Addis Ababa University

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School of Chemical and Bio-Engineering

Characterization and Clarification of Cane Molasses to Produce Bakery Yeast

Process Engineering Stream

Done By

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Characterization and Clarification of Cane Molasses to Produce Bakery Yeast

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by

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DECLARATION

I, the undersigned, declare that this thesis is my own work and all sources of material used for the thesis have been duly acknowledged.

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Abstract

Since the beginning of the twenty centuries molasses have been one of the major leading raw materials for yeast production. However molasses contains substances that inhibit the micro-organisms' growth and can lead to difficulties in yeast production processes. To overcome this problem, this study has been conducted with the objective to characterize the cane molasses and clarification of molasses to produce bakery yeast.

The study has been conducted in such a way that, first the raw molasses has been collected from different sugar mills such as Methara and Wongi sugar factory , then characterization of the raw molasses has been done .From the given results the molasses of the given sugar mills has a ph of 5.72 ±0.02,density of 1431.825 ,Brix of 83 ,moisture content of 19.3 %,ash 12.4 %,Fe 28.75 mg/100 gm, mg 4.17 mg/100gm maximum composition of calcium in the form of CaO and ash ,which was about 488.72 mg/100 gm, 530.02 mg/100gm(or 4.88% and 5.3%) respectively, which is extremely high when compared to world average range of 1.5 % CaO % molasses and excessive amounts of calcium has been analyzed. Therefore the main factor affecting yeast production is the excess calcium content of the molasses. For solving such a problems removal of excess calcium through precipitation by the addition of acid (sulfuric acid) and subsequent centrifugation is the best technology. Because, the reaction of calcium with sulfuric acid results in precipitation of calcium salts, such as $CaSO_4$ this is insoluble in water and separated by sedimentation of the given solution. Separation through sedimentation could be done naturally with the earth gravity; nevertheless, it would take a longer time, Therefore Centrifugation makes that natural process much faster. Experiments has been conducted with varying conditions and finally 75 ^{0} C temperature,42 ^{0} brix ,3.5 pH and optimum rotation speed of 3500 rpm has been determined as the optimum processes conditions, and about 461 mg/100gm has been removed at the given conditions. At the given processes condition 26.88 mg/100gm has been obtained.

Depending on the optimum conditions determined experimentally and the existing condition of the plant, molasses treatment plant process flow sheet has been proposed and the equipments for clarification plant have been designed

Key word ; Molasses, Bakery yeast, Clarification, Characterization ,Calcium

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L IST OF SYMBOLS AND ABBREVATIONS

3-D	Three dimensional
ANOVA	Analysis of variance
Brix	Percentage by weight of the solid in a pure sucro se solution
CCD	Central composite design
C_p	Centipoises
Db	Bundle diameter
E.D.T.A	Ethylene diamine tetra acetic acid
ICUMSA	International commission for uniform methods of sugar analysis
PPM	parts per million
RSM	Response surface methodology
SASTA	South African sugar technologists association
SD	Standard deviation
ES	Ethiopian standard
RFM	Refractometer
DMA	Density meter
AAS	Atomic absorbance spectroscopy
N_t	number of tubes
HAT	hot acid treatment
Cp	specific heat capacity

CHAPTER ONE
INTRODUCTION

1.1. Background

Molasses is final effluent obtained in the preparation of sucrose by repeated evaporation, crystallization and centrifugation of juices from sugar cane and from sugar beets.(Olbrich, 2006) Practically obtainable molasses is the end syrup from which, with maintenance of the technical conditions promoting crystallization, no significant additional amounts of saccharose can be recovered by further concentration (Bekatorou, A., Psarianos.C. and Koutins, A. ,2006). This black strap consist colloidal suspension of inorganic and organic non-sugars along with dissolved impurities.

Molasses can be used in different application areas ,such as animal feed, production of citric acid ,alcohol, pharmaceutics, distilled spirits Preparation of rum , Production of glycerin ,manufacture of yeast ,etc. Those who ferment are concerned with the fermentable sugar content, while the yeast manufacturer pays special attention to the over-all composition. Yeast manufacturing industry is strictest on quality aspects of molasses, including sugar concentration (saccharose), pH, and sulfur dioxide content (Madsen, 1953). Molasses supplies all the sugar that yeast needs for growth and energy along with part of the needed nitrogen. Molasses contains many substances that darken and impart unpleasant flavor to the yeast paste, so the latter may be unsuitable for bread applications. One major disadvantage in using molasses for bakery yeast production is its calcium content and high ash content that contain some trace metals, which inhibits micro-organisms' growth and can lead to difficulties in downstream process. Presence of heavy metal ions mainly potassium ions also have a negative impact on the yeast (Walker et al, 1996; Ryan and Johnson, 2000). To reduce or eliminate the inhibitory action of metal, different types of treatment must be given to the molasses solution. Before feeding to the yeast, molasses must be, clarified, and heat sterilized. Yeast growth has influenced by different factor like sugar, vitamins, biotin and minerals content of the molasses. The composition of molasses shows wide variation. Its composition is influenced by factor such as soil type, ambient temperature, moisture, season of production, variety and technology of sugar mills can control the amount of sucrose extracted. Because of this the sugar content of molasses produced in different countries will vary according to the production technology employed. According to (Curtin ,1983), changes in the design of centrifuges used to separate sugar and syrup constitute one of the major advancements in the cane sugar industry.

Molasses Clarification depends on the composition of molasses that affect the quality of bakery yeast. Soil particles, wax, fat, protein, gum, pectin, tannins, and coloring matters are extracted from the cane during juice extraction and sugar production processes and they remain in colloid form.In general term clarification means the extraction or separation of desired material and discarding the rest in a particular system either by means of chemical treatment or by mechanical operation. At times both may be applied for ultimate degree of separation requirement. Clarification of sugarcane molasses can be classified into two categories such as chemical clarification and mechanical clarification. (Eggleston et al , 2008). According to (Walter , 1953) mechanical clarifying of crude molasses revolutionized molasses clarification in yeast plants. Four chemical processes were generally used such as: Treatment with sulfuric acid, followed by boiling, treatment with alkaline compounds such as lime and others with boiling, under neutral conditions, with boiling and, under highly acidic conditions, without boiling. In general, diluted molasses first acidified with mineral acid and this solution is boiled by steam to sterilize it, cooled and, after the sedimentation of the dark mud, the clear solution is decanted and diluted to the desired concentration and acidity.

