Teshome Soboksa	**……. ENGR/851/09**
3. Furi Tulu	**……. ENGR/379/09**
4. Abay Tadese	**……...ENGR/001/09**
5. Tolewak Degefe	**……ENGR/883/09**

Advisor: Mr. Teshager Legesse

This thesis Submitted to Wolkite University College of Engineering and Technology, Department of Chemical Engineering under process engineering stream in Partial Fulfillment of the requirement for Degree of Bachler of Science.

Wolkite, Ethiopia

August, 2021

Declaration

We declare that this thesis is our own original work, except for flotations and citations which have been duly acknowledged. It's carried out under the supervisions of Mr. Teshager Legesse and submitted to the Department of Chemical Engineering for the Degree Bachelor of Science in Chemical Engineering.

Name of the students: Signature

1. Abduba Gelo _____

2. Teshome Soboksa _____

3. Furi Tulu _____

4. Abay Tadese _____

5 Tolewak Degefe _____

Date of submission: August 2021 G.C

Place: Wolkite

This thesis has been submitted for examination with my approval as a university advisor.

Advisor Name: Mr. Teshager Legesse

Advisor's Signature: _____

Department Head: _____

Name Signature Date

Acknowledgement

First and foremost, we would like to thank the almighty God for giving us the strength to withstand all the problems we faced throughout our life. We would like to thank our advisor Teshager Legesse (MSc,) for his spectacular help and we would like to express very special thanks to Wolkite University Chemical Engineering Department laboratory assistances Mr. Yonas, Mr. Meseret, for being with us during the laboratory work and providing us with most of the required laboratory equipment as well as for assisting during data entry and analysis. We would like to express our heartfelt thanks and deep appreciation to our family for their constant support persistent encouragement, and assistance in all aspects especially financial and spiritual support rendered throughout our study period. Finally, many thanks go to all our friends who helped us in laboratory in technical aspects and for their open mindedness from the beginning to the end. May Almighty God bless and protect every one of them in all that they do.

Abstract

Pectin is a structural hetero polysaccharide, commonly obtained from the peels of citrus fruits and its prime commercial use as a gelling agent and stabilizer in food industries. The lemon peels if treated as waste materials, which may create environmental problems for local communities since the presence of biomaterials in lemon peel. The objective of this research was to extract pectin from lemon peels and characterization of the extracted pectin. Its significant was economically feasible, environmental significance, and also create job opportunity for local business because pectin extraction is simple technology. In the present study, pectin was extracted using alcohol precipitation method from the peels of lemon. By direct boiling water bath method, raw material was prepared and pectin was extracted using hydrochloric acid at different pH, time, and temperature. At three different temperatures (40 °C, 60 °C, & 80 °C), pH (1.0, 2.75, & 4.5) and the experiments was carried out in water bath for 60, 90, 120 minutes. A total of 9 experiments was conducted at various extraction conditions. When the extraction condition was varied one-at-a-time, a maximum yield of 16% was obtained from lemon peel. The characterization of the extracted pectin was carried out by calculating the yield, ash content, moisture content, solubility and color.

Key Words: *Pectin;* Citrus peel; Extraction; Yield

Table of Contents

Declaration i

Acknowledgement ii

Abstract iii

List of tables viii

List of figures ix

Acronyms x

Chapter one 1

Introduction 1

1.1 Background 1

1.2 Statement of Problem 3

1.3 Objectives 4

1.3.1 General Objective 4

1.3.2 Specific Objectives 4

1.4 Significance of the Study 4

1.5 Scope of the research 4

1.6 Limitation of the study 5

Chapter Two 6

Literature Review 6

2.1 Over view of lemon fruit 6

2.1.1 Different variety of lemon 7

2.2 chemical composition of lemon 9

2.3 Benefits and Uses of Lemon Peel 10

2.3.1 High nutritional value 10

2.3. 2 support oral health 10

2.3.3 High in antioxidants 10
2.3.4 antimicrobial and antifungal properties 11
2.3.5 promote heart health 11
2.3.6 anticancer properties 11
2.3.7 treat gallstones 12
2.4 Lemon production in Ethiopia 12
2.5 Historical background of pectin production 12
2.6 pectin production globally 13
2.7 Pectin consumption in Ethiopia 14
2.8 Sources of pectin 15
2.9 Structure of pectin 16
2.10 Gelling mechanism 17
2.10.1 Production of Low Sugar Jams and Jellies 18
2.10.2 Gelation of Pectin 18
2.10.3 Low Methoxyl pectin (LM) 18
2.10.4 High Methoxyl pectin (HM) 19
2.11 Commercial pectin 20
2.12 General Properties of Pectin 21
2.12.1 Colloidal 21
2.12.2 Gelation 21
2.12.3 Solubility 21
2.12.4 Viscosity 22
2.12.5 Storage stability 22
2.12.6 Stability in Solution 22
2.13 Applications of Pectin 22
2.13.1 Pectin in Food Applications 23
2.13.2 Pharmaceutical applications of pectin 23
2.13.3 Cholesterol regulation 24
2.13 .4 Anti-cancer action 24

2.14 production process of pectin 24
2.14.1 Water based extraction 25
2.14.2 Microwave heating extraction 26
Chapter three 27
Materials and method 27
3.1 Materials and Chemicals used 27
3.2 Equipment's used 27
3.3 methods 27
3.3.1 Raw material Preparation 28
3.3.2 Extraction 29
3.3.3 Experimental procedure: 29
3.4 Characterization of pectin 33
3.4.1 Qualitative tests 33
3.4.2 Quantitative tests 33
Chapter four 35
Results and Discussions 35
4.1 Yield 35
4.2 Effect of pH on pectin yield 36
4.3 Effect of temperature on pectin yield 37
4.4 Effect of temperature and pH 38
4.5 Effects of extraction time on Pectin yield 38
4.6 Characterization of Extracted Pectin 39
4.7 calculated value of characterized pectin 40
Chapter five 41
Mass and Energy Balance 41
5.1 Total mass balance 41

5.2. Energy balance 47
5.2.1. Energy balance on stove 47
5.2.2. Energy balance on oven 47
Chapter six 48
Economic Evaluation and Site Selection 48
6.1 Cost estimation 48
6.1.2 Estimating capital investment 49
6.1.3 Estimation of fixed capital 50
6.1.4 Estimation of working capital 51
6.1.5 Estimation of total manufacturing cost (TMC) 51
6.2 Fixed charges 52
6.2.1 Plant-overhead costs 53
6.2.2 General expenses 53
6.3 Profitability analysis 54
6.4 Economic evaluation 55
6.4.1 Gross profit 55
6.4.2 Rate of return (ROR) 55
6.4.3 Payback period 57
6.5 Plant layout and site selection 57
6.6 Plant layout 59
Chapter seven 61
Conclusions and Recommendations 61
7.1 Conclusion 61
7.2 Recommendations 62
References 63

List of tables

Table 1 World largest lemon production countries source: www.wikepediea 7
Table 2 pectin imported to Ethiopia in the year 2015-2017 Source (CSA,2018)..... 15
Table 3 shows experimental run and average yield..... 36
Table 4 Comparison of solubility 39
Table 5 shows calculated value of characterized pectin..... 40
Table 6 Comparison of extracted and commercial pectin and results reported in literature 40
Table 7 Density of materials..... 41
Table 8 Major cost of equipment and machineries for pectin extraction 49
Table 9 Estimating capital investment; Source: (Timmerhaus & peters, 1991, pp. 183-187)..... 50
Table 10 Estimation of total raw material cost..... 51
Table 11 Estimation of Costs for Operating the Plant and Selling the Products..... 54

List of figures

Figure 1 Lemon plant 6
Figure 2 different variety of lemon fruit. 8
Figure 3 chemistry of lemon. 9
Figure 4 Location of pectin in the lemon 15
Figure 5 structure of pectin 17
Figure 6 Structure of polygalacturonic acid 17
Figure 7 flow sheet for extraction of pectin 28
Figure 8 collection lemon fruits from local market 29
Figure 9 washing of lemon peel 29
Figure 10 cutting of lemon peel 30
Figure 11 drying of lemon peel 30
Figure 12 powdered lemon peel 30
Figure 13 mixing peel powder water 30
Figure 14 heating of mixed solution. 31
Figure 15 filtration by using filter paper and centrifugal machine 31
Figure 16 precipitate pectin 32
Figure 17 Dried pectin 32
Figure 18 shows the graph of yield vs. PH 37
Figure 19 shows the graph of yield vs. Temperature 38
Figure 20 shows the graph of yield vs. Time 39
Figure 21 plant lay out of pectin extraction from lemon peel 60

Acronyms

AOAC……. Association of Official Analytical Chemists

AUA……Anhydrounic acid

CDTA……. Cyclohexane diamine tetra acetic acid

DV……. Daily Value

DE……. degree of esterification

EDTA…… Ethylene diamine tetra acetic acid

GP……. Gross profit

GRAS…… Generally recognized as safe

HDL……High-density lipoprotein

HM……. high methoxyl

LM……. low methoxyl

LDL……Low-density lipoprotein

MAE……. microwave assisted extraction method

NPV……... . .Net percent Value

PBP……. Payback period

R2……. Coefficient of determination

RoR……. Rate of Return

SEA…….……. Statistical Agency of Ethiopia

TCI…….…….…..…… Total Capital Investment

TMC……Total Manufacturing Cost

WKU……. Wolkite university

Chapter one

Introduction

1.1 Background

Lemon was originated in Southeast Asia, China, and the Malayan Archipelago. Lemon varieties were first introduced into the Mediterranean countries when Romans navigated through the red sea to India. The common Mediterranean type of lemon has not been found growing wild in any part of the world region [6]. Lemons are widely produced in Italy and other Mediterranean countries, like Spain, Egypt and Turkey. The southern Italian regions of Sicily, Calabria and Campania are among the main producers of lemon essence for processing. The production of citrus juice generates a large quantity of citrus processing waste, with around 44–60% of the mass of processed fruit ending up as citrous processing waste [6]. Citrus waste contains many useful components which can be extracted and utilized in different products. One of these components is pectin. Hence, citrus peel has become one of the most important sources of commercial pectin [3].

Pectin is a high-molecular-weight carbohydrate polymer which is present in virtually all plants where it contributes to the cell structure. It also contains non-sugar substituents, essentially methanol, acetic acid, phenolic acids and occasionally amide groups. The presence of acetyl groups prevents gel formation with calcium ions but provides the pectin with emulsion stabilizing properties [2]. Pectin is soluble in pure water and is a naturally occurring biopolymer that is getting more and more applications in the food, pharmaceutical and biotechnology industry. It has been used successfully for many years in the food and beverage industry as a thickening agent, a gelling agent and a colloidal stabilizer. The term pectin covers a number of polymers which vary according to their molecular weight, chemical configuration, and content of neutral sugars, and different plant. It also has several unique properties that have enabled it to be used as a matrix for the entrapment and/or delivery of a variety of drugs, proteins and cells. As a natural food additive, it is used extensively in the food industry, and its world market demand is in excess of 30,000 tons annually with a trend of growing by about 4–5% per annum [3].

Pectin makes up about one third of the cell wall of the dry substance of higher plants. types produce pectin with different functional properties. The word ‘pectin’ comes from the

Greek word *pektos* which means firm and hard, reflecting pectin's ability to form gels. The gelling properties of pectin have been known for centuries, but the isolation of commercial pectin only started at the beginning of the twentieth century. In this document we highlight the chemistry, origin and production, and the functional properties of pectin. Pectin is produced commercially in the form of white to light brown powder, mainly extracted from citrus fruits and is used in food as a gelling agent particularly in jams and jellies.

Several studies have reported novel pectin usages, like biodegradable water-soluble films, bulking agents, coating agents, chelators, emulsifiers and duration and viscosity modifiers the amount, structure and chemical composition of the pectin differs between plants, within a plant over time and in different parts of a single plant. At present, commercial pectins are almost exclusively pectin derived from citrus peel or apple pomace, both of which are by-products of juice manufacturing units. Apple pomace contains 10-15% of pectin on a dry matter basis. Citrus peel contains relatively higher, i.e., 20-30% of pectin as compared to that of apples [3]. The extraction of pectin usually uses two kinds of solvents: inorganic acid solvent such as hydrochloric, sulfuric or nitric acid and organic acid solvent such as oxalic, tartaric or acetic acid. The most commonly method for pectin extraction is direct boiling in hot, acidified water followed by isolation of the pectin from the ensuing solution. It takes approximately two hours to obtain good yield of pectin. Due to relatively long period of direct heating, pectin undergoes thermal degradation (5). However, in microwave assisted extraction method (MAE) The extraction process is more rapid than Soxhlet, and reduces solvent consumption, but it is more complicated and time-consuming than blending. The selection of solvent, microwave energy applied and extraction time are the main parameters controlled in MAE. The user should use proper extraction vessels and equipment in MAE, because very high pressures can be generated and explosions may result if appropriate precautions are not taken. The manufacture of pectin typically comprises extraction, purification/concentration, and drying. The use of a suitable method for pectin extraction is significant in order to maximize its yield and quality. The yield of pectin also depends on extraction operation conditions such as the temperature, the extraction time, the pH, the types of extraction solvents used and the use of extra cheating agents such as EDTA (Ethylene diamine tetra acetic acid) and CDTA to help release pectin from the cell wall [10–11]. In this study, pectin extraction from lemon peel with direct

boiling water bath method extraction process has been studied experimentally. Various extraction conditions including the extraction solvent, length of extraction, pH of aqueous extraction solution, as well as effectiveness of extra chelating chemicals on the yield from pectin extraction have been investigated. For each category of extraction conditions, all parameters were studied. Generally, the purpose of the present study was to investigate the influence of process parameter of the conventional extraction and water-based heating method of pectin from Citrus fruit. This study also reports the qualitative and quantitative characteristics of lemon pectin, extracted using citric acid and inorganic acids solvents.