1.2. Statement of the Problem

The growth of bakery yeast market is directly linked to the increasing trend of processed and fast food consumption, especially bakery yeast as its demand is continuously increasing with the rise in population and changing demand of bakery products (Bekatorou et al.,2006). In Ethiopia growth in income and population, urbanization and the shift from traditional to fast foods and bread have an increasing impact on the demand for baker's yeast. Currently the demand for bakery yeast increase by the rate of 4.5% (statistical data from Industry minister) in each year. However demand for bakery product is currently fulfilled through import which leads to loss of foreign currency. Ethiopia has three large sugar factories, such as methehara, Fincha, and Wonji/Shoa sugar factories which can produce molasses as by-product. (Ethiopian Statics Authority, 2010) reported average annual molasses production is about 150,278 tons per year, having average composition of sugar is about 48.2 % sugar as inverted sugar , Ph of 5.5 and about 0.145% of sulfur dioxide and can be used as raw material for yeast production . Ethiopian cane molasses also faces a shortage of basic elements for yeast growth such as nitrogen, phosphors, magnesium; among them the most useful one is nitrogen that can be supplied as aqueous ammonia. In addition Ethiopian molasses has high calcium and ash content.

Bakery yeast production process requires a high degree of purity, must be free from any contamination, therefore in the case of fermentation process of bakery yeast, the quality of the molasses is the main concern, since Ethiopian molasses has excess in calcium content and ash content. Molasses contains different chemicals which results in down process, colour change in the final product, even stopping the fermentation process, and resulting in lowering the concentration of Yeast biomass, therefore the molasses it must be clarified and must be free from any microorganisms.

Different alcohol factories face different quality problems in their production process; this might be scaling of different equipments, rate of production and so on. This is due to lack of clarification process of molasses in sugar milling industries, therefore any alcohol company will have extra cost for treatment of the molasses. These sugar mills are mostly providing molasses for those companies that rely up on molasses alcohol producing companies, animal feed producers, energy providing sectors …etc, without adding any value to the raw material they are providing, in addition there are about 7 additional sugar industries that are going to be established in the coming GDP plan and results in increasing the sugar and cane molasses production capacity, this results in surplus of cane molasses as raw material for different sectors and must be considered in production of bakery yeast.

1.3. Objectives

General Objective

The general objective of this study was characterization and clarification of Cane molasses to produce bakery yeast

Specific Objectives

- Characterization of cane molasses from different sugar mills
- measure the concentration of calcium and ash
- Clarification of cane molasses through different methods
- Checking the possibility of Ethiopian molasses for yeast production
- Selection of the best clarification method
- Design and propose a technological system for clarification of molasses

1.4. Scope of the Study

The scope the study was characterization of the physical and chemical properties of the given molasses which were brought from Methara and Wongi sugar mills and determining their inhibitory factors for yeast development and clarifying the given molasses through different techniques up to selecting the best among them, and finally it was engaged in designing the bakery plant in industrial scale.

1.5. Significant of the project

The potential beneficiaries are the sugar milling companies, Bakery yeast related companies, such as Bakers, Bakery yeast importers. Highlighting the possibility of bakery yeast production plant in Ethiopia perspective, by having this in mind it will benefit the sugar milling companies to introduce the possibility of their black strap in bakery yeast production in parallel to alcohol, animal feed, fuel production process. Will introduce the possibility of using different technologies for clarification purpose of molasses, in resulting the sugar companies to produce high quality molasses for the sake of bakery yeast in order to use their molasses as a feed to bakery yeast production plant, possibility of clarifying there molasses and save foreign currency that is going to be lost through importing baker's, and bakery related items. Highlight the sugar companies to produce a high grade molasses with maximum purity and selling it as a feed to bakery yeast producers, income generation for the company.

CHAPTER TWO
LITTRATURE REVIEW

2.1 Molasses

Initially the term molasses referred specifically to the final effluent obtained in the preparation of sucrose by repeated evaporation, crystallization and centrifugation of juices from sugar cane and from sugar beets. Today, several types of molasses are recognized and in general, any liquid feed ingredient that contains in excess of 43% sugars is termed molasses.(Mott Mac Donald, 2010) Cane molasses are acid and have a more acidulous or fruity-aromatic odor; only rarely do they show an alkaline reaction (pH > 7)(Hubert OLBRICH, 2006)

2.2 Constituents of molasses

Composition of molasses varies from country to country and from factory to factory within the same country and from season to season with in the factory. The highly viscous molasses is not a homogeneous liquid or true solution of sugar in a non sugar solution; molasses always contains suspended components of varying composition and in varying amounts. (Bemhardt, HW ,1996)

These materials include;

(a) Constituents in the raw material (cane) which have gone through the stages of the sugar factory unchanged and which cannot be removed economically; for example, the so called harmful non sugar components or colloidal finely suspended non sugars.

(b) Constituents that originate during the manufacturing operations or are changed in such a manner that they finally reach the molasses; for instance, the degradation products of the sugars and proteins in insoluble form.

(c) Non sugars which become insoluble during the concentration and crystallization process as a result of their low solubility's in highly concentrated solutions.

The components of molasses include: Major components: water, sugar, non-sugars and Minor components: trace elements, vitamins and growth substances. Its composition is influenced by factors such as s oil type, ambient temperature, moisture, season of production, variety, production practice s at a particular processing plant, and by storage variables. Consequently, considerable variation may be found in nutrient content, flavor, color, viscosity and total sugar content.

a)Major Components

Water

The water in molasses is mostly unbound but a part is held as hydration water or hydrate water. Commercial molasses have an average water content of 20%. The original end-products in the factory contain 12-17% water.

Sugar components

The sugar in beet molasses consists predominantly of saccharose, but some invert sugar and Raffinose are present. It should be pointed out that from the standpoint of the sugar manufacturer the term 'sugar' devotes saccharose exclusively and consequently all substances, with the exception of saccharose, are included in the 'non sugar components' (brix minus saccharose; in this case, however, not brix minus pol). Raffinose and invert sugar fall in the category of non-sugar components.. The term "non-sugar components" is limited in another manner in grading cane molasses. Invert sugar is included with sucrose as total sugars. This includes certain non-fermentable reducing substances, which are however reported in the determination of the total sugar by copper reduction methods. One of the reasons for the presence of these substances is the conversion of a slight portion of the 'sugars' on boiling. These materials have a reducing action; they show no tendency to crystallize and therefore enter the molasses.

Non sugar components

Non sugar components include all constituents of cane molasses except saccharose. For practical reasons Raffinose and invert sugar were treated above with saccharose. A knowledge of the sugar contents and quotients is not sufficient to characterize a molasses sample and thus to define normal molasses. Special significance has to be attached to the non-sugar constituents, not only as to their total amounts, but especially as to the components. Disregarding the water content, the non-sugar constituents of molasses can be classified as organic and inorganic non sugars. The non sugars in molasses do not exert enough influence on the fermentation to warrant special attention. Only a portion of the amino acids in molasses is consumed in the yeast metabolism to form fusel oil; the quantity of fusel oil is proportional to the quantity of dry yeast substance formed. The yield of fusel oil can be reduced by adding ammonium salts, as the yeast is able to cover its nitrogen requirement more easily from ammonium salts than from the deamination of the amino acids.

b) Minor components

Protein

In addition to saccharose, there are also nitrogenous materials in molasses, in fact the assimilatable nitrogen amounts to 0.3-0.8%. Since a good quality of yeast in high yields cannot be grown without organic nitrogen, it is imperative, in case no molasses nitrogen is available; to rely on equivalent nitrogen such as is present in malt sprouts. From the standpoint of composition, the soluble malt sprout nitrogen, like that derived from molasses, consists predominantly of amino acids and to a slight extent of acid amides. None of the molasses types contain significant levels of crude protein also; the nitrogenous materials which are present consist mainly of non-protein nitrogen compounds which include amides, albuminoids, amino acids and other simple nitrogenous compounds.