1.2 Statement of Problem

The lemon peels if treated as waste materials, which may create environmental problems for local communities since the presence of biomaterials in lemon peel. Every food, fruit and vegetable wastes emit CO_2 and bad smell, because of biological digestion of the organic matter. There was a great need for development of new and environmentally friendly design processing techniques could be turned into an asset. Lemon waste contains many useful components which can be extracted and utilized in different products. One of these components was pectin. Hence, citrus peel has become one of the most important sources of commercial pectin. When lemon juice producer was done squishing his lemons, a lot of lemon peel was left unused. This peel was considered by everyone as a waste and used to feed the cattle or perhaps as fertilizer, but lemon peel was used for a better purpose. In Ethiopia lemon peel was widely available, but this country doesn't produce pectin and the pectin product was imported from foreign country.

1.3 Objectives

1.3.1 General Objective

- The general objective of the research was production and characterization of pectin from lemon peel.

1.3.2 Specific Objectives

- To evaluate the yield of extracted pectin on each run.
- To characterize the physiochemical properties (Moisture content, ash content, solubility and color) of pectin extracted.
- To evaluate the effect of operating parameters temperature, pH and time on the product quality and quantity.
- To compare and contrast the extracted pectin with commercial pectin.

1.4 Significance of the Study

The significance of extraction of pectin from lemon peel can see in economic, social and environmental perspective. When we see economically in Ethiopia lemon peel was widely available, but this country doesn't produce pectin and the pectin product was imported from foreign country. So, producing pectin locally can reduce imported pectin demand, and also environmentally the production of pectin to manage a waste or by products from restaurants and food processing industries that causes environmental pollution. So, converting of lemon peel in pectin can reduce the environmental problem. In the social aspect to create a good job opportunity for the society by establishing pectin technology in our country.

1.5 Scope of the research

This project work on how pectin was extracted from lemon peels. It further to imply about the per cent yield of pectin, the extraction method and also the economic analysis of pectin production. The data was analyzed properly. General property was studied. Its moisture content and ash content were characterized. Mass balance, energy balance and sizing were performed. Cost estimation and profitability was estimated. The result was highly discussed. The major production processes are supported by flow sheet, photograph and laboratory experiment.

1.6 Limitation of the study

So as to achieve our objective there was some sort during the course of this work, i.e. The Shortage of time to conduct enough number of experiments, and unavailability of centrifugal and oven which was effect on the quality of our product. Some chemicals were not available for the production of extraction of pectin in laboratory in, shortage of well-equipped laboratory in the department for the production of this work and lack of prior laboratory experience.

Chapter Two

Literature Review

2.1 Over view of lemon fruit

Lemon was originated in Southeast Asia, China, and the Malayan Archipelago. Lemon varieties were first introduced into the Mediterranean countries when Romans navigated through the red sea to India. The common Mediterranean type of lemon has not been found growing wild in any part of the world region. Lemons are widely produced in Italy and other Mediterranean countries, like Spain, Egypt and Turkey. The southern Italian regions of Sicily, Calabria and Campania are among the main producers of lemon essence for processing [1]. The lemon is a species of small evergreen tree native to Asia, China, and the Malayan Archipelago, India and it grow in regions with temperate summers and mild winters. Lemon scientifically known as Citrus Limon. Lemons are oval in shape and feature a yellow, texturized outer peel. Like other citrus fruits, their inner flesh is encased in segments, with the average lemon having eight to ten. While most lemons are tart, acidic and astringent, they are also surprisingly refreshing. The two main types of sour lemons are the Eureka and the Lisbon. The Eureka generally has more texturized skin, a short neck at one end and a few seeds, while the Lisbon has smoother skin, no neck and is generally seedless. In addition to these sour lemons, there are also some varieties that are sweet in flavor. [1].



Figure 1 Lemon plant

Today lemons are grown commercially throughout the Mediterranean region including Spain, Italy, Morocco, Greece, Turkey, Cyprus, Lebanon, and Israel. They are also grown in areas of the world with Mediterranean climates such as California and Chile and tropical areas such as Belize. During the marketing year 2019/2020, Mexico was the leading global producer of lemons and limes, with production amounting to about 2.2 million metric tons. In that year, the global fresh lemon and lime production amounted to a total of about 7.55 million metric tons.

Table 1 World largest lemon production countries *source: www.wikepediea*

Country	Production (Tons)	(Hectare)
USA	822,000	22,055
Iran	457,270	457,270
Italy	379,282	25,311
Egypt	341,451	14,981

2.1.1 Different variety of lemon

Lemons are a type of yellow-skinned citrus fruits that grow on the lemon tree. All types of lemons are known for their acidic, sour taste with some varieties being sweeter than others. There are actually only a few varieties of lemons that are classed as "true" lemons. Many kinds of lemons are actually hybrids of true lemons and other types of citrus fruits [4].

The botanical name for lemon species is *Citrus limon*. Thought to have originated in South Asia, lemons are now a popular citrus fruit used all over the world. Some of the most popular types of true lemons are Lisbon lemons and Eureka lemons. Although the majority of lemons have yellow juicy flesh, some types of lemons have pink flesh and are referred to as pink lemons [9].

Bear's lemon: Bear's lemons are from Italy but now grown in Florida since the 1950s. These high-quality juicy lemons contain an ample amount of lemon oil in their peel as well. This is one of the popular, different types of lemons [5].

Bush lemon: This lemon variety is also known as rough lemon, due to the thick and rigid appearance of the rind that has a strong flavor. They are wild-growing species, found in subtropical regions of Australia. Bush lemons do not contain much juice and mainly used for transplanting other lemons [7].

Eureka lemon: Eureka lemons grow all over the world, excluding a few Mediterranean countries, Italy and Spain. They resemble the Lisbon lemon. The thornless tree carries fruit year-round. Also, Eureka lemons are a popular variety and you can find them in every store [8].

Meyer lemon: Meyer lemon is a crossbreed between citron and mandarin orange; it has a smooth golden edible skin, no tartness like common lemons, and a good amount of juice. You can use this sweet, fragrant lemon in desserts, sauces, roasts, and salads [5].

Lisbon lemon: Another type of true lemon, the Lisbon lemon (*Citrus limon 'Lisbon'*) looks similar to the Eureka lemon with its slightly pitted skin and oblong shape. Lisbon lemons are not in the class of sweet lemons as they have a very acidic taste. The skin is medium-thick and is a good source of lemon oil and vitamin C. The juicy lemon flesh is generally seedless and produces a lot of juice [8].

Yen Ben Lemons: Yen Ben lemons (*Citrus × limon 'Yen Ben'*) are an Australian variety of lemon that looks similar to Lisbon lemons. one of the reasons why Yen Ben lemons are so popular in the Southern Hemisphere is because of their good quality. Their thin light-yellow rind means that there is more flesh than Eureka or Lisbon varieties. Also, the lemon fruit has a high juice yield with very few seeds in it [8].

Primofiori lemon: Native to Spain, Primofiori is popular for having a soft and thin peel. The fruit is acidic and contains a good amount of juice. The name implies 'first flowers' since the fruit ripens first during the harvest season. This is one of the popular, different types of lemons [8]



Figure 2 different variety of lemon fruit.

2.2 chemical composition of lemon

The lemon is divided in three zones, the most external one is the exocarp or flavedo. Formed by an epidermis with small vesicles that contain essential oils, used in colognes and aromatic scents. the following layer is the mesocarp or albedo, spongy and white.

To finish with, we find the endocarp pulp, where juice bags and seeds are stored. The juice bags or vesicles are lengthy structures that grow in the endocarp and extend towards the interior of the fruit, until they fill it up completely. These vesicles contain organic acids and sugars that along with water constitute the juice.

Lemon has many bioactive components such as citric acid, Ascorbic acid, minerals, flavonoids and essential oils. Citrus essential oils are generally recognized as safe (GRAS) and a complex mixture of about 400 constituents consisting of 85-99% volatile and 1-15% non-volatile components. A 30-gram serving of lemon juice contains 2.1 milligrams of calcium, 1.8 milligrams of magnesium, 1.8 milligrams of phosphorus and 0.3 milligrams of sodium, which are negligible percentages of the recommended daily value [14].

Lemon juice in its natural state is acidic with a pH of about 2. So, outside the body, anyone can see that lemon juice is very acidic. However, once fully digested, its effect is proven to be alkalizing with many health benefits. Because they contain a high amount of citric acid, Lemons contain a high amount of vitamin C, soluble fiber, and plant compounds that give them a number of health benefits. Lemons may aid weight loss and reduce your risk of heart disease, anemia, kidney stones, digestive issues, and cancer. [14]

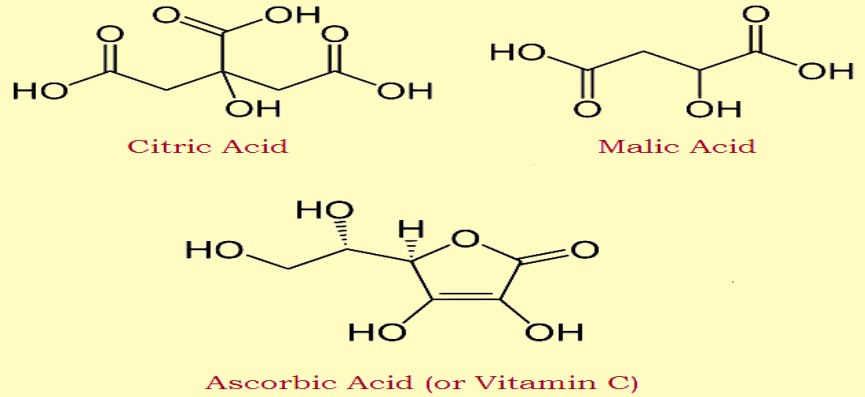


Figure 3 chemistry of lemon.

2.3 Benefits and Uses of Lemon Peel

Lemon (*Citrus limon*) is a common citrus fruit, alongside grapefruits, limes, and oranges. While the pulp and juice are used the most, the peel tends to be discarded. However, studies have determined that lemon peel is full of bioactive compounds that may provide numerous health benefits.

2.3.1 High nutritional value

Despite being eaten in small amounts, lemon peels are very nutritious. One tablespoon (6 grams) provides: Calories 3g, Carbs 1g, Fiber 1g, Vitamin C 9% of the Daily Value (DV). Lemon peel packs a high amount of fiber and vitamin C, providing 9% of the DV in only 1 tablespoon (6 grams). Additionally, it boasts small amounts of calcium, potassium, and magnesium. D-limonene, a compound that gives lemon its characteristic aroma, is also found in the peel and may be responsible for many of this fruit's health benefits.

summary lemon peel is very low in calories while high in fiber, vitamin c, and d-limonene. it also contains several minerals.

2.3. 2 support oral health

Dental cavities and gum infections are widespread oral diseases caused by bacteria like Streptococcus mutants. Lemon peel contains antibacterial substances that may inhibit microorganism growth. In one study, researchers identified four compounds in lemon peel that have powerful antibacterial properties and effectively fight common oral-disease-causing bacteria. What's more, a test-tube study found that lemon peel extract combats Streptococcus mutants' activity, with higher doses being more effective.

Summary Lemon peel has antibacterial properties that may block the growth of microorganisms responsible for oral diseases.

2.3.3 High in antioxidants

Antioxidants are plant compounds that prevent cellular damage by fighting free radicals in your body. Lemon peel is high in antioxidants, including D-limonene and vitamin Intake of flavonoid antioxidants like D-limonene is linked to a reduced risk of certain conditions, such as heart disease and One test-tube study determined that lemon peel had stronger antioxidant activity than grapefruit or tangerine peels. Animal studies also show that D-limonene increases the activity of an enzyme that helps reduce oxidative stress. Oxidative

stress is associated with tissue damage and accelerated aging. Additionally, the vitamin C in lemon peel acts as a powerful antioxidant and likewise promotes immune health.

Summary Lemon peel offers several antioxidants, including D-limonene and vitamin C, that protect your immune system and reduce your risk of disease.

2.3.4 antimicrobial and antifungal properties

Lemon peel may have several antimicrobial and antifungal properties. Notably, in a test-tube study, this peel significantly harmed and reduced the growth of antibiotic-resistant bacteria. Another test-tube study showed that lemon peel extract fought a drug-resistant fungus that causes skin infections. Despite these promising findings, human studies are needed.

Summary Lemon peel may offer antimicrobial and antifungal effects even against antibiotic-resistant strains. However, more research is needed.

2.3.5 promote heart health

High blood pressure, high cholesterol, and obesity are all risk factors for heart disease, which is the leading cause of death in the United State. Research suggests that compounds such as flavonoids, vitamin C, and pectin the main fiber in lemon peel may reduce your risk. A review of 14 studies in 344,488 people found that an average increase of 10 mg of flavonoids per day reduced heart disease risk by 5%. Additionally, in a study in mice with obesity, D-limonene lowered blood sugar, triglyceride, and LDL (bad) cholesterol levels, while increasing HDL (good) cholesterol. A 4-week study in 60 children with excess weight noted that supplementing with lemon powder (containing peel) led to reductions in blood pressure and LDL (bad) cholesterol.

The pectin in lemon peels may also reduce cholesterol levels by increasing the excretion of bile acids, which are produced by your liver and bind to cholesterol.

Summary Flavonoids, vitamin C, and pectin in lemon peel may promote heart health by lowering blood cholesterol levels and other risk factors for heart disease.

2.3.6 anticancer properties

Lemon peel may have several cancer-fighting properties. For example, flavonoid intake is associated with a reduced risk of several types of cancer, and vitamin C may bolster the growth of white blood cells, which help eliminate mutated cancer cells. D-limonene may also have anticancer properties, specifically against stomach cancer. One test-tube study

found that this compound helped kill stomach cancer cells. Similarly, a 52-week study in rats noted that different concentrations of D-limonene inhibited stomach cancer by increasing the death rate of the mutated cells. Nevertheless, lemon peel should not be considered a treatment or cure for cancer. Human research is needed.

Summary Some compounds in lemon peel may have anticancer potential. However, human studies are necessary to confirm these findings.

2.3.7 treat gallstones

Some studies suggest that D-limonene may help treat gallstones hard deposits that can develop in your gallbladder. In a study in 200 people with gallstones, 48% of those injected with a D-limonene solvent experienced complete gallstone disappearance, suggesting that this treatment could be an effective alternative to surgery. All the same, follow-up research is necessary.

Summary Although more studies are needed, the D-limonene in lemon peel may dissolve gallstones.

2.4 Lemon production in Ethiopia

The main Ethiopia lemon growing areas include Melkassa to the southeast and Upper Awash Valley in the center of the country. At least 1100ha of lime and lemon combined were available in Ethiopia in 2015. The lemon is popular in Ethiopia as a romantic method of securing a wife. In weddings, people throw the fruits at one another as an indication of love, particularly around January, the year's wedding time [6]. It is not hard to find a reason for the popularity of Ethiopia lemon. Its pectin fiber that comes from the squeezed juice keeps the weight down. This same fiber also works on the cholesterol levels by burning bad cholesterol fat away. It is also a great beauty product which acts as an organic skin brightener [6].

2.5 Historical background of pectin production

Pectin was first isolated and described in 1825 by Henri Braconnot, though the action of pectin to make jams and marmalades was known long before. To obtain well-set jams from fruits that had little or only poor-quality pectin, pectin-rich fruits or their extracts were mixed into the recipe.

During the Industrial Revolution, the makers of fruit preserves turned to producers of apple juice to obtain dried apple pomace that was cooked to extract pectin. Later, in the 1920s and 1930s, factories were built that commercially extracted pectin from dried apple pomace and later citrus peel in regions that produced apple juice in both the US and Europe.

Pectin was first sold as a liquid extract, but is now most often used as dried powder, which is easier than a liquid to store and handle. Pectin is a naturally occurring biopolymer that is finding increasing applications in the pharmaceutical and biotechnology industry [2]. The pectin of commerce is characterized by a high Content of galacturonic acid, and this has become part of the legal definition for pectin used as food additives or for pharmaceutical purposes. Soluble fibers pull in water to create a gel in the digestive system, and are important to health, digestion, and disease prevention. Pectin is naturally occurring soluble fibers found in plants, and are comprised of linked galacturonic acids, or carbohydrates. Pectin strengthens the cell walls in fruits and other plant parts and binds the cells together [3].

Pectin also attaches to water molecules and contains elastic properties that enable plants to bend flexibly in windy weather. Commercially available in natural and synthetic forms, pectin is found in all plants and fruits to some degree. Although pectin is not digestible in its natural form, it is modifiable, and is mainly used in the food industry as an ingredient in jams and jellies [2].

The jelling and thickening agent in pectin is derived from fruits. In particular, pectin has been reported as one of the main raw materials to obtain edible films by its natural abundance, low cost and renewable character [3].

Pectin was extracted by two different acids, such as Hydrochloric acid & Citric acid at three different temperatures (40 °C, 60°C & 80°C), time (60, 90 & 120 mints) and PH. Many studies report the effect of the acid used in pectin extraction.

2.6 pectin production globally

Production of pectin started in Germany in 1908 when producers of apple juice started to cook dried apple pomace, the main by-product from the apple juice manufacture. The extracted pectin was sold as gelling agent. Demand was high, and in the 1930s the process was industrialized by new companies such as *Opetka*, *Obipektin* or *Herbstreith & Fox* at

new industrial sites established close to producers of apple juice. Production started Today pectin is mostly (85%) produced from citrus peels (56% from lemons, 30% from limes, and 13% from oranges), and from apple pomace (14%), with a minor fraction being obtained from sugar beet. Pectin for use in food is defined as a polymer containing at least 65% galacturonic acid units. shortly afterwards also in the United States and continued until the early 1990s when it was relocated to Mexico (and Brazil), as the environmental regulation of pectin's plants in the US was made considerably stricter. In only one-decade, annual sales of *Yantal Andre Pectin* reached €30 million, and the company today is one of the worlds largest. Similarly, *CP Kelko* between 2011 and 2015 increased the company's production capacity by more than 50% at its pectin manufacturing facilities in Denmark and in Brazil. In 2009 a technologist at a primary pectin manufacturer quantified the pectin market at 30,000 tones (including 5,000 tons of low methoxyl (LM) pectin). The overall annual growth rate was reported to be 6% with prices esteemed at $11.00/kg for HM pectin and $12.90/kg for LM pectin (113). Yet, in 2021 a leading chemical magazine reported that the global pectin market had reached $1 billion [18]. growth is driven by rising demand for functional food products, which translates into expanded market for hydrocolloids [19], as well as increasing use by the cosmetic and pharmaceutical industries.

2.7 Pectin consumption in Ethiopia

Ethiopia has been importing pectin for its uses in food processing and pharmaceutical industries with a hard currency from in a foreign country. According to the data obtained from the Central Statistical Agency of Ethiopia (SEA 2018) (from 2015 up to December 2017), there was a rapid increase of the amount imported in each year (Table 2.3). The local demand for fruit jam, jellies and marmalade is growing rapidly and the consumption of pectin also increases but pectin not produces indoor the country. In Ethiopia many kinds of raw material are available to manufacture pectin and similar products. Waste of citrus peel and other fruit peel are a major source of pectin raw materials to find for marmalade and juice factories.

Table 2 pectin imported to Ethiopia in the year 2015-2017 Source (CSA,2018*)*

Year (GC)	Imported volume (Kg)	Value, USD ($)
2015	2457.36	41,986.77
2016	450.00	7701.301
2017	7907,3	115,706.3

2.8 Sources of pectin

Pectin is a complex mixture of polysaccharides that makes up about one third of the cell wall of dry substance of higher plants. Much smaller proportions of these substances are also found in the cell walls of grasses. The highest concentration of pectin is found in the middle lamella of cell wall, with a gradual decrease as moving through the primary wall gradual decrease as moving through the primary wall toward the plasma membrane. Although pectin occurs commonly in most of the plant tissues, the number of sources that may be used for the commercial manufacture of pectin is limited. This is because; the ability of pectin to form gel depends on the molecular size and degree of esterification (DE) [6]. The amount of pectin varies depend on sources for instance;

- Apple pomace 10-15%,
- Citrus peel 25-35%,
- Sugar beet 10-20%
- Sunflower 15-25%.

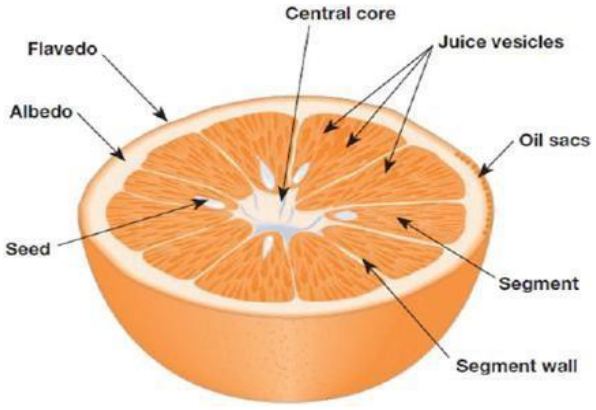


Figure 4 Location of pectin in the lemon

The pectin from different sources does not have the same gelling ability due to variations in numerous numbers of parameters. Therefore, detection of a large quality of pectin in a fruit alone is not in itself enough to qualify that fruit as a source of commercial pectin. At

present, commercial pectin are almost exclusively derived from citrus peel or apple pomace, both of which are by-products from juice manufacturing units. Apple pomace contains 10-15% of pectin on a dry matter basis. Citrus peel contains relatively higher i.e., 20-30% of pectin as compared to that of apple [7]. High methoxyl pectins are mainly used as gelling agents in fruit-based products, especially in the manufacture of jams and fruit preservatives. Other food applications include milk desserts, fruit preparations for yoghurt and tart glazing, confectionery jellies, heat-resistant bakery jams, stabilization of acidified milk products, fruit juices, or soft drinks. Low methoxyl pectins are used to prepare gels with a reduced level of dissolved solids, and are of great interest because of their reduced calorific value. Applications in food industry are diversified, including jams and jellies of low-sugar content, dairy desserts, where usually addition of calcium salt is not needed, fruit gels for use in ice cream, as food coatings, and as thickening agents of syrups for fruit and vegetable canning, among many others [7].

2.9 Structure of pectin

Pectin is a polysaccharide, composed of different sub-structural entities that vary with the extraction methodology, raw material, location, and other environmental factors. The linear backbone of the pectin polymer is called homogalacturonan, and is built by sequences of α (1→ 4) linked D-galacturonic acid residues. These building blocks of polygalacturonic acid can be esterified and present as the methyl esters and the free acid groups. They may be partly or fully neutralized with cations such as sodium, potassium, calcium, or ammonium. The ratio of esterified galacturonic acid groups to total galacturonic acid groups is termed the degree of esterification (DE). It is possible that the homogalacturonan is fully methyl esterified when synthesized in the plant, but the highest DE that can be achieved by extraction of natural raw material is approximately 80%. Pectin with DE from 5%-75% is produced by controlled de-esterification in the manufacturing process. A DE of 50% conventionally divides commercial pectin products into HM and LM pectin. The DE has a vital influence on the properties of pectin [9].

HM pectin requires a minimum number of soluble solids (SS) and a pH around 3.0 or lowers in order to form gels. LM pectin requires the presence of a controlled amount of

calcium, or other divalent cations, to form a gel by "bridging" between adjacent chains and therefore is more flexible with respect to sugar and/or acid [9].

Pectin's are complex polysaccharides mainly composed of 1-4 linked α-D-galacturonic acid (Fig. 2) and found in middle lamella of plant cell membrane.

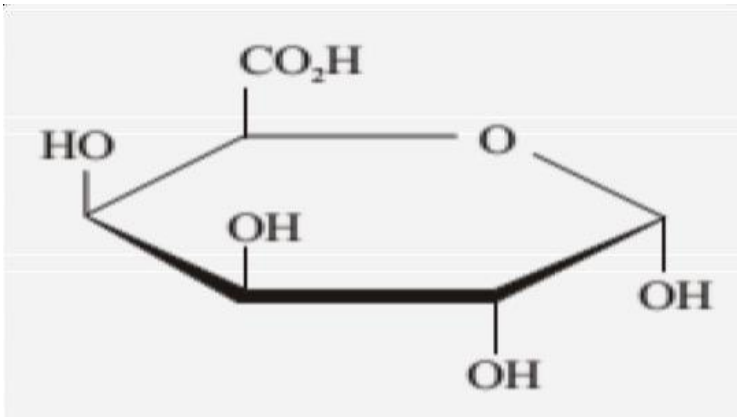


Figure 5 structure of pectin

D-Galacturonic acid is a sugar acid, an oxidized form of D-galactose and is present as polygalacturonic acid in pectin as shown in (Fig. 2). It has an aldehyde group at C1 and a carboxylic acid group at C6. Other oxidized forms of D-galactose are D-galactonic acid (carboxylic group at C1) and meso-galactaric acid (mucic acid) (carboxylic groups at C1 and C6). It is also an ironic acid or hexuronic acid [19].

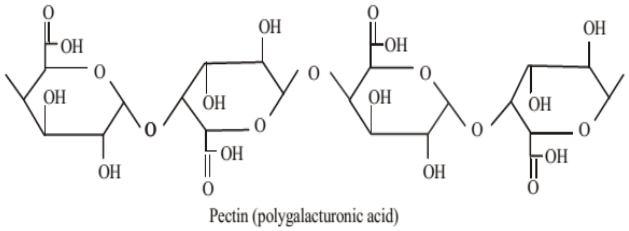


Figure 6 Structure of polygalacturonic acid

2.10 Gelling mechanism

A gel is a semi-solid that can have properties ranging from soft and weak to hard and tough. Gels are defined as a substantially dilute cross-linked system, which exhibits no flow when in the steady-state. Gels with water-soluble polymers are normally prepared by first making aqueous systems in which the polymers are dissolved, and then, afterwards, introducing gelling conditions [10]. For example, jam made with pectin is typically prepared as a

mixture of water, fruit, sugar, and pectin at a temperature close to boiling. In this system the pectin is in a solution. A suitable acid, e.g., citric acid or hydrochloric acid, are then added, reducing the pH slightly to bring the system closer to gelling conditions. Finally, the system is cooled whereby gelation occurs. In the case of gels with pectin.

2.10.1 Production of Low Sugar Jams and Jellies

Traditionally, HM pectin is used for the preparation of jams and jellies. The gelling mechanism of HM pectin is based on hydrophobic interactions and dehydration at low pH (<4.0). In such gels, the presence of high concentrations of sugar (>60 %) is essential for gelling. In contrast, LM pectin forms gels by ionic interactions in which calcium or other divalent cations interact with free carboxylic acid of two adjacent chains, and give rise to cross-linking of these chains. In such a gelling mechanism, the sugar concentration is not very important. Thus, LM pectin is suitable for the production of low sugar (diabetic) jams and jellies [8].

2.10.2 Gelation of Pectin

Gelatin is a common substitute for pectin. Like pectin, it's a powder that dissolves in warm water or any other liquid. Once it cools, the liquid forms a gel. However, gelatin is derived from the skin, bones, and connective tissues of animals or fish, so it's not vegan- or vegetarian-friendly. Pectin gelation characteristics can be divided into two main types: high methoxy gelation and low methoxy gelation. Gelation of high methoxy pectin usually takes at a pH of below 3.5 and total solids (Sucrose) content of above 55%. This is the typical gel formed during jam making. High methoxy pectin’s are characterized by their setting time and the gel strength. Setting time is usually categorized as rapid set, medium set and slow set. High methoxy pectin gel slower as more of the methoxy groups are removed during processing. The gelling of pectin is a combined action of two different mechanisms those are; HM-mechanism and LM-mechanism.

2.10.3 Low Methoxyl pectin (LM)

LM pectin can gel in the presence of divalent cations, usually calcium. In these systems gelation is due to the formation of intermolecular junction zones between homogalacturonic smooth regions of different chains. The structure of such a junction zone is generally ascribed to the so called 'egg box' binding process. Initial strong association of

two polymers into a dimer is followed by the formation of weak inter-dimer aggregation, mainly governed by electrostatic interactions. The gel forming ability of LM pectin increases with decreasing degree of methylation. LM pectin with a block wise distribution of free carboxyl groups is very sensitive to low calcium levels. The presence of acetyl groups prevents gel formation with calcium ions but gives the pectin emulsion stabilizing properties [9].