Minerals

However, in comparison to the commonly used sources of dietary energy, mainly cereal grains, the calcium content of cane and citrus molasses is high, where as the phosphorus content is low. Cane and beet molasses are comparatively high in potassium, magnesium, sodium, chlorine and sulfur. Additional comparisons between types of molasses show that in general, cane molasses is higher than beet molasses in calcium, phosphorus and chlorine, where as beet molasses is higher in potassium and sodium.

Trace Minerals

Cane and citrus molasses contain higher amounts of copper, iron and manganese than beet molasses. Within a molasses type, the trace mineral variability can be quite high. Curtin (1973) reported that cane molasses contained an average of 297 mg/kg iron with a range of 145-640 mg/kg and that beet molasses contained an average of 65 mg/kg zinc with a range o f 4 to 264 mg/kg. Similar ranges also were presented for copper and manganese**.**

Table 2.2 Trace Minerals in Molasses

Mineral (mg/kg)	**Cane**
Copper	**36**
Iron	**249**
Manganese	**35**
Zinc	**13**

Source (Curtin , 1973)

Vitamins

Cane molasses contained approximately 6,000 mg/kg inositol, 800 mg/kg niacin and 5 mg/kg pyridoxine. In comparison to commonly used grains, the biotin content is quite high in both cane and beet molasses. However, data presented by Curtin (1973) and Olbrich (2006) indicated that the vitamin content of molasses was subject to wide variations. These variations coupled with their relatively low content in molasses tend to diminish their nutritional significance.

Hubert Olbrich has been reported as the world average of molasses composition as follows in (Table 2.2).

Table2.2 Average composition of cane molasses

constituent	Cane molasses (%)
water	**20**
Organic constituent	72
➢ **sugars**	**62**
• saccharose	32
• Glucose	14
• Fructose	16
• Invert sugar	---
• raffinose	---
➢ **Non sugar**	**10**
• Nitrogenouse material, free and bound acids, soluble gummy substances	10
➢ **Inorganic constituents(ash)**	**8**
• SiO_2	0.5
• K_2O	3.5
• CaO	1.5
• MgO	0.1
• P_2O_5	0.2
• Na_2O	---
• Fe_2O_3	0.2
• Al_2O_3	---
• Soda and carbonate residue(as CO_2)	---
• Sulfate residue(as SO_3)	1.6
• Chloride	0.4

Source (Hubert OLBRICH, 2006)

Cane molasses in general have a lower content of non sugar substances and ash. On the other hand, their total sugar content is higher; this often is above 50% in commercial cane molasses. A remarkably high proportion of the reducing substances are not fermentable and of no value for yeast production; this may amount to as much as 10% of the total sugar content of cane molasses. The amount and composition of the ash of cane molasses are affected by the cane variety, the conditions under which it was grown (climate, soil) and by the methods employed in the sugar factory. In general, cane molasses produces less ash than beet molasses .Cane molasses have a higher content of SiO_2, CaO and P_2O_5than beet molasses. Salts are known to affect the solubility of the sugar. In fact, the uncrystallizability of the sugar in final molasses is due to the solubility-enhancing effect of the salts.

2.3 Physical properties of Cane Molasses

Table 2.3 Physical and Chemical Properties

PHYSICAL AND CHEMICAL PROPERTIES	
CHEMICAL FORMULA FOR MOLASSES	$C_6H_{12}NNaO_3S$
FORMULA WEIGHT	201.22
APPEARANCE	Black/brown, clear viscous liquid
ODOR	Fruity sweet
SPECIFIC HEAT CAPACITY	2162.48 J/kgk
DENSITY	1400
SOLUBILITY IN WATER	Highly soluble
SPECIFIC GRAVITY (H0 = 1)	1.4
VISCOSITY	5000 – 10,000 cp
PH	5.1
COLOR	Black/brown, clear viscous liquid
STORAGE LIFE AT 70° F	> 1 Year

2.4 Utilization of Molasses for different Applications

Cane final molasses has been used as raw material for the production of alcohol, and bio chemicals, for example, monosodium glutamate by fermentation, for the production of yeast, and in livestock and poultry feeds. The relationships involved in the qualitative and quantitative variations of molasses characteristics are of direct interest to consumers in different degrees. The manufacturer of stock feeds has a subordinate interest in the detailed composition of molasses. On the other hand, those who ferment are concerned with the fermentable sugar content, while the yeast manufacturer pays special attention to the over-all composition, namely the content of nitrogenous compounds as well as the total amount of sugars present.

2.5 Fermentation of Molasses

A) Production of alcohol from molasses

Alcoholic fermentation normally splits sugar into approximately equal parts of carbon dioxide and alcohol, with slight amounts of succinic acid and glycerin, when the fermentation proceeds in weakly acid to neutral surroundings. When molasses is to be fermented to alcohol, the sugar content should be high. Raffinose, which amounts to 0.5 to 2% in beet molasses, is broken down into fructose and melibiose by yeasts which contain the enzyme saccharase. Melibiose in turn is broken down by some yeast (e.g. bottom yeasts) into glucose and glucose.

B) Production of glycerin from molasses

In normal alcoholic fermentation, about 3% of the weight of the sugar is converted into glycerin, which thus represents theoretically a by-product. In weak alkaline solution the fermentation can be guided in such a manner that glycerin and acetaldehyde are the predominant products, together with alcohol and carbon dioxide.

C) Preparation of rum from beet molasses

The biochemical utilization of molasses sugar has witnessed in Germany in the preparation of rum from beet molasses the combination of acidulation processes with alcoholic fermentation. Manufacture of rum is typically and traditionally indigenous to the cane sugar regions. Cane molasses and the products resulting from the manufacture of cane sugar are mainly employed for the rum mashes. The word ‘rum’ comes from the Sanskrit ‘roma’, i.e. water. Rum is produced mainly from cane molasses and from the residues and waste products of cane sugar manufacture. The rum mash intended for the fermentation is prepared from three components, whose quantities may vary. ‘skimmings’, i.e.the sugar-containing foam obtained by skimming off the foam which forms when the cane juice is boiled, and to which are added sugared water and crushed sugar cane; original cane molasses which has been subjected to a souring process for several days and then diluted with water to 17-22° Bg , ‘dunder’ important for producing the characteristic rum esters.