2.10.4 High Methoxyl pectin (HM)

Jams, marmalades, preserves and conserves are fruit products preserved by sugar. These products differ in gel consistency, ingredients and how the fruit is prepared. They are easy to make at home. Jams are made from crushed or ground fruit and usually have a thick consistency due to high pectin content. Jams and preserves are of course the main use of industrially extracted pectin. High dissolved sugar and acid conditions ensure that chain-chain interactions dominate over chain-solvent interactions. Most chain-chain interactions in these systems are not based on electrostatic interactions and so the other hydrophobic and hydrogen bonding effects exert most influence. High sugar conditions create low water activities which can be mimicked by other solutes with the same resulting gels. This is reflected in the subdivision of HM pectin into rapid-set pectin of HM~77 to slow-set with HM~60. The larger hydrophobic element in HM pectin allows for rapid arrest of the systems [10]. Many factors influence the conditions of gel formation and the gel strength achieved. The major role is played by the pectin molecules, their chain length, and the chemical nature of the junction zones. Under equal conditions gel strengths increase with the molecular weight of the pectin used, and any treatment depolymerizing the pectin chains is reflected in weaker gels. Rupture strength depends on the number of junction zones per single long chain molecule whereas for rigidity the number of junction zones per unit gel volume plays a greater role. Acetyl groups prevent gelation and the HM within the group of high Methoxyl pectin determines the setting temperature of a gel. Powdered HM-pectin slowly lose their ability to from gels if stored under humid or warm conditions while LM-pectin are more stable and loss should not be significant after one-year storage at room temperature. [10].

2.11 Commercial pectin

Even though most plant tissues contain pectin, the major sources for the commercial production of pectin are citrus peel and apple pomace. This is mainly because of the availability of citrus peel and apple pomace from commercial processing operations. In addition, both sources have high contents of galacturonic acid and good gelling properties for food applications. Pectin is usually isolated from either wet or dry fruit residues. Pectin, with better quality characteristics, is obtained from wet fruit residues, since pectin is a heat labile material and quality is lost in pomace drying process. However, apple pomace and citrus peel, in the wet state, are very perishable, especially due to microbial activity. Mold's infestations could produce pectin degrading enzymes (i.e., pectinases), which render pectin in the raw material unacceptable for food uses. Therefore, in order to allow the storage, transportation, and supply throughout the year the starting material is generally dried [16]. Pectin production is sometimes considered an art rather than a science due to the multiple factors influencing the extraction process and their inter-dependencies. Extraction temperature, extraction pH, and hot acid extraction time are considered the most important factors in the pectin extraction process because they have shown significant effects on different pectin characteristics; molecular weight, degree of esterification and yield. Generally, higher yields of pectin have been obtained at high extraction temperature, low extraction pH, and long hot acid extraction time. However, under these conditions the degradation of the pectin molecule is promoted, resulting in low molecular weights and low esterification, which negatively affect the functional properties of pectin. Selecting the ideal combination of raw material and extraction conditions is crit ical inobtaining high yields of pectin, without compromising the desired quality [17]. Generally Commercial pectins consist mainly of a backbone of α (1→4)-D-galacturonic acid with partial methyl esterification of the carboxyl groups [4, 22]. At least 65% of the extracted material must be galacturonic acid, in order for extracted material to be classified as commercial pectin [10].

2.12 General Properties of Pectin

Pectin is soluble in pure water. Monovalent cation (alkali metal) salts of pectinic and pectic acids are usually soluble in water; di-and trivalent cations salts are weakly soluble or insoluble. Dry powdered pectin, when added to water, has a tendency to hydrate very rapidly, forming clumps. Pectin shows gel forming, thickening and stabilizing properties if it is properly dissolved in water and stored in a cool and dry place. Pectin can be characterized by different parameters, the most important being the degree of methylation or degree of methyl esterification, which refers to the percentage of methoxylated C6 atoms in the galacturonic acid backbone, and is closely related to the gelling properties [11]. The general characteristics of pectin are;

2.12.1 Colloidal

Pectin precipitates as a solid gel on treating with a dehydrating agent like alcohol. They are extremely sensitive to dehydration and get effected by any other hydrophilic colloids as well, thus they are known to be insoluble in most of the bio-colloids. The negative charge of pectin depends on the number of free carboxyl group that is mainly responsible for its precipitation. [11]

2.12.2 Gelation

One of the most interesting properties of pectin is its ability to form gel in the presence of either acid or calcium or sugar, this enables them to be used in many food industries [10]. Hydrogen bonding and hydrophobic interactions between polymer chains stabilizes the pectin polymer [5].

2.12.3 Solubility

Pectin must be completely dissolved to ensure full utilization and to avoid heterogeneous gel formation. Pectin must be completely dissolved to ensure full utilization. Complete dissolution presumes dispersion without lumping. If pectin lumps are allowed to form, they are extremely difficult to dissolve. Pectin, like other gelling agents, will not dissolve in a system where gelling conditions exist. HM pectin is therefore increasingly difficult to dissolve as the SS in the system increases. It is recommended that HM pectin is dissolved at SS below 20%, and preferably in water. Once the pectin is dissolved, it is possible to add more sugar [12].

2.12.4 Viscosity

Pectin solution shows lower viscosity compared to another thickening agent. Salt (such as Ca++ and Mg++) increases the viscosity of pectin solution in calcium free solution the viscosity drops when the acidity is increased. Viscosity of pectin solution was measured by viscometer [12].

2.12.5 Storage stability

Pectin should be stored in a cool dry environment at increased temperature, above ambient the degradation of pectin will occur due to the reduction of molecular weight [12].

2.12.6 Stability in Solution

Dissolved pectin may, if exposed to unsuitable conditions of pH and temperature, degrade by depolymerization as well as by desertification. Further, it is susceptible to attack by microorganisms and enzymes. Best chemical stability is found at approximately pH 4.

pH less than 3, methyl ester groups and glycosidic linkages of the galacturonide gradually hydrolyses. At even higher pH, methyl ester groups may be removed by saponification elimination requires the presence of methyl ester groups which explains why the reaction runs pronouncedly faster on HM than LM pectin. While hydrolysis occurring at low pH rarely causes a problem under food-relevant conditions [10].

2.13 Applications of Pectin

Pectin is widely used to impart gel formation, thickening, and physical stability to a wide range of foods, mainly fruit-based products. The gel forming ability of pectin depends primarily on the degree of esterification (DE), which is the proportion of galacturonic acid units that are esterified with methanol [14] Commercial pectins are classified based on their DE; high methoxyl pectins (HM, DE>50) and low methoxyl pectins (LM, DE <50). A pectin gel is formed when portions of the homogalacturonan backbone are crossed-linked forming a continuous three-dimensional network, which is able to entrap water and solutes [9] The “joints” of homogalacturonan portions are often referred as “junction zones”. Various forces may be involved in the formation of a junction zone in high methoxyl (HM) pectins junction zones are formed by hydrogen bonds and hydrophobic forces between methoxyl groups of pectin 13 molecules. To permit the formation of junction zones in HM pectins, low pH (<3.6) and soluble solids (usually sucrose) at a concentration higher than

55% (w/w) were required. In contrast, LM pectins require the presence of divalent metallic cations, such as calcium, to form junction zones by ionic cross-linking between non-esterified carboxyl groups [4] The rheology of pectin gels depends on properties of the pectin, such as molecular weight, attached neutral sugars, and degree of acetylation Pectin, like most naturally occurring polysaccharides, can create viscous solutions; viscosity depends largely on the concentration of pectin and its molecular weight. At low concentrations (<0.5% w/w), pectin solutions exhibit Newtonian behavior, but as the concentration increases pectin solutions exhibit non-Newtonian, pseudoplastic characteristics. Pectins with higher molecular weight will exert higher viscosity. Other factors, such as degree of esterification, solvent, pH, soluble solids, and temperature also influence the viscosity of pectin [12]. In addition to the gelling and thickening properties, certain pectin possesses emulsifying and/or emulsion stabilizing properties. Studies have suggested that the emulsifying property of pectin could be originating from (a) the presence of acetyl groups, which enhance the hydrophobicity of pectin, (b) the protein residues present within the pectin, or (c) a combination of both. However, in dairy applications, especially low pH dairy drinks, the consumption of pectin has been growing rapidly in recent years. Pharmaceutical applications, medical devices and cosmetic applications are also areas where the many different properties of pectin are being utilized. [12]

2.13.1 Pectin in Food Applications

Both LMC, LMA, and HM pectin are used in jams and jellies. The role of the pectin is to impart a gel texture to the jam or jelly. This texture must be strong enough to allow transportation and storage without changes.

2.13.2 Pharmaceutical applications of pectin

The use of pectin in the pharmaceutical industry is growing, but the amount used is much smaller compared to the food uses. Pectin is used in many pharmaceutical preparations as an excipient, thickener, stabilizer, film coating, and binding agent. Due to its ability to bind positively charged heavy metal ions, pectin is used as a detoxifying agent. It has been used to remove toxic heavy metal ions, such as lead and mercury, from the gastrointestinal tract and respiratory organs of individuals who have been poisoned with heavy metals. Since pectin is able to delay blood clotting.

2.13.3 Cholesterol regulation

Pectin preparations with high viscosity appear to be more effective in lowering cholesterol than are pectin preparations with lower viscosity. High viscosity pectin is thought to lower cholesterol levels by raising the excretion of fecal bile acids and neutral sterols. High-viscosity pectin may interfere with the formation of micelles and/or lower the diffusion rate of bile acid and cholesterol-containing micelles through the bolus, consequently diminishing the uptake of cholesterol and bile acids. In a small early study, administration of 15 grams of pectin daily for three weeks resulted in a mean 13% reduction in plasma cholesterol levels.

2.13 .4 Anti-cancer action

Lemons, oranges and grapefruits are pectin rich fruits that may help decrease cancer tumor formation. According to Memorial Sloan-Kettering Cancer Centre, the citrus pectin acts as a ligand for galectin-3, a protein involved in cell growth and cell cycles. Elevated galectin-3 is associated with inflammation of the heart and cancer tumors. Institute, N.B. and Walding had reported that pectin supplementation in the diet forbids excess galectin-3 from binding to receptors that might result in the spread of cancer cells through angiogenesis or blood vessel growth. Reported that in terms of nutrition, pectin has been shown to lower blood cholesterol levels and low-density lipoprotein cholesterol fractions, which is beneficial for human health [14].

2.14 production process of pectin

The world's largest producers of dried citrus peel are in Argentina and Mexico but producers are located also in Peru, Spain and Bolivia. While current production in Germany mainly relies on apple pomace. Regardless of the type of raw material, however, the current manufacturing process is based on extraction via acid hydrolysis in hot water. In order to control polymeric degradation, both the pH and hydrolysis time need to be checked carefully. Protopectin in the washed and dried citrus peel is solubilized with a dilute mineral acid (HCI or HNO3 or H2SO4) at pH 2-3, for several hours at 50-100ºC. Following separation from the spent peel, the pectin extract is filtered and precipitated with alcohol (isopropyl alcohol). The alcohol is recovered by distillation while pectin is washed, dried and sold in powder form [12].

Pectin extraction is a multiple stage physicochemical process which involves hydrolysis and extraction of pectin macromolecules from plant tissue, purification of the liquid extract and isolation of the extracted pectin from the liquid. These processes are influenced by various factors, mainly temperature, pH and time. The most commonly used methods for extraction of pectin are direct boiling (water-based extraction) and microwave heating extraction.

2.14.1 Water based extraction

The conventional water-based extraction involves extracting the pectin using acidified water (pH up to 2) at temperature not more than 70 °C. The assembly is run for 2-4 h duration and pectic substances are precipitated using ethanol or isopropyl alcohol.

Extraction with the hot water is the simplest and oldest method for removing the pectic substances. The most commonly used acidifying materials are mineral acids including, sulfuric, hydrochloric and phosphoric acids. Commercially, pectin is extracted by treating the raw material with hot dilute mineral acid at pH about two. The precise length of extinction time varies with raw material, the type of pectin desired, and from one manufacturer to another. The hot pectin extract is separated from the solid residue as efficiently as possible. This is not easy since the solids are by now soft and the liquid phase are viscous. The viscosity increases with pectin concentration and molecular weight. There is a compromise between efficient extraction and solids separation and operating cost. The pectin extract may be further clarified by filtration through a filter aid. The clarified extract is then concentrated under vacuum. Powdered pectin can be produced by mixing the concentrated liquid from either apple or citrus with an alcohol (usually isopropanol). The pectin is separated as a stringy gelatinous mass, which is pressed and washed to remove the mother liquor, dried and grounded [20].

2.14.2 Microwave heating extraction

Compared with water-based extraction microwave heating extraction reduces the extraction period considerably. A fifteen-minute microwave heating period is enough to extract almost the same amount of pectin as that obtained from water-based extraction with a three-hour extraction period, during microwave heating considerable pressure builds up inside a material. The high pressure then modifies the physical properties of material tissues, breaking down the cell structure and improving the capillary porous structure of tissues. This feature allows better penetration of extracting solvent into the tissues; improving the subsequent extraction of pectin. Microwave extraction also gave a higher rate and amount of extraction than the simple water-based methods. In the recent year's supercritical fluid extraction technique, for extraction of natural polymers has come into existence. The relevancy of using the above technique for pectin extraction is yet to be proved over the other techniques available [20]

Chapter three

Materials and method

The study was carried out at Wolkite University (WKU) college of engineering and Technology Department of chemical Engineering process engineering laboratory by using direct boiling water bath method. The major methodologies that were used to gather data and processed were laboratory work and data Analysis, which was done after laboratory work.

3.1 Materials and Chemicals used

The main raw material for this study was lemon peel. The lemon fruits were obtained from local market. All chemicals that we were used in this study were hydrochloride acid (HCl) used for adjusting PH value, ethanol Used for precipitating agent, Sodium hydroxide used as catalyst and Distilled water used for extraction of pectin.