2.6 Manufacture of Yeast from Molasses

Molasses is used as a raw material for baker's yeast production process, for it is presently the cheapest source of sugar, it acts as a nutrient for the yeast in the fermenter and remains the most used substrate in the fermentation industry. It is left over as a by-product during sugar refining, once no more sugar can be crystallized from the raw mixture. As well as residual sugar, molasses also contains vitamins and minerals that boost the growth of the fermenting micro-organisms, on the other hand it also contains substances that inhibit the micro-organisms growth and can lead to difficulties in the downstream process, and among these are sand calcium and proteins derived from the sugar crop itself or from the sugar production process. One major disadvantage in using molasses for yeast production is its high ash content that contain some trace metals, which inhibits yeast production. To reduce or eliminate the inhibitory action of metal, appropriate pretreatment is given to the molasses solution.

The introduction of molasses as the principal raw material for the production of yeast resulted in a fundamental change in this industry. Yeast production till that time had been based on the use of grains. The use of molasses introduced a fundamentally altered manufacturing process; it initiated a development that led to a certain standardization of the manufacturing processes. Molasses and cheaper inorganic nutrients, aeration, the feeding system, yeast culture, and the separator station as well as the yeast filtration constitute distinguishing features of the modern methods of producing yeast. Certain steps within the usual sugar manufacturing process resulting in an improvement in the molasses quality can be looked on as a realizable objective. A substantial contribution is made by careful attention to all filtrations of the sugar products will be as free as possible from suspended materials and by relieving the yeast manufacturer of a part of the clarification problems. Similarly, prompt cooling of the freshly centrifuged cane molasses before storage is of direct interest to the processing industry, because of the reaction, which results in the conversion of fructose to non-fermentable reducing materials which are of little or no value to the yeast organism. Of all industries processing molasses the manufacture of yeast makes the highest demands on the quality of commercial molasses. The rating of molasses is based on analytical data. The primary factor for the value of molasses and its grading for the industry is the sugar content. No matter how low the price for which a molasses may be bought, it is always expensive if no commercial yeast can be made from it by the usual procedure.

The disinclination of yeast manufacturers to use cane molasses and their preference for beet molasses are due to the fact that the characteristics and components of the two kinds of molasses which are important to the growth of yeasts are precisely those which prove themselves unfavorable in the case of cane molasses. However, the divergent utilization of the two varieties of molasses involves still other considerations. The possibilities of using cane molasses in the countries in which it is produced are limited. In addition, the utilization of cane molasses has certain features which are peculiar to this kind of molasses.

2.7 Factors affecting the quality of molasses for yeast production

The quality of the yeast may never be affected unfavorably by the molasses used in its manufacture. Any molasses which requires a special pretreatment beyond the ordinary routine contains different deleterious factors. The deleterious factors in molasses include: High calcium content and ash content, excessive content of sulfurous acid & nitrates, Volatile acids, abnormally dark color, colloidal and suspended matter

2.8 Removal of harmful constituents by clarification of the molasses

Crude molasses may contain components which are harmful to or interfere with the manufacturing process or the preparation of yeast. The processing of molasses, which contain downgrading factors, is connected with losses and increasing costs. The lowering of the quality extends from increase in color to loss of storing ability, and smeary consistency of the yeast. As a rule, a more or less extensive pretreatment of the molasses is a necessity; the objectives being:

A) **clarification** : removal of suspended matter, colloids, coloring materials, volatile acids, nitrites and sulfites

B) **disinfection:** reducing or elimination of the fungus flora

Since these two goals can usually be attained in a single procedure, and since the clarification effect is most obvious, this pretreatment of the molasses is referred to as the clarification process. The choice of the pretreatment depends on the kind and condition of the molasses involved and on the working conditions and special circumstances in the factory.

About 53 patents issued between 1900 and 2009 on processes and equipment for treating molasses. Most of these inventions were developed between 1920 and 1934 and were based on the chemical purification with acids, coagulants, or centrifugation. According to Walter (1953), mechanical clarifying of crude molasses revolutionized molasses clarification in yeast plants, as first described in a patent filed in 1931 by Ramesohl & Schmidt Aktiengesellschaft (later renamed Westfalia Separator AG) in Oelde, Germany.

In the early days of the use of molasses by the yeast industry, inventors first proposed chemical treatments to clarify molasses. However, these processes were long, complicated, expensive, and involved high levels of energy (steam and cooling water) and large vessels to allow proper sedimentation.

Four chemical processes were generally used: (1) with sulfuric acid, with boiling (the most popular), (2) with alkaline compounds such as lime and others, with boiling, (3) under neutral conditions, with boiling, and (4) under highly acidic conditions, without boiling. In general, diluted molasses was first acidified with mineral acid or by the action of lactic acid bacteria with a small amount of malt; this solution was then boiled by steam to sterilize it, cooled and, after the sedimentation of the dark mud, the clear solution was diluted to the desired concentration and acidity. For example, filtration of diluted molasses over sand was proposed to expedite its clarification. A number of clarification methods can be employed singly or in combination for the coagulation, flocculation and removal of the undesirable substances from molasses. The methods most commonly used are, Hot-acid procedure; Centrifugation (centrifugal clarification)

A) Hot-Acid Treatment

This stage is used for the reduction of the level of impurities in the molasses. Molasses treatment results in decreased level of inhibitory substances like Ca, Cu, and Fe in the molasses solution which improves ethanol production and yeast production processes through reducing calcium compounds which highly affect the efficiency of the plant by scale forming on the heating surface and affecting a yeast production processe.

The first process step in molasses treatment is dilution of the molasses from 80 - 86 ^{0}brix to 50 – 60^{0}brix to reduce its viscosity and therefore to facilitate heating. Then, the next step is heating the diluted molasses to temperature of 60 to 65 ^{0}C which facilitates the reaction between calcium oxides and H_2SO_4.After preheating, its pH adjusted by addition of sulfuric acid (H_2SO_4)until pH becomes 4 to 5.finally ,the molasses heated to 95 to 100^{0}C in continuous operation. Under the effect of both temperature and acidification, calcium sulfate ($CaSO_4$) precipitation, flocculation of long chain colloidal, and insolublization of gums and waxes reactions takes place within the molasses.

$$CaO + H_2SO_4 \longrightarrow (CaSO_4) + H_2O$$

To reduce its high viscosity, the raw molasses is first diluted with water in a mixture and then preheated via a heat exchanger. The molasses must then be acidified with sulphuric acid. As a result of acidification, the calcium is precipitated as calcium sulphate and can therefore be easily separated during the subsequent separation process. (Teshale Firdessa,2012)

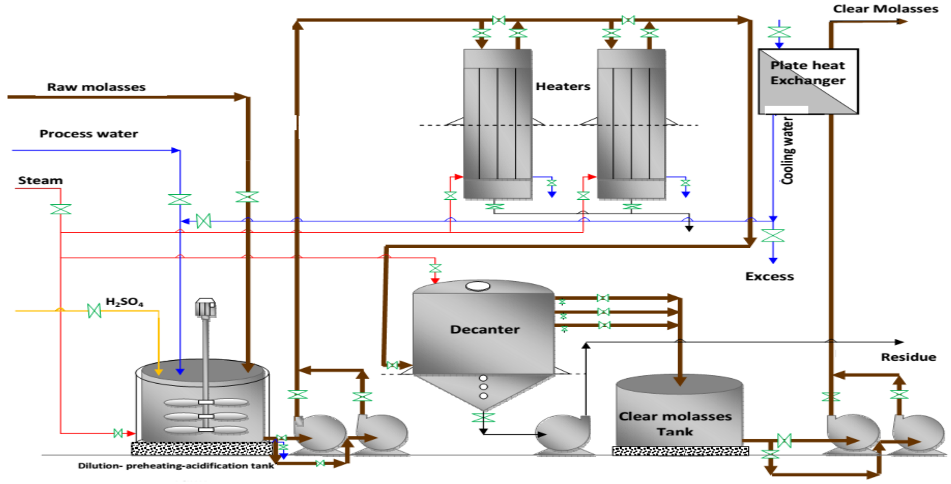

Figure 2.2: Process flow sheet for molasses clarification

Although the acid content of molasses is rather high in the hot-acid clarification, only a small percentage of the sugar is inverted by this pretreatment. The amount ranges between 5 and 10%, because the free acids are organic acids of the molasses, liberated by the added sulfuric acid. The remaining 90-95% of the molasses saccharose is inverted when the starter yeast is introduced.

Cane molasses contains a number of negatively charged colloids, which can be flocculated by various acids. The coagulation optimum for hydrochloric acid is at pH 3.2. The concentration of a solution most favorable for coagulation is 30-40 brix , at higher concentrations of molasses there is a decrease in the coagulation rate. The coagulation and sedimentation proceed three to four times faster in solutions that have not been filtered, i.e. the rate and extent of the formation of the flocks are promoted by the suspended non sugars. Heat increases the flocculation. Complete coagulation was obtained in a 20% molasses solution at pH 3.2, kept at 80° for 2 minutes, and then 5 minutes at pH 5.7. The negatively charged molasses colloids include the caramel substances and the melanoidines, which are both closely related to the humus substances and which coagulate only in the acid region, namely below pH 6.9 . The brown residues obtained by drying the precipitates are more strongly colored as the pH decreases; the flocks obtained in ;the pH range from 6.9 to 8.0 have a dirty grey color

B. Centrifugal clarification

In this case the fluid is introduced into some form of rotating bowl and is rapidly accelerated. Because the frictional drag within the fluid ensures that there is very little rotational slip or relative motion between fluid layers within the bowl, all the fluid tends to rotate at a constant angular velocity ω and a forced vortex is established. Centrifugation as a means of removing solid ash constituents from molasses has been in used for many years. It is a process of separating components of the molasses in accordance with density difference. The final molasses is diluted with water until the specified brix becomes between the range of 15-20 brix, then the given diluted molasses solution is brought to a heat exchanger and heated up to the temperature of 100 ^{0}c and, in order to facilitate reduction of viscosity then heating followed by centrifugation of the given molasses solution, after centrifugation the supernatant will be sterilized for the sake of removal of micro organisms, the held up to a molasses storage tank. Because of the variability of the composition of cane molasses a single method of pretreatment will not give optimal Ca removal for every type of molasses. Centrifugal clarification is characterized by its simplicity; it saves space, steam and time and can be carried out with very slight losses. These advantages outweigh its objectionable feature, namely, that this process is not quite as safe as the hot-acid clarification method, since after precipitations may occur during the yeasting.

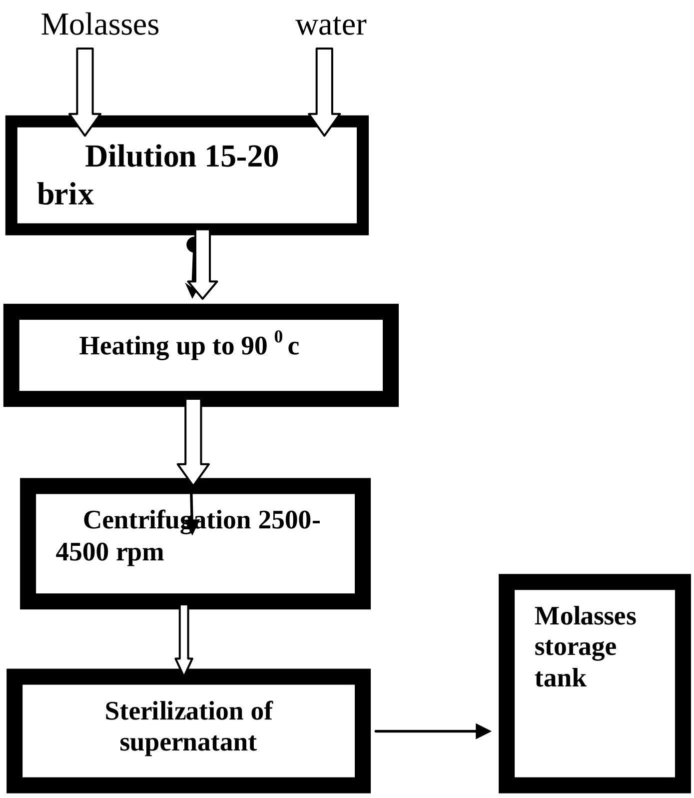

Figure 2.3: Process flow diagram for centrifugal clarification

C. Acid Centrifugation

The compositions of the various organic and inorganic species in cane molasses show wide variations. Centrifugation can be used to remove suspended solid particles. The bulk of these are precipitated calcium compounds. Removal of calcium by precipitation and subsequent centrifugation can be enhanced by the addition of sulphuric acid and heating . If these factors are applied to the method of diluting the molasses with water, adding sulphuric acid and heating, while stirring for a certain length of time prior to centrifugation, then it will be desirable to dilute as little as possible, to use the minimum amount of acid, to agitate no more than is necessary for adequate precipitate formation, and to conduct the process at the lowest temperature that will give adequate precipitation and solid separation in the centrifuge. (Davis et al. 1997)

To reduce its high viscosity, the raw molasses is first diluted with water in a mixer and then preheated via heat exchanger, the molasses must then be acidified with sulphuric acid ,as a result of acidification, the calcium is precipitated as calcium sulfate and can therefore be easily separated during the subsequent separation process. Coarse erosive particles, such as sand, are separated by means of rotary brush strainer /or a hydro cyclone, in order to protect the downstream centrifuges against wear. The actual clarification of molasses takes place in the separator centrifuges. Separator centrifugal clarifiers are manufactured from high quality stainless steels, in order to withstand the high temperatures and the product's acid content. The tried- and – tested stainless duplex steel is used ,with its characteristic high strength and excellent corrosion resistance .The clarified molasses is then sterilized and the volatile acid removed in an expansion tank .en route to the storage tank, the sterilized molasses passes through a heat exchanger ,where the high temperature heats the raw molasses.