3.2 Equipment's used

Flask was used to mix chemicals, Nylon cloth was used to separate solid from clear liquid solution, Centrifuge was used to separate pectinate substance from residue, Miller or Electrical grinder was used to crush the peel to powder form, Filter paper that was used in the place of centrifuge, Water bath was used to heat the mixture in desired temperature Washing tank, Oven was used to drying the lemon peels, Knife was used to chopping the lemon peels, Washing tank was used to remove the residue from the peels, peter dish was used to collect jelly pectin, Aluminum foil was used to protect the jelly pectin from contamination, Measuring balance was used to measure the samples, Sieve was used to sieve in wanted mesh size.

3.3 methods

The experiments were carried out at Wolkite university college of Engineering and Technology department of Chemical Engineering laboratory. The most commonly used method for extraction of pectin includes direct boiling and microwave heating. Among this method convection or water based was selected. Because it was used in large scale production, it is simple, cheap and available; but microwave extraction uses in small scale production, time consuming due to complex structure, pressure build inside the material

and it is costly to extract the pectin. The major methodologies that were to have under taken to gather data and proceed are laboratory work and data Analysis, which does after laboratory work.

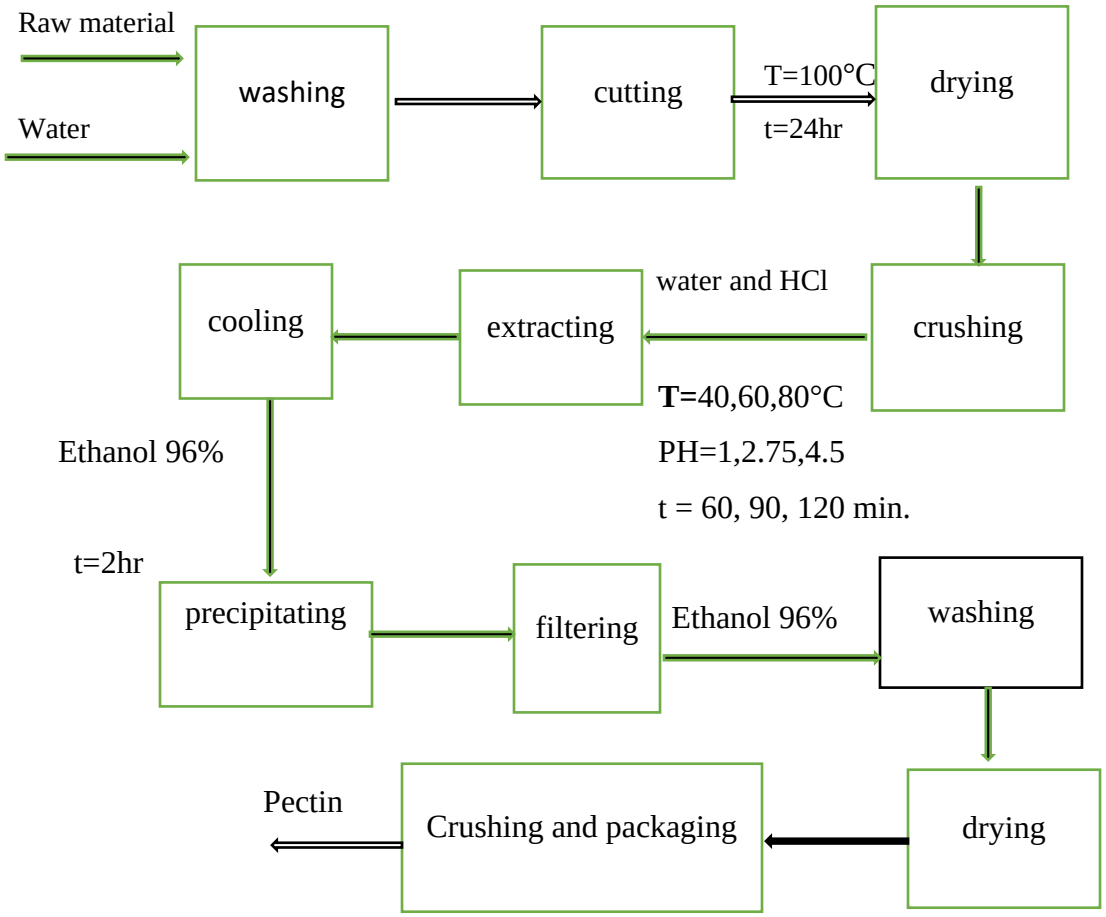


Figure 7 flow sheet for extraction of pectin

3.3.1 Raw material Preparation

4kg of lemon varieties were collected from local market. The samples were washed carefully with tap water to remove dirt soil from surface; they were cut into slices (2-3 mm thickness) with a sharp knife. The juice was extracted; after juice extraction the peel was chopped into small pieces in a vegetable cutter dried at 100°C for 24 hr. in an oven followed by grinding into powder using electrical mill. The powder was then sieved using sieve. The obtained powder was finally stored at ambient temperature for further use.

3.3.2 Extraction

Method for extraction of pectin consisted of adding 150 ml of distilled water to 5g pectin peel powder in a beaker and addition of hydrochloric acid adjusted at different pH (1, 2.75, and 4.5) and then heating the mixture to 40ºC, 60°C and 80ºC for 60min, 90min ,120min respectively, in a hot water bath. The hot acid extract was filtered using centrifugal machine at 3000 rpm for 10 minutes. The pectin extract obtained from different extractions, after cooling to room temperature, was precipitated with 96% ethanol (alcoholic precipitation). The filtrate was coagulated using an equal volume of 96% ethanol and left for 2hr. to allow the pectin to float on the surface. The gelatinous pectin flocculants were then skimmed off. Filtration was again done for separation of coagulated pectin. The coagulated pectin was then kept for drying in oven at 60 °C for 24hr. After drying the pectin was ground. The dried pectin obtained from peels stored in a cool dry place until further analysis. Finally, percentage yield was calculated.

3.3.3 Experimental procedure:

Collection of raw material: The raw materials or lemon (4kg of fresh lemon) were collected from gubre town that used for extraction of pectin.



Figure 8 collection lemon fruits from local market

Washing with water: The collected fresh lemons were washed carefully with tap water to remove dirt soil from surface or to remove impurity that affect quality extracted pectin.



Figure 9 washing of lemon peel

Cutting the peel: Cutting knives were used to remove pesticide residues, leaves and then cut the peels were in to thin slices. the peel was cut to dry with short period of time.



Figure 10 cutting of lemon peel

Drying: The lemon peel that have been peeled and chopped were for efficient drying by oven for 24 hours at temperature 100 °C and removing moisture as much as possible for grinding the dried peel.



Figure 11 drying of lemon peel

Crushing: The dry peel was crushed by milling machine to get powder form.



Figure 12 powdered lemon peel

Mixing. 5g of powder peel was mixed with 150 ml of distillated water.

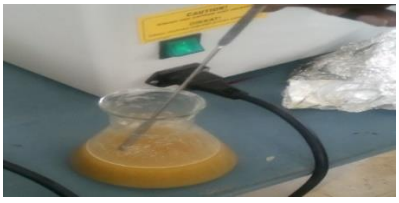


Figure 13 mixing peel powder water

Heating: this process was done in water bath at temperature of 40ºc 60ºc and 80ºc for 60min 90min, and 120min and at PH 1,2.75 and 4.5 to heat the solution for further extraction. Heating the mixture was heated in water bath in desired. However, over long heating degrades the pectin and it loses some of its gelling power.



Figure 14 heating of mixed solution.

Filtration: separation of filtrate from cake by using centrifuge filter or filter paper. Cake used for animal's feed.



Figure 15 filtration by using filter paper and centrifugal machine

Filtrate: the solution after separate from the cake and ethanol was added for precipitation and remove impurity Cooling the mixture of heating it can be stored for a 1hr at room temperature it has been cooled and precipitate 96% ethanol then kept 2hr for coagulation process.

Separation of precipitate: filtered by using centrifuge or filter paper after the filtrate was settled down the precipitate was removed. Washing it was washed by diluted 96% ethanol for removal of impurities and further treatments to remove acid.



Figure 16 precipitate pectin

Drying: Draying the coagulated pectin has been kept for drying for in oven at 60°C in petri dish for 24hr.

Pectin: the final result of the process.



Figure 17 Dried pectin

The Processes descriptions of pectin production from lemon peel steps;

Washing water was used to remove any adhered impurities such as dirt or dust particles. Cutting knives were used to remove pesticide residues and to increase the surface area of the peels in to a thin slice. Drying the chopped peels have then introduced to oven for efficient drying. Crushing The dry peel was crushed by milling machine to get powder form. Heating the mixture is heated in water bath at desired temperature. However, over long heating degrades the pectin and it loses some of its gelling ability. Cooling the heated mixture stored for a 1hr at room temperature it has been cooled and precipitate by using 96%ethanol then kept for 2hr for coagulation process and filtered by using nylon cloth or filter paper. Washing it was washed by diluted 96% ethanol for removal of impurities and further treatments to remove acid. Draying the coagulated pectin has been kept for drying in oven at 60°C. After drying the pectin was kept in petri dish at room temperature.

3.4 Characterization of pectin

The dried pectin samples obtained from lemon peels were subjected to the following qualitative and quantitative tests in order to characterize them.

3.4.1 Qualitative tests

Solubility of Dry Pectin in Water: 5g of the pectin samples was placed in conical flask, followed by addition of 10 mL of 96% ethanol and 50 ml of distilled water. The mixture in the flask is shack vigorously to form a suspension which will then heated at 85-95°C for 15 min.

Color: This was done by visual observation

Solubility of Pectin Solution in Alkali: 1 ml of 0.1 N NaOH in conical flask, 5ml of pectin solution will added then heated at 85- 90°C for 15 min.

Solubility of Pectin Solution in Acid: 1 mL of 0.1 N HCl in conical flask, 5ml of pectin solution was added and the second flask was heated at 85- 90°C for 15 min.

3.4.2 Quantitative tests

Percentage yield: Yield % of pectin is based on the gram of peel sample taken, and was calculated by formula as given below;

$$\textbf{Yield \%} = \frac{P}{Bi} * 100 \quad \textbf{..... (1)}$$

Where; Y pec (%) is the extracted pectin yield in percent (%),

P is the amount of dry pectin in g and

Bi is the initial amount of lemon peel in gram.

Ash content: A dry porcelain dish containing about 5g sample was placed in a muffle furnace (GALLENKAMP, Model FSL 340-0100, U.K.) set at 550°C for 1hr and was cooled in a desiccator and then weighed. The ash content was determined according to AOAC (2000) by applying the formula:

$$\textbf{Ash \%} = \frac{W2-W}{W1-W} \textbf{x100} \quad \textbf{..... (2)}$$

Where: W = is weight in grams of empty dish

W 1 = Weight in grams of the dish plus the dried test material

W 2 = is Final weight of dish with Ash.

Moisture content: Moisture of the pectin was determined according to AOAC (2000). A clean dried dish was weighed, and 2g of the sample was transferred to the dish. The dish was then placed in the oven at 102 °C for 5hr and cooled in desiccators and re-weighed. Then, the moisture content was estimated by the formula: -

$$\textbf{Moisture content \%} = \frac{W2-W3}{W2-W1} * 100 \quad \textbf{..... (3)}$$

Where: W 1 = weight dish (g)

W 2 = weight of fresh sample and dish(g)

W 3 = weight of dry sample and dish (g)

Chapter four

Results and Discussions

4.1 Yield

The extraction parameters were very important to produce both a good quality and a reasonable amount of pectin. As a result, to achieve these objectives different parameters with different levels were used during the extraction process. The parameters were temperature, pH and time. By using literature reviews as spring point and taking into consideration the levels of temperature were 40 °C, 60 °C, and 80 °C. The second important factor and that was necessarily investigated was pH and its levels were pH 1.0, pH 2.75, and pH 4.5.

The percentage yield of pectin extracted by using hydrochloric acid from lemon peel powder ranged from 6% to 16%. The percentage yield was maximum (16%) for lemon peel powder using hydrochloric acid at treatment combination of pH 1.0 at 60 °C for 60 min while minimum yield obtained was 6% at treatment combination of pH 4.5 at 40 °C for 120 minutes. Srivastava and Malviya (2011) suggested that through conventional water-based extraction method at lower pH with temperature not more than 70 °C one can find maximum amount of pectin yield. It is recognized that an increase in acid strength (that is, decreasing pH) plays an important role in increasing the content of galacturonic acid. In general, pectin extraction yield from different sources may vary depending on processing parameters and sample features. Acids were generally the strongest extracting agents with regards to the yield of extracted pectin. Pectin yields greater than 10% is commercially feasible. The highest yield obtained in this study was more than 10%, which makes it feasible for commercial use.

Table 3 shows experimental run and average yield

Run	Temperature (°C)	Acid concentration PH	Time in hour	Average Response (%)
1	40	1	1	7.68
2	60	1	1	16
3	80	1	1	7.26
4	40	2.75	1:30	8.2
5	60	2.75	1:30	12.34
6	80	2.75	1:30	11.73
7	40	4.5	2	6
8	60	4.5	2	9.12
9	80	4.5	2	8.03

4.2 Effect of pH on pectin yield

With regards to the extraction parameters, pH was considered as one of the most crucial parameters affecting both the amount and properties of pectin being extracted. It has previously been reported that several acids can be utilized for the extraction of pectin. However, mineral acids such as sulfuric, hydrochloric and nitric acids tend to be widely used. Therefore, in this study, the effects of pH on pectin yield were initially investigated. As shown in table 3 was evident that pectin extraction at pH 1 gave significantly higher yield than that of pH 2.75, and pH 4.5. This is likely due to the enhanced ability of acid in solubilizing the proto pectin from the albedo with an increase of acid strength. This observation was in good agreement with the previous works of Khan et al., (2015) and Sharma et al., (2006), which reported significant influences of acid concentration on yields. Therefore, hydrochloric acid at pH 1 would be preferential in view of pectin extraction from both varieties. Acids affect not only the yield but also the molecular characteristics of pectin such as DE, gelling properties, ratio of galacturonic acid to rhamnose, average molecular weight and gel strength. The pectin yield decreases with increasing PH. It is evident that pectin yield decreases with increased of PH. Lower pectin yield at higher pH might be due to some pectin that might still be attached to the cell wall components,

although pectin molecules can be partially solubilized from plant tissues without degradation in a weak acid solution.