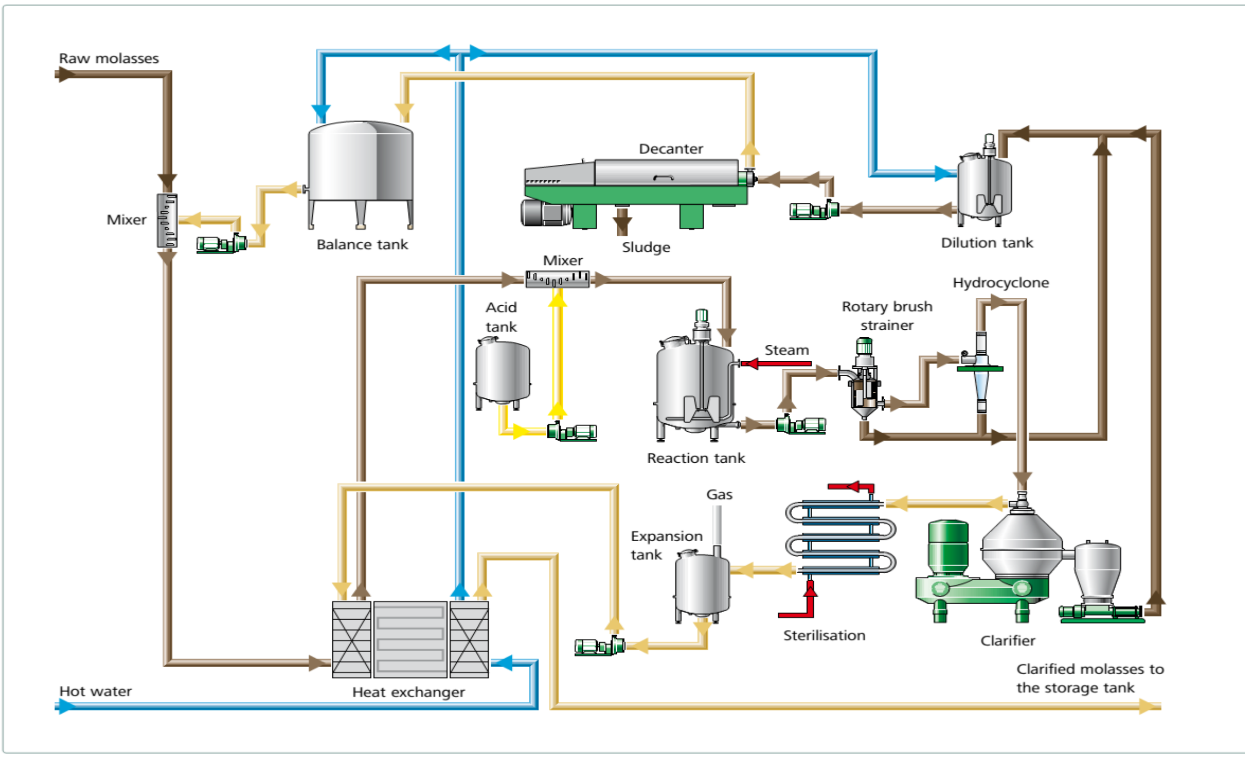

Figure 2.3: Process flow sheet for hot acid centrifugation

CHAPTER THREE

MATERIALS AND METHOD

3.1. Materials

3.1.1Sugar cane molasses

Cane molasses was collected from different sugar factories such as Wonji-Showa Sugar mill , Methara Sugar mill using 30 liter aluminum jars. The given aluminum jars were cleaned by soaking in dilute HCl solution (about 1%) for 24 hours , washed with tap water and finally thoroughly washed with distilled water and heat sterilized before sample collection . Therefore we can conclude that sample Collection mechanism has been clean and free from microorganisms, contamination, and some infections, because these defects lead the molasses to some reactions which convert its fructose in to a non-fermentable sugar . The sample were collected from the out let of the molasses storage tank, agitated thoroughly, freshly centrifuged cane molasses has been cooled as much as possible before being placed in storage and labeled. The samples were kept in the refrigerator until the experiment conducted.

3.1.2. Chemicals and Apparatus

i. Sample

The sample used in this characterization is cane molasses which is collected from Metahara and Wonji sugar factory.

ii. Apparatus

The equipments used to conduct this study were, Refractometer (RFM960) , muffle furnace , fume cupboard , Bunsen burner, E balance, PH meter (HANNA), Density meter (DMA4100M) Desiccators, hot plate ,what-man filter paper (No6), 250ml volumetric flask ,Funnel, beaker of 50ml, 150ml,250ml,500ml , KJLDHL apparatus, spectrophotometer, Glass rod, crucibles, oven, desiccators, 25ml burette, conical flask of 250 ml , measuring cylinders of 5ml, 50ml, 100ml, 2000ml , digital weighing balance (precision, ±0.0001 gm) , magnetic stirrer and stirrer.

Iii. Reagent

Different analytical grade chemical and reagents has been used for raw materials and product analysis such as, Distilled water, Sulphuric acid(98 %), Fehling`s solution, HCl, Phenolphthalein solution, methylene blue solution , boric acid – indicator solution , NaOH , EDTA solution , H_4Cl , Orthophosphoric acid ,Hydrogen peroxide, boric acid, pH buffer solutions 4.00 and 7.00.

3.2. Methods

3.2.1. Molasses characterization

A. Determination of Raw Molasses pH

pH was determined using an electronic pH meter, first pH meter was calibrated using pH 4.0 and 7.0 buffers prior to determination of the pH of the samples and these leading the pH meter reading to proper pH range. About 10 gm of molasses samples were weighed in triplicates in 250 ml beaker and mixed with 50 ml of distilled water and stirred for 10 min, then pH of the given molasses sample was determined by dipping the electrode of the pH meter (HANNA) in the mixture, pH reading was displayed on the screen, the given reading for the two samples. The pH of the molasses samples was determined according to the method of AOAC (1984)

B. Determination of Raw Molasses Density

Was determined using a standard density meter **(DMA4100M)** the density mater. The first step was taking the sample using a siring and inserted through the u tube like glass, which was displayed on the screen. When the reading became stable the gray color of the number brought in to black. molasses samples of Methara and Wongi were prepared ,and the first calibration was done using wongi molasses, the molasses sample was inserted in to the density meter using a syringe, density reading was displayed on the screen, after reading the density, the density meter was rinsed using a distilled water for several times .