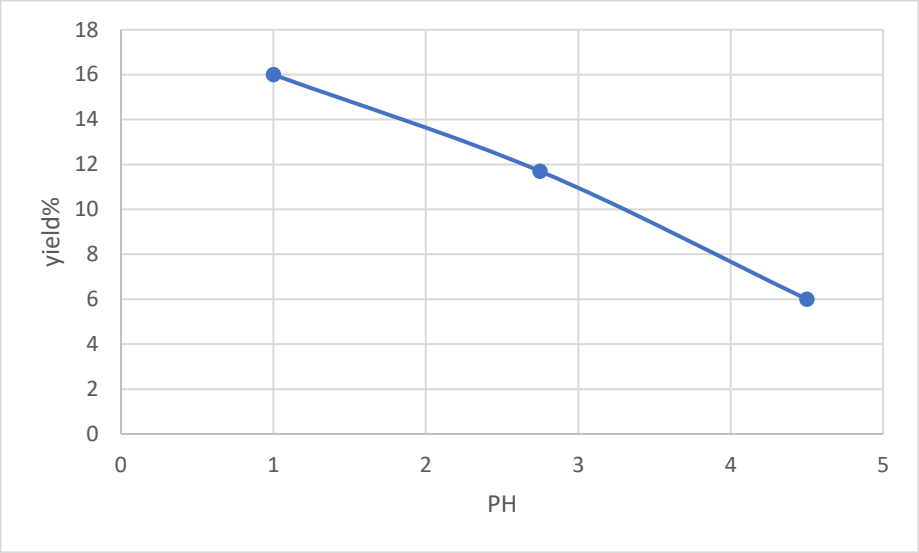


Figure 18 shows the graph of yield vs. Ph

4.3 Effect of temperature on pectin yield

Figure 18 shows as the extraction temperature increases pectin yield also increased. But some literatures suggest that increased temperature beyond 80°C may denature pectin and it is better to extract it below 80°C for maximum yield. Literatures suggest that extracting pectin using acidified water (pH up to 2) at temperature not more than 70°C could give maximum yield. In our work maximum yield was obtained at temperature 60°C. Similar result has been observed by kanmani et al. (2014) the optimum extraction temperature for pectin was 65°C. In the above figure at temperature 60°C and at pH=1 we have maximum yield of 16%. Clearly from the figure can observed that as the temperature increase beyond 65°C pectin yield decreases. The above figure clearly shows the change in the yield of pectin at different temperature while the pH and time is kept constant.

The figure show that minimum yield is obtained at temperature of 40°C for all pH and time. The figures also predict maximum yield could be found from the temperature 60°C up to 65°C, the pectin yield is influenced by temperature. The yield increases with the increasing temperature for the lemon peel until 65°C. Because increasing the extraction temperature would increase the solubility of the extracted pectin, giving a higher rate of extraction. However, further increase in temperature from 65 to 80°C shows a decreasing

tendency of pectin yield, since too high temperature would lead to break down of pectin molecules as pectin is composed of α-(1-4) linked units of galacturonic acid or methyl ester resulting in pectin of lower molecular size which is not perceptible with alcohol.

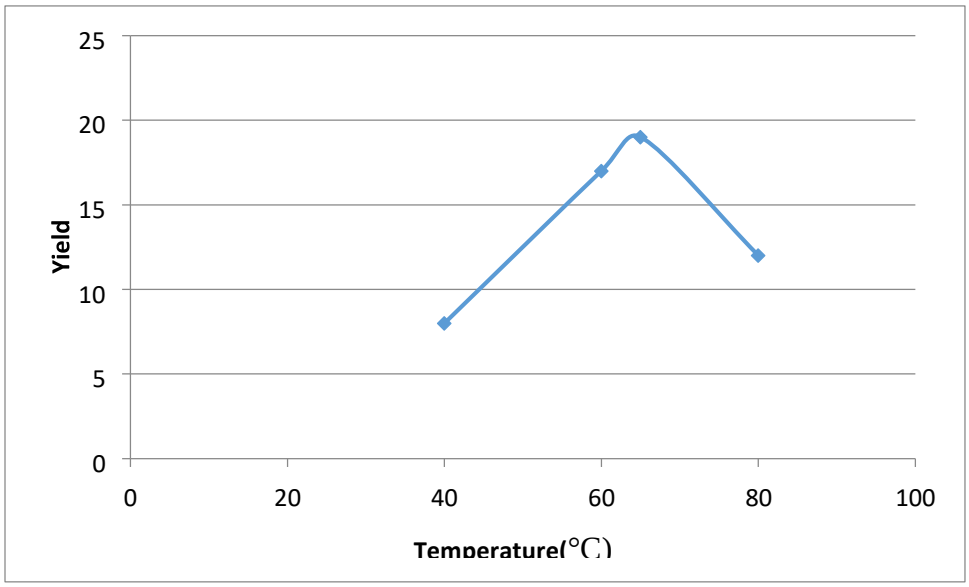


Figure 19 shows the graph of yield vs. Temperature

4.4 Effect of temperature and pH

The influence of the temperature and pH at fixed time on the pectin yield indicated that, for lower temperature the yield of pectin decreased with increasing PH. At lower and higher levels of both pH and temperature decreased the yield of pectin was observed. At low pH and higher extraction temperature it was found that there was increased on percentage of pectin yield. However, the pectin degraded and the color of pectin became deep when the pH value was too low and lower extraction when pH value was too high.

4.5 Effects of extraction time on Pectin yield

pectin yield increased significantly with the increasing in the extraction time shows that the yield of pectin increases from 60 up to 75 minute then at 90 minutes it become slightly decrease finally at 120 minutes the yield become low this shows that pectin yield increase with extraction time until to some limit then a relatively long period of extraction would cause a thermal degradation effect on the extracted pectin, thus causing a decrease in the amount of yield and perceptible by alcohol. Besides, the color of the pectin extract became dark brown for longer periods of extraction which in turn required a higher number of

alcoholic washings of the precipitate. Generally, the result shows that the yield increases with increase in extraction time physicochemical properties of pectin from Lemon variety at time of 60 minutes.

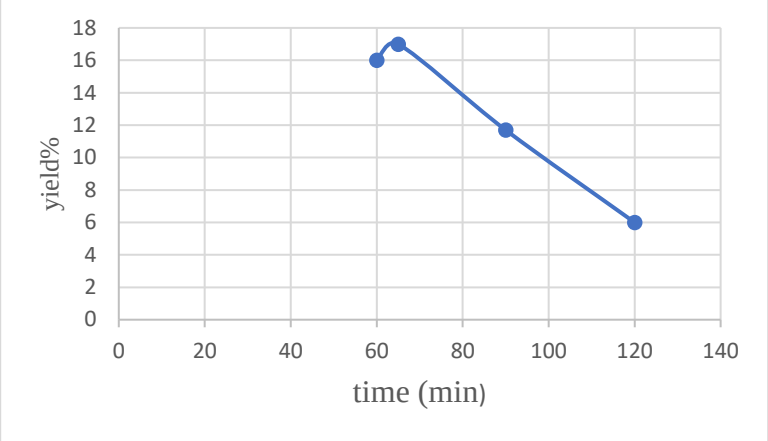


Figure 20 shows the graph of yield vs. Time

4.6 Characterization of Extracted Pectin

The dried pectin obtained from the peels of the lemon was subjected to the following characterization parameters.

Color: This was done by visual observation and the pectin is important as it affects the appearance of the gel produced. And it was observed to be white red.

Pectin solubility in acid, base and water

Pectin's are soluble in water and form viscous solution. As solubility increase viscosity also increase. Pectin is also soluble in base and acid. When we compare three of them pectin's are quickly soluble in acid than base and water. When it compared in base and water, pectin's are soluble quickly in base than water. Therefore, solubility decreases in acid, base and water respectively. The quantitative test was done after the extraction of the pectin which is the color of pectin is light to brown.

Table 4 Comparison of solubility

Characterization	**Acid**	**Base**	**Water**
Solubility	High	Medium	Low

Ash content: Ash content of pectin extracted from lemon peel powder varied from (2.45-2.81%) by using hydrochloric acid. Rangana (1977) stipulated that the pectin of high ash content contains about 10.69% ash content and the pectin of low ash content contains about 0.76% ash content.

Moisture content: The moisture content was determined by (AOAC, 2000) using equation above. The moisture content of pectin extracted from lemon peel was between (9.9-10.2%). Based on the quality standards of commercial pectin, all of pectin is produced to meet the standards not far above 12%.

4.7 calculated value of characterized pectin

Table 5 shows calculated value of characterized pectin

Temp.	pH	Ash Content (%)	Moisture content (%)
60 °C	1	2.45	10.2

Table 6 Comparison of extracted and commercial pectin and results reported in literature

Characteristics	Extracted pectin	Commercial pectin	Literature
Moisture content	12.2%	11.27%	11.3% [12]
Ash content	3.3%	15.2%	6.9-11.6 [1].

Chapter five

Mass and Energy Balance

5.1 Total mass balance

Accumulation=Output + Consumption - Input-Generation.

Since there is no reaction consumption and generation terms are zero, no accumulation

Therefore, Input=Output

Density = mass /volume

Table 7 Density of materials

Raw material	Density gm/ml
H_2O	1
36%HCL	1.179
96% C_2H_3OH	0.795

Run 1:

At temperature=40℃ and pH=1, time=60min

Water=150ml

powder peel=5gm

Ethanol=60ml

Hydrochloric acid=2ml

Mass H_2O=density H_2O*volume H_2O

=150ml*1gm/ml

= 150gm

Mass C_2H_3OH=density C_2H_3OH*volume C_2H_3OH

=60ml*0.795gm/ml

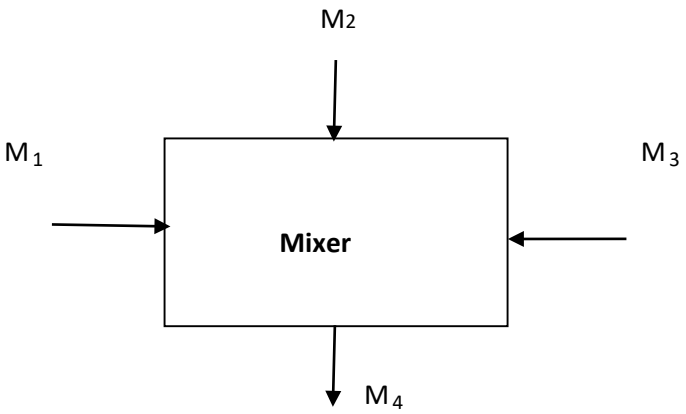
=47.7gm

Mass HCl=density HCl*volume HCl

= 1.179gm/ml*2ml

=2.358gm

Mass balance on mixer



Where, M_1=mass of H_2O

M_2=mass of powder peels

M_3=mass of HCl

M_4=mass of mixed solution Therefore,

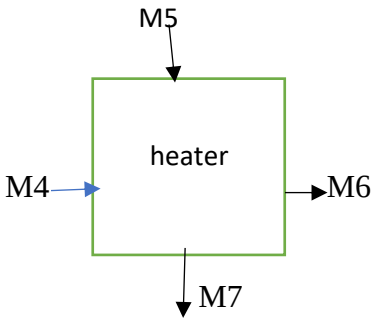
Input= Output

$M_4=M_1+M_2+M_3$

M_4=150gm+5gm+2.358gm

M_4=157.358g mixed solution

Mass balance on heater & filter



Where

M_4=mass of mixed solution

M_5=mass of gas

M_6= mass of water

M_7=mass of heated solution

So,

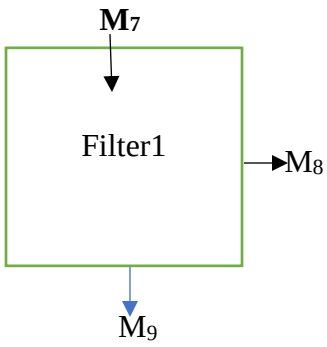
Input=Output

$M_4=M_5+M6+M_7$

157.358g $=M_5+M_6$ +154.773gm

M_5+M_6=2.585gm lost

Mass balance on filter



Where,

M_7=mass of heated solution

M_8=mass of filter cake

M_9=mass of filtrate

Mass of input=Mass of output

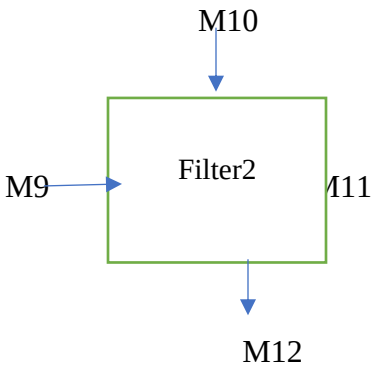
$M_7=M_8+M_9$

154.773gm$=M_8$+86.171gm

154.773gm -86.171gm$=M_8$

M_8=68.602 gm

Mass balance on filter 2



Where,

M9=mass of filtrate1

M10= mass of ethanol

M11=mass loss of water, C_2H_3OH and HCl

M_{12}=mass of filtrate 2

Input = output

M9+M10=M11+M12

86.171gm+47.7gm =M11+129.256gm

M11= 133.871gm -129.256gm =4.615gm

Mass balance on oven

Where

M_{12}=mass of filtrate 2

M_{13}=lost mass of H2O, C2H3OH and HCl

M_{14}=pectin

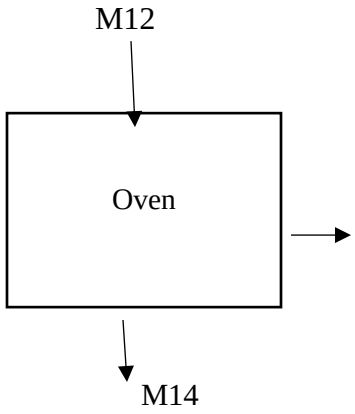
So,

$M_{12}=M_{13}+M_{14}$

129.256gm=M_{13}+2.112gm

M13=129.256gm -2.112gm

M_{13}=127.144gm



Run 2:

At temperature =60℃ and at pH=4.5, at time=120min

Water=150ml powder peel=5gm

Ethanol=60ml Hydrochloric acid=1.25ml

Mass H2O=density H2O*volume H2O

=150ml*1gm/ml= 150gm

Mass C2H3OH=density C2H3OH*volume C2H3OH

=60ml*0.795gm/ml =47.7gm

Mass HCl=density HCl*volume HCl = 1.179gm/ml*1.25ml =1.474gm

Following the same procedure, we got the mass balance as follow:

Mass balance on mixer

Where,

A_1=mass of H2O

A_2=mass of powder peels

A_3= mass HCl

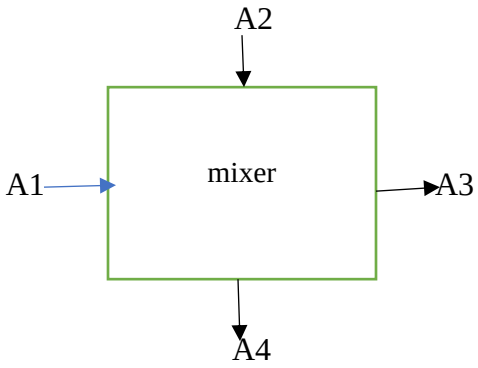
A_4= mass of mixed solution Therefore

Input= Output

$A_4=A1+A2+A3$

A_4=150gm+5gm+1.474gm

A_4=156.474gm



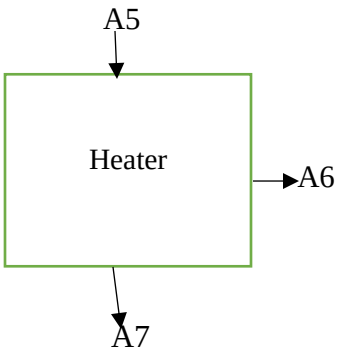
Mass balance on heater

Where,

A5=mass of gas

A6 =mass of water

A7= mass of heated solution



So,

In put= output

$A_4=A_5+A_6+A_7$

156.474gm=A_5+A_6+154.451gm

A_5+A_6=156.474gm-154.451gm

A_5+A_6= 2.023gm

Mass balance on filter 1

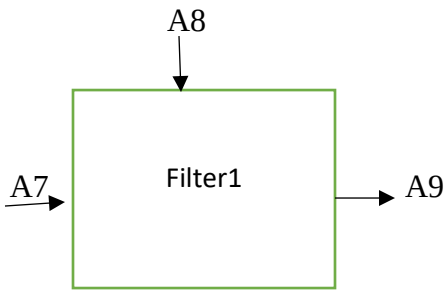
Where,

A_8=filter cake

A_9=filtrate solution 1

Input= Output

$A_7=A_8+A_9$



154.451gm=A_8+102.543gm

A_8=154.451gm-102.543gm

A_8=51.908gm

Mass balance on filter 2

Where,

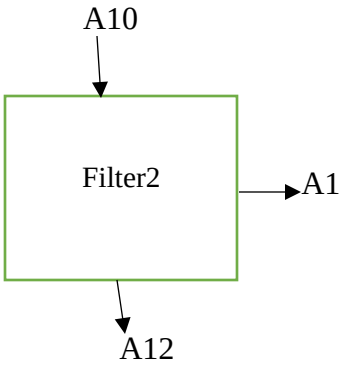
A_{10}=mass of C2H3OH

A_{11}= lost mass of H2O, C2H3OH and HCl

A_{12}= mass of filtrate 2

Input= output

So, $A_9+A_{10}=A_{11}+A_{12}$



= 102.543gm +47.7gm=A_{11}+ 121.805gm

150.243gm-121.805gm=A_{11}

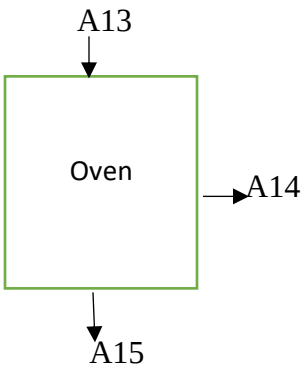
A_{11}=28.438gm

Mass balance on oven

Where,

A13=mass of lost H2O, C2H3OH and HCl

A14=mass of pectin extracted



Therefore,

A12= A13+A14

121.805gm=A13 +2.578gm

A13=119.227gm

Take

M1= mass of lemon peel grind before drying

M2 = mass of lemon peel residue after drying.

% of pectin yield = ((M2)/M1) *100%

= ((5 gram)/30 gram) *100%

= 16.6 % per one batch.

To scale up for industry level

Assume total working days = 300 days with 24 hour per day

Therefore, mass of pectin produced per year equals,

17 gram/hr. * 300 days/year * 24 hrs./day= 122.4 kg/year

Note: For one batch process or to produce 17 gram of pectin we were used 30 gram of lemon peel. And to produce 122.4 kg of lemon peel pectin we need 223.2 kg of lemon peel.

5.2. Energy balance

5.2.1. Energy balance on stove

150ml of distilled water mixed with 5gm of powder peel we want to heat our water from 25℃ to 60℃energy required at a time of 60min.the specific heat capacity of lemon solution is 1.8KJ/Kg.℃.

E=Cp*m*(T2-T1)

Where,

E=energy

Cp=specific heat capacity of lemon solution

m= mass of sample

T= Temperature

E=1.8KJ/Kg. ℃ *0.005kg (60-25) ℃ E=0.315KJ

So, to calculate how much power did we need to do this work in a given time?

Power= energy/time

P=315J/3600S

P=0.0875J/S=0.0000875KW

1KW=0.75 cent

0.0000875kw=?

P = (0.0000875KW*0.75cent)/1KW

P=0.0000656cent

5.2.2. Energy balance on oven

E=Cp*m*(T2-T1)

E =1.8KJ/Kg.0c *0.129256kg *(55-25)0C

E =6.980KJ

Power= energy/time=6.980kJ/86400s

P=0.0000808kJ/S= (0.0000808KJ/s*0.75cent)/1KJ/s=0.0000606cent.

Chapter six

Economic Evaluation and Site Selection

6.1 Cost estimation

Design cost estimation is the monetary description of the costs associated to the plant that is based on fixed and working capital.

Total investment; required for the plant design is the sum of fixed and working capital.

Fixed Capital; is the total cost required to erect a full functional plant ready to start up. This is the cost paid to install the plant with its equipment and eventually this will end up as the scrap value after the end of the project life span.

Working capital; is the additional fund required for the process continuation once it is started up to the point of income generation.

6.1.1 Estimating purchased equipment cost

The equipment prices are found from online in US dollar with their size and material of construction. For the whole cost estimation calculation, we have used in Ethiopian Birr. The following table shows price of equipment in US dollar and comparative conversion value of Ethiopian Birr (1US$=44 Birr)

Table 8 Major cost of equipment and machineries for pectin extraction

Description	Capacity	Quantity	Unit cost(dollar)	Unit cost(birr)	Total cost(birr)
Fruit peel washing tank	5580kg/hr.	2	5724	1251856	503717
Storage tank	8.38m3	2	1000	44,000	88,000
Mixing tank	2877kg/hr.		4086.42	179802.48	359604.96
Mixer, jacketed & agitated	22m3	1	20510.4	902457.6	902457.6
Dryer drum and Rotary	2650kg/hr.	1	2833.31	124665.64	124665.64
Cooling device	22m3	2	658.9	28952	57904
Centrifugal mill	2943kg/hr.	1	66947.19	2945676.36	2945676.36
Dryer drum and rotary pectin	819kg/hr.	2	2350.26	103400	206800
Filtering plate	1471kg/hr.	2	36739.475	1616536.9	3233073.8
Precipitation Tank (stainless steel)	44m3	1	8225.1	361904.4	361904.4
Laboratory equipment (pH meter & analytical balances)	Balance	2	65.00	2860	5720
	PH meter	2	335.5	14762	29524
Packing	40,000 pcs	1	0.02	800	800
Total cost					8819847.4 birr

Total purchased equipment cost (TPEC) =8819847.4 birr

Delivery cost =10%TPEC=0.1*8819847.4 birr =881984.74 birr

Purchased-delivery equipment cost = PEC + delivery cost

=8819847.4birr +881984.74 birr

=9701832.14 birr

6.1.2 Estimating capital investment

The following table shows typical percentages of fixed capital investment values for direct and indirect segments for pectin plant facilities which are used to calculate total capital investment and Total product cost.

Table 9 Estimating capital investment; Source: (Timmerhaus & peters, 1991, pp. 183-187).

Manufacturing (direct cost)	Percentage (%)	Price(birr)
Purchased and Delivered equipment cost	100	9701832.14
Purchased equipment installation	25	2425458.04
Instrumentation and controls	5	485091.607
Piping installation	3	291054.96
Electrical installation	5	485091.607
Buildings (including services)	30	2910549.64
Yard improvement	10	970183.20
Service facility	20	1940366.43
Land	5	485091.60
Total manufacturing cost (TMC)		19094719.23
Indirect cost		
Engineering and supervision	7	679128.25
Construction Expense	10	970183.24
Contractor's fee (about 5% of directly & Indirect plant cost)	4	388073.28
Contingency (about 10% of direct & indirect plant cost)	3	291054.96
Total non-manufacturing cost (TNMC)		2328439.73

6.1.3 Estimation of fixed capital

FCI=direct cost+ indirect cost

FCI=TMC+TNMC

FCI=**21423158.96 birr**

6.1.4 Estimation of working capital

Working capital is an additional investment needed above the fixed capital to start up and operate the plant to the point in which income is earned. Working capital investment: 10 – 20% of TCI.

Assume 15%, therefore:

TWC=15%TCI

Total capital investment: = FCI + WC

TCI = 0.15 TCI + FCI by rearranging

$$TCI = \frac{FCI}{0.85} = \frac{21423158.96 birr}{0.85}$$

TCI =25203716.43 birr

6.1.5 Estimation of total manufacturing cost (TMC)

Annual operating costs were mainly considered as having two components- variable costs (costs that increase with the increase in production activity) and fixed costs (costs incurred throughout the year regardless of production activity).

TMC = Production cost + fixed charges + Plant overhead expenses

Direct production costs

1 Raw material cost**:** The major raw materials required for production of pectin is lemon peel. All the raw materials are locally available. The raw material requirements and the corresponding cost are shown in below.

Raw material cost= (10 to 50%) of the total product cost, then take average 30% =30%TPC=0.3TPC

Table 10 Estimation of total raw material cost

NO.	Raw material	Daily consumption (ton)	Annual consumption (ton)	Unit price (birr/kg)	Cost per annual (birr)
1	Lemon peel	10	3000	10	3,000,000
2	97%Ethanol	0.2	60	85	5,100,000
3	Hydrochloric acid	0.1	15	116.6	1,749,000
Total					9,849,000

1 Operating labor = (10-20% of total product cost), take average 15%

Operating labor =15% TPC =0.15 *TPC

2 Direct supervisory and electrical labor = (l0-25% of operating labor), then take average 17%. =0.17*0.15TPC=0.0255TPC

3 Utilities = (10-20% of total product cost) take average 15% =0.15*TPC

4 Maintenance and repairs = (2-10% of fixed-capital investment) take average 6%

=0.06*FCI

= 0.06*21423158.96 birr

=12853389.54birr.

6 Operating supplies (OS): (10-20% of maintenance) Assume 15%

= 0.15 * MC

=0.15*12853389.54birr

=1928008.43birr

7 Laboratory charges: (10-20% of OL) Assume 15%

= 0.15 * OL

=0.15*1928008.43birr

=289201.26birr

Total direct production cost (TDC); =A+B+C+D+E+F+G, TDC =9,849,000+0.15 *TPC +0.0255TPC+0.15*TPC+12853389.54+1928008.43+289201.26

=24919599.23 birr+0.3255(TPC)

6.2 Fixed charges

A) Depreciation = (10% of fixed-capital investment)

= 0.1*FCI =0.1*21423158.96 birr

=**2142315.9 birr**

B) Local taxes = (1-4% of fixed-capital investment)

=0.02* FCI =0.02*21423158.96 birr

=428463.18birr

C) Insurance = (0.4-1% of fixed capital investment)

= 0.05*FCI =0.05*21423158.96 birr

=1071157.95 birr

D) Rent and Buildings = Rent (8-12% of fixed capital investment)

= 0.1*FCI =0.1*21423158.96 birr

=2142315.9 birr

Total fixed charge; =A+B+C+D

Therefore, total fixed charges =2142315.9+428463.18+1071157.95+ 2142315.9

TFC =5784282.9 birr

But, fixed charges = (5-15% of TPC) Assume 10%

Therefore, Total production cost $=\frac{TFC}{0.1}=\frac{5784282.9birr}{0.1}$

TPC =57842829.9birr

6.2.1 Plant-overhead costs

Plant-overhead costs = (5-15% of total product cost) = 0.1*TPC

=5784282.9 birr

Then we can calculate total manufacturing cost

Total manufacturing cost = direct production costs + fixed charges + plant overhead costs

=24919599.23 + 0.3255(TPC) + 5784282.9 + 57842829.9

TMC =82454953.7 birr

6.2.2 General expenses

General expenses = administrative costs + distribution and selling costs + research and development costs.

Administrative costs = (2-6% of total product cost) = 0.04*TPC

=3298198.148 birr

Distribution and selling costs = (2-11% of total product cost) = 0.06*TPC

=4947297.2 birr

Research and development costs = (2% of total product cost)

= 0.02*TPC

=1649099.074 birr

Financing (interest) = (0-l0% of total capital investment)

= 0.05* TCI =1260185.8 birr

Total general expenses = 0.04*TPC+0.06*TPC+0.02*TPC+0.05* TCI

=11154780.24 birr

The table shows Estimation of Costs for Operating the Plant and Selling the Products from the above calculations

Table 11 Estimation of Costs for Operating the Plant and Selling the Products

Manufacturing cost	Percentage %	Cost (birr)
Direct		
Raw materials	17*TPC	9,849,000
Plant labor	15*TPC	8,676,424.5
Supervisor and clerical labor	17*TPC	9,833,281.1
Maintenances and repair	6 *FCI	12,853,389.54
Operating Supplies	15*FCI	3,213,473.8
Utilities	15*TPC	8,676,424.5
Laboratory charges	15*TPC	8,676,424.5
Fixed charge		
Deprecation	10*FCI	2,142,315.9
Local Property taxes	2*FCI	428,463.2
Insurance	5*FCI	1,071,158
Rent and Buildings	10* FCI	2,142,315.9
Plant-overhead	10*TPC	5,784,283
Total		73,346,954

6.3 Profitability analysis

The current market price of pectin is obtained from online and the factory assumed to be operating 300 days per year.