Fig 3.1.Density meter (DMA4100M)

C. Determination of total solids

The reading was taken using both instruments refracto meter (RFM960). 10g of cane molasses was Weighted and diluted with 50 gm of distilled water to bring a total of 60 gm, and filtered through a fluted what man filter paper, Reject the first 20 ml of filtrate collect sufficient filtrate (about 100 ms) in a 150 ml beaker for determination of refract metric index at 20^0C in order to bring the temperature of the molasses solution to 20^0C water bath thermostatically controlled was used, finally read the refractive index of the solution at 20^0C and convert the instrument reading to Brix at 20^0C from table that belongs Ethiopian standard . Brix reading was done in accordance with Ethiopian standard (ES, 2004).

Figure 3.2.Refracto meter (RFM960)

D. Water content (moisture content)

Four crucibles have been cleaned and dried it in an oven at 105 ^{0}C for 1 hour and placed it in desiccators to cool, the weight of the crucible after cooling (W_1) were determined, weigh 5gm of molasses samples in the dry crucibles (W_2) and dry at 105 ^{0}C for 3hrs, after cooling in desiccators to room temperature it is again weigh (W_3).repeat until a constant weight obtained. (Ethiopian standard, 2004)

$$\text{Moisture content in percent (\%)} = \frac{W2-W3}{W2-W1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (3.1)$$

E. Determination of Sulphated Ash

Four crucibles were selected for ash determination purpose. The selected crucibles were cleaned by soaking in dilute HCl solution (about 1%) for 24 hours, washed with tap water and finally thoroughly washed with distilled water. Crucibles were dried in oven at 105°C for 30 minutes and cooled to room temperature over silica in desiccators. Crucibles were numbered using sharpened lead pencil. Numbering was literal, from 1 to 4, for 2 sample molasses duplicates. Numbers were written at the side and the bottom of the crucible. Crucibles were placed in muffle furnace with numbering order. This will help identify any numbering that may disappear during ignition process. The empty crucibles were ignited in the furnace at 550°C for 90 minutes and cooled to room temperature in desiccators over granular silica gel. Crucibles were weighed using appropriate 6 digits analytical balance capable of measuring 0.1mg and value was recorded as W1.Approximately 2.50 gram of sample was weighed into tarred crucible and the combined weight of crucible and sample was weighed and recorded as W2.Samples in crucibles were charred by placing on hot plate in fume hood. The temperature of hot plate was set at about 100°C initially, but was increased up to 200°C when charring progressed. After fumes have been completely removed by charring on hot plate, crucibles were carefully placed orderly in muffle furnace. Temperature of the muffle furnace was set to 550°C. The ignition time was 5 hours counted from the time when the set temperature was achieved (roughly after 50 minutes of starting the ignition).After 5 hours of ignition, the muffle furnace was switched off and allowed to cool. After cooling to below 200°C, crucibles were removed carefully, using tongs, and placed in desiccators in the numbering order. Cooling to room temperature was achieved after about 1 hour. The crucibles with resulting ash were weighed as W3. Samples were further wetted with few drops of de ionized water and 3 drops of concentrated nitric acid. After drying on hot plate, second phase of ignition was carried out in muffle furnace for 90 minutes at 550°C. This step was necessary to completely ash remaining organic matter within the crucibles. After cooling to below 200°C, crucibles were removed and cooled to room temperature over granular silica gel in desiccators. The cooling time takes up to one hour. The final weight of crucible and ash were weighed and recorded as W3 (complete ashing). (Ethiopian standard, 2004)

The percent of ash was calculated using the following formula:

$$Ash\ (\%) = \frac{W3 - W1}{W2 - W1} \times 100 \quad \text{……………. ………………. (3.2)}$$

Where; W1 = Weight of clean dry crucible

W2 = Weight of crucible and sample (W1 + sample weight),

W3 = Weight of ash and crucible after ashing (W1 + ash)

F. Mineral Analysis

The ash was dissolved by 5ml of 6M HCL at low temperature on hot plate for about 2hrs,then 7ml of 3M HCL was added and heated on hot plate until the solution boils, the digest was cooled and filtered through a filter paper (what man)in to a 50 ml volumetric flask, then 5ml of 3M HCL was added to the dish and heated to dissolve the residues in the dishes and then transferred to the volumetric flask, then the filter paper was washed thoroughly and the washing was collected in the flask made to the mark, after wards the mineral concentration was determined by AAS. For calcium determination 2.5 ml of 10% lanthanum chloride solution was added to the flask, and then diluted to 50 ml mark with de ionized water, the blank was prepared by taking the same amount of reagents through the steps all of the above without the sample. The instrument was set based on the instruction and the reagent blank solutions were measured first, then the samples were run following the calibration values. The calibration curve was prepared for the required metal by plotting the absorption values against the metal concentration in ppm. The mineral content of each sample were calculated using the following formula. Using method described by (Addis Ababa University food laboratory manual, 2009))

$$\textbf{Metal content (mg/100gm)} = \frac{(a-b)\times V}{10\times W} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(3.3)}$$

Where W= $weight\ of\ the\ sample\ in\ gm$ $\quad V = volume\ in\ ml$

a=concentration of sample solution in ppm

b=concentration of blank solution in ppm

G. Determination of Nitrogen and Protein

Weighing out molasses sample transferred into a tecator tube, 5 ml of NH4cl solution has been added in to each tecator tubes and 6 ml of the acid mixture (5 parts of conc. Orthophosphoric acid with 100 parts of conc. Sulphuric acid). Molasses sample and acid mixed thoroughly, 3.5 ml of hydrogen peroxide was added step-by-step and there was a violent reaction, 3gm of the catalyst mixture has been added for 30 min before digestion. Digestion has been done for more than 3 hour at 370^0C. Distillation has been placed on a 250 ml conical flask contain 25 ml of the boric acid – indicator solution under the condenser of the distiller with its tip immersed into the solution. Transfer the digested and diluted solution into the sample compartment and added 25 ml of the 40 % sodium hydroxide solution into the compartment, it has been rinsed down with a small amount of water, and switch on the steam. It has been distilled until 100 ml then continued until a total volume of a few ml of water before the receiver was removed. Then it was titrated with 0.1N sulphuric acid to a reddish color using the radio meter PH stat. (Using KJELDAHL method described by ES (2004)).

Total percent of nitrogen in a sample= $\frac{(\boldsymbol{T}-\boldsymbol{B})*\boldsymbol{N}*\mathbf{14}*100\%}{\boldsymbol{W}}$ …………………….. **(3.4)**

T: Volume in ml of the standard sulphuric acid solution used in the titration for the test

B: Volume in ml of the standard sulphuric acid solution used in the titration for the blank determination.