Quantity of product manufactured per year= 2,500kg/day*300 days= 750,000kg/yr.

Unit price = = $\frac{57842829.9\text{birr}}{750{,}000kg}$ = 77.10 birr/kg

Selling price = 97.80 ETB/k

6.4 Economic evaluation

6.4.1 Gross profit

The life time of the factory is 10 years' minimum risk 14%.

Total income = Selling price × Quantity of product manufactured

= 97.80Birr/kg*750,000kg/yr.

=73,350000birr/yr.

Gross profit (GP) = Total Income – Total Product Cost

=73,350,000-57842829

15,507,171 birrs

Depreciation (DP) = $\frac{21,423,158.96}{5}$ =4,284,631.8 birr

Tax = 35%

Income tax1-5 = 35% (GP - DP) = 0.35(15,507,171-4,284,631.8)

=3,927,888.72 birr

Income tax$_{5-10}$ = 35% GP =0.35*15,507,171 = 5427509.85birr

Net profit$_{1-5}$ = GP – DP – Income tax$_{1-5}$= 15,507,171-4,284,631.8-5427509.85

=5,795,029.35birr

Net profit$_{5-10}$ = GP – Income tax$_{5-10}$ =15,507,171-5,795,029.35

=9,712,141.65birr

6.4.2 Rate of return (ROR)

A) ROR before tax

$$\text{ROR overall} = \left(\frac{net\ \text{profit}}{TCI*project\ life\ year}\right)*100\%$$

$$=\frac{Total\ GP-Total\ DP}{TCI*project\ life\ year}$$

$$=\frac{10(15,507,171)-5(4,284,631.8)}{25203716.43*10}*100\%$$

$$=\frac{133,648,551}{252,037,164.3}*100\%$$

$$= 53\%$$

$$\text{ROR}_{1-5} = \frac{\text{Annual GP_ Annual DP}}{TCI}*100\%$$

$$= \frac{11,222,539.20}{25203716.43} * 100\%$$

$$= 44.5\%$$

$$ROR_{5\text{-}10} = \frac{\text{Annual GP}}{\text{TCI}} * 100\%$$

$$= \frac{15,507,171}{25203716.43} * 100\%$$

$$= 61\%$$

B) ROR after tax

$$\text{ROR overall} = \frac{\text{Total net profit}}{\text{TCI} * \text{project life year`}} * 100\%$$

ROR=5(net profit1-5) + (net profit5-10)/TCL*project life year*100%

$$= \frac{5(\text{net profit}1-5)+(\text{net profit}5-10)}{10 * TCI}$$

$$= \frac{5(5,795,029.35)+5(9,712,141.65)}{252,037,164.3} * 100\%$$

$$= 30.7\%$$

$$ROR1\text{-}5 = \frac{\text{net profit}1-5}{\text{TCI}} * 100\%$$

$$= \frac{5,795,029.35}{25203716.43} * 100\%$$

$$= 23\%$$

ROR5-10/TCI*100%= *100%

$$= \frac{9,712,141.65}{25203716.43} * 100\%$$

$$= 38.5\%$$

Annual Net profit= 5(net profit1-5) +5(net profit 5-10)/project life year*100%

$$= \frac{5(5,795,029.35) + 5(9,712,141.65)}{10}$$

$$= 7753585.5$$

6.4.3 Payback period

$$PBP = \frac{FCI}{\text{annual net return}}$$

Annual net return= average profit+ average depreciation, therefore

$$PBP = \frac{21423158.96}{\text{average profit+ average depreciation}}$$

$$= \frac{21423158.96}{77634631,8}$$

= 1.8year ≈ 2 years

The payback period is approximately 2 years means the project initial investment will be fully recovered within 2 years.

6.5 Plant layout and site selection

To select proper locations and sites, certain key requirements or criteria should be set, that would allow the assessment of a number of potential locations, and the rejection of those not fulfilling those requirements. The remaining alternatives are subject to a more in-depth qualitative and quantitative analysis of technical and financial criteria, including social, environmental and economic aspects of location and site selection.

The basic criteria for selection of the pectin processing plant location were minimizing the average production cost, including transport and amount of handling time which means that fresh lemon peels are more likely to be in good condition when they arrive at the processing unit within a short period of time. Beside the supply of good water, availability of raw material, availability of manpower, proximity to transport facilities and adequate market were taken into consideration.

The major market for pectin is Wolkite, Addis Ababa, hosanna and other towns. Hence the choice for locating the processing plant near raw materials supply and market proximity would depend on the annual quantity of raw materials, ingredients, packaging materials and final products that are transported between the two sites, other towns. As a result, weliso was selected for locating the processing plant. Locating the plant around weliso town has additional benefit in reducing injury from handling and deterioration from changes during long transportation after processing. We select our plant location in weliso due to the reason given below, our plant will require 10,000 square meter land. So, there is

huge free area that will help our production process significantly and it is convenient of list the more important factors influencing plant location as follow:

Raw Materials: The raw material source is one of the most important factors influencing in the selection of a plant site. This is particularly true if large volumes of raw materials are consumed, so location near to raw materials source permits considerable reduction in transportation and storage charges. Attention should be given to the purchased price of the raw materials, distance between site and source, transportation expenses, reliability of supply, purity of the available raw materials, and Exit strategy when storage happened. Therefore, we select Dada and Three-D juice manufacturer plc. for raw material supplier.

Market: The location of markets or intermediate distribution centers affects the cost of product distribution and the time required for shipping. Proximity to the major markets is an important consideration in the selection of a plant site, because the buyer usually finds it advantageous to purchase from nearby sources. It should be noted that markets are needed for by products as well as for the major final products.

Climate; if the prevailing temperature is high, Excessive humidity or extremes of hot or cold weather can have a serious effect on the economic operation of a plant, and these factors should be examined when picking a plant site. Therefore, in weliso there is almost regular climate which is not hot not cold.

Transportation Facilities: Water, railroads and high ways are the common means of transportation used by industrial concerns. The kind, amount and types of raw materials and product need the most suitable type of transportation facilities. In any case, careful attention should be given to local freight rates and existing railroad lines. There is usually need for convenient air and rail transportation between the plant and the main company headquarters, and effective transportation facilities for the plant workers are necessary

Water Supply: The process industries use large quantities of water used for cooling, washing, steam generation, and use raw materials. Therefore, the pectin plant must be located where a dependable supply of water is available. If the water supply shows seasonal fluctuations, it may be desirable to construct a reservoir or to drill several stands by wells. The temperature, mineral contents, slit or sand content, bacteriological content, and cost for supply and purification treatment must also be considered when choosing a water supply.

Labor Supply: The type and supply of labor available in the vicinity of a proposed plant site must be examined. Consideration should be given to prevailing pay rates restriction on number of hours worked per week, competing industries that can cause dissatisfaction or high turnover rates among the workers racial problem and variations in the skill and intelligence of the workers.

Taxation and Legal Restrictions: State and local tax rates on property, income, unemployment insurance and similar items vary from one location to another. Similarly, local regulations on zoning, building codes, nuisance aspects, and transportation facilities can have a major influence on the final choice of the plant site. In fact, zoning difficulties can often be much more important in terms of cost and time delays than many of the factors discussed in the preceding sections.

Community Factors: The character and facilities of a community can have quite an effect on the location of the plant. If a certain minimum number of facilities for satisfactory living of plant personnel don't exist, it often becomes a burden for the plant to subsidize such facilities. Cultural facilities of the community are important to sound growth. Mosques, Churches, schools, civic theaters, concert associations, and other similar groups, if active and dynamic, do much to make a community progressive. The problem of recreation deserves special consideration. The efficiency, character, and history of both state and local government should be evaluated.

6.6 Plant layout

The economic construction and efficient operation of process until will depend on how well the plant and equipment specified on the process flow sheet is laid out. The equipment that needs to have frequent operator attention should be located convenient to the control room. For example, in our plant layout the water bath is located in front of control room. Equipment that requires dismantling for maintenance, such as large pumps, should place under cover. The figure below shows a plant lay out pectin extraction from lemon peel.



Figure 21 plant lay out of pectin extraction from lemon peel

Chapter seven

Conclusions and Recommendations

7.1 Conclusion

Generally, it can be concluded that pectin can be successfully produced from lemon peels. The effects of the three process variables namely, temperature, extraction time and pH on the pectin yield were found to be significant. Maximum yield obtained at extraction temperature of 60°C, 60 min extraction time and 1 pH results of 16%.

The yield of lemon peel pectin was comparable to those of apple pomace and orange, thus, signifying the potential use of lemon peel as an alternative source for the commercial pectin production. Hence, according to experimental studies lemon peel pectin is more suitable for industrial application. Finally, it can be concluded that the industrial utilization of lemon peel for manufacturing of pectin would not only solve the problem of waste disposal but also save valuable foreign exchange by reducing the pectin imports and by using the general factorial analysis. The physical properties of the product such as moisture content, ash content, solubility, and Color is as same as is in the range of those reported in the literature. The greatest extraction yields in pectin were obtained when highest acid strength and exposure of highest temperature was employed. The results revealed that extraction temperature, time and pH significantly affect the yield of pectin.

7.2 Recommendations

Apple pomace contains 10- 15% of pectin on a dry matter basis. Papaya peel contains 4-6%.but Citrus peels like lemon contains relatively higher than 20-30% of pectin. This project was based on extraction of pectin from lemon peels and had a yield of 17%. When it is compared to that of apples, it has high amount of pectin so it is recommended that other researchers may work on citrus fruits to extract pectin.

The yield of pectin significantly decreases with increase of maturation of fruits so any researcher in the future should consider the maturity vs. yield interaction.

we recommend on our work that since the quantity and quality of pectin obtained from peels are suitable for the commercial production of pectin; further work is needed in this regard. This includes:

- Since rural area of Ethiopian people use lemon tree for only lemon fruit, the people need to be fully aware as the lemon peel had value such as for pectin extraction.
- Modification of the pectin extraction procedures needed to get better yield.

Therefore, we recommended that pectin production process needs these activities to act up on for improving its performance, use the normal temperature, pH precipitation time and to get good quality of pectin.

References

[1]. A. Legentil, I. Guichard, B. Piffaut and J.P. Haluk, Characterization of strawberry pectin extracted by chemical means, Lebensmittel-Wissenschaft und Technologie (Food Sci. Technol.), 28(6) (1995) 569– 576.

[2]. B. n. Sharma, overview on pectin, 2006.

[3] Brownl, Rosner B, Willet ww, sacks FM (1999). Cholesterol-lowering effect of dietry fiber.

[4]. Burt, 2002, Reichling et al., 2009, Mondello et al., 2006).

[5]. C. Bucher, A comparison of solvent systems for extraction of pectin substances from fruits and vegetables, MSc Thesis, Cornell University, Ithaca, New York, 1984, pp. 7–33.

[6]. C. Di Vaio, G. Graziani, A. Gaspari, G. Scaglione, S. Nocerino and A. Ritieni (16 June 2010), Essential oils content and antioxidant properties of peel ethanol extract in 18 lemon cultivars, University of Naples Federico II, Naples, Italy

[7]."Eureka Lemon and Lisbon Lemon: Kitchen Basics". Harvest to Table. Retrieved September 27, 2020.

[8]. "Frost Lisbon". citrusvariety.ucr.edu. Retrieved September 27, 2020.

[9] John S, Monica SJ, Priyadarshini S, Sivaraj C, Arumugam P (2017) Antioxidant and Antimicrobial Efficacy of Lemon (Citrus limonum L.) Peel. Int J Pharm Sci Rev Res 46: 115-118. Link: https://bit.ly/3gdBNmd

[10]. K. (abdel et al., extraction of pectin from lemon, 2013.

[11]. K. kirshnamurti cr, preparation and composition of pectin from indian fruit, augest 25 1948.

[12]. Mandal. L, Martinez-Agasto, J.A; Evans c.j, Havrtensteinv., Banersee, u. (2007). A.

[13]. Nabil Bousbia, Maryline Abert Vain, Mohamed A. Ferhat, Brahim Y. Meklati and Farid Chemat (2009), A new process for extraction of essential oil from Citrus peels, Institutes National Agronomique, El Harrach, Alger, Algeria

[14]. Oikeh EI, Omoregie ES, Oviasogie FE, Oriakhi K (2016) Phytochemical, antimicrobial, and antioxidant activities of different citrus juice concentrates. Food Sci Nutr 4: 103-109. Link: https://bit.ly/2zWvu5Y

[15]. p. p. bagage, pectin development from citrous peels,2006.

[16]. Robards K., Antolovich M. Analytical chemistry of fruit bioflavonoids. A

[17]. Srivastava, P., & Malviya, R. (2011). Sources of pectin, extraction and its applications in pharmaceutical industry: An Overview. Indian journal of natural products and resources Vol.2(1), 10-18.

[18]. s. summer, the ins and outs of pectin retrieved from the world, 2016

[19]. Structural and spectroscopic study of pectin isolated from citrus peel by using FTIR and Colin D…et al 1998.

[20]. The Chemistry of a Lemon

[21]. Umashanker M, Shruti S (2011) Traditional Indian herbal medicine used as antipyretic, antiulcer, anti-diabetic and anticancer: A review. Int J Res Pharm Chem 1: 1152-1159. Link: https://bit.ly/2zawq6J.

[22]. Vaiegated pink at the Citrus Variety Collection

[23]. WGT Willats, JPKnox, DJ mikkelsen-trends in food science and ….2006 Elsevier.

[24]. wong.t.w. Colombo, pectin matrix as oral drug, 2011.

[25]. www.ijirset.com, pectin application, 2017.