N: Normality of standard sulphuric acid

W: Weigh in grams of the test material

H. Determination of total reducing sugars

This method relies upon reducing sugar to reduce Fehling`s solution under standard conditions. 50 g/l hydrolyzed cane molasses solution was prepared and 25ml of the cane molasses solutiotransferred in to a 250ml volumetric flask. 6.34 N HCl acids of 5 ml from a 25ml burette was added and mixed gently. Then the flask was immersed in the water bath and swirled gently for 3 minutes in order to raise the temperature of the sample, then allowed to stay for further 12 minutes, after heating the flask was cooled and diluted further till 125 ml with water. A few drops of phenolphthalein solution was added, then 2N NaOH was added to impart a red dish color to the solution. The solution was agitated gently, then red colour was discharged by adding a few drops of 0.5N HCl, and 4.0 ml of EDTA solution mixed well and make up to the volume with water at 20 ^{0}C . 20 ml of the hydrolyzed cane molasses solution with 2 – 4 drops paraffin was added in boiling flask then 20 ml Fehling’s s solution was pipette. The flask was placed on hot pate to reach its boiling point and 4 drops of methylene blue solution was added. Titration was preceded by initially adding increments of 2ml molasses solution and progressively reducing the additions down to 0.2ml and attempting to obtain the end point in about 2 minutes from the time the solution commencing boiling. The end point was denoted by the disappearance of the blue color, and reddish colour was appeared describing the reduction of cupper. Calculate total reducing sugars concentration according to (Ethiopian standard, 2004 and John, 1954.)

Percent total reducing sugar (**TRS**) **=** $\mathbf{100}/_{\boldsymbol{C}*\boldsymbol{T}}$ ……………………………**(3.5)**

Where **C** = concentration of molasses test (gm/100ml) (0.5 gm/ml)

T = volume of molasses solution used in ml(volume of titer (ml))

3.3. Molasses Treatment Methods

3.3.1 Methods

i. Factors Affecting Molasses Treatment

Apart from sugars (mainly sucrose, glucose and fructose), final molasses contains a variety of chemical constituents including cat ions such as Ca, Mg and K, anions like sulphates, phosphates and chlorides, and a variety of organic components such as acids, colour bodies and several degradation products.Ca ions, in particular, form insoluble complexes with many other chemical species normally present in molasses and these complexes give rise to numerous down-stream processing problems such as fouling of evaporators, the scaling of heat exchangers and adversely affecting fermentation processes and yeast production processes. An important aspect of the pretreatment therefore involves maximizing the removal of Ca ions.(Bemhardt, HW (1996)) Removal of Ca from molasses can be affected by different factors such as pH, temperature, brix ,retention time, flocculent usage and other minor factors. Only three factors, pH(acid addition), Temperature, brix(dilution) have significant effect on molasses clarification. These experiments has been carried out at various levels of these three factors, Dilution (brix), Temperature, pH(acid addition) each at three replicates, and one response Ca(mg/100g) molasses in the supernatant.

ii. Experimental Design

To conduct this experiment and optimize these variables response surface with central composite design has been used. Because, response surface methodology, is a collection of mathematical and statistical techniques that are useful for the modeling and analysis of problems in which a response of interest is influenced by several variables and the objective is to optimize this response (Douglas C. Montgomery, 2001). The response surface methodology (RSM), based on statistical principles, was employed as an interesting strategy to implement process conditions that drive to optimal removal of Ca from molasses by performing a minimum number of experiments. Therefore, the analysis has been done using CCD experiments, and design expert 6.0.0 software package has been employed.

3.3.2 Hot acid treatment

Has been carried out at various levels of these three factors, Temperature (80-90 ^{0}C),Dilution(30-50 Brix),Acidity (3.5-5.5 ph) each at three levels with three replicates, and one response Ca molasses in clear diluted molasses a total of 60 runs has been conducted.

Table 3.1 Experimental design using design expert (RSM of CCD)

Std	Run	Block	Factor 1 A:Temperatur 0 C	Factor 2 B:Dilution Brix	Factor 3 C:Acidity ph	Response 1 Ca befor mg/100gm	Response 2 Ca after mg/100gm	Response 3 Ca removed mg/100gm
1	5	Block 1	80.00	30.00	3.50			
2	7	Block 1	95.00	30.00	3.50			
3	12	Block 1	80.00	50.00	3.50			
4	20	Block 1	95.00	50.00	3.50			
5	18	Block 1	80.00	30.00	5.50			
6	9	Block 1	95.00	30.00	5.50			
7	17	Block 1	80.00	50.00	5.50			
8	2	Block 1	95.00	50.00	5.50			
9	14	Block 1	80.00	40.00	4.50			
10	3	Block 1	95.00	40.00	4.50			
11	19	Block 1	87.50	30.00	4.50			
12	1	Block 1	87.50	50.00	4.50			
13	11	Block 1	87.50	40.00	3.50			
14	15	Block 1	87.50	40.00	5.50			
15	6	Block 1	87.50	40.00	4.50			
16	8	Block 1	87.50	40.00	4.50			
17	13	Block 1	87.50	40.00	4.50			
18	16	Block 1	87.50	40.00	4.50			
19	4	Block 1	87.50	40.00	4.50			
20	10	Block 1	87.50	40.00	4.50			

I. Experimental Procedure for HAT

First the sample of raw molasses which has been analyzed for Ca content, brix, ph and density was prepared for the experiment. Depending on the initial brix, distilled water was prepared in accordance with the data from *Table 3.1* above by simple mass balance and mixed together in order to reduce the viscosity of the given molasses, after dilution ph was adjusted by drop by drop addition of sulfuric acid up on agitation, finally the solution was heated via water bath up to the required temperature order to facilitate the reaction between sulfuric acid and calcium compounds for the formation of precipitate. Finally the solution was transferred in to the 250 ml measuring cylinder and allowed to settle. For example the first experiment from the above data has been done in such a way that, initially molasses having the brix of 83,ph of 5.1,was used for this experiment. 100gm of molasses and 172 gm of distilled water has been used to bring the molasses solution to the required 30^{0} Bx, then Ph was adjusted to 3.5 using sulphuric acid, then followed by heating at 80^{0}C on water bath for 1hrs, then the given solution was transferred in to a 250 ml measuring cylinder for the sedimentation processes and allowed to settle and finally the precipitate settles at the bottom and the supernatant remains at the top, and analyzed for Ca content.

Fig 3.3 Experimental procedure for HAT

II. Sedimentation rate in HAT

The concept of sedimentation processes relies up on the settling of particles due to the effect of gravity. Each of the 20 experiments from the above table, passed the process of sedimentation and the experiment has been done using 250 ml measuring cylinder as a sedimentation tank . each of the experiment has taken a longer time approximately up to 4 hrs for determining the uniform settling rate, at which the volume of the mud becomes constant. In order to determine the retention time the given molasses solution which passed the previous clarification steps, will be transferred to the given measuring cylinder which is about 250 ml. The volume of the mud (sludge) was measured in every 10 minute, and recorded.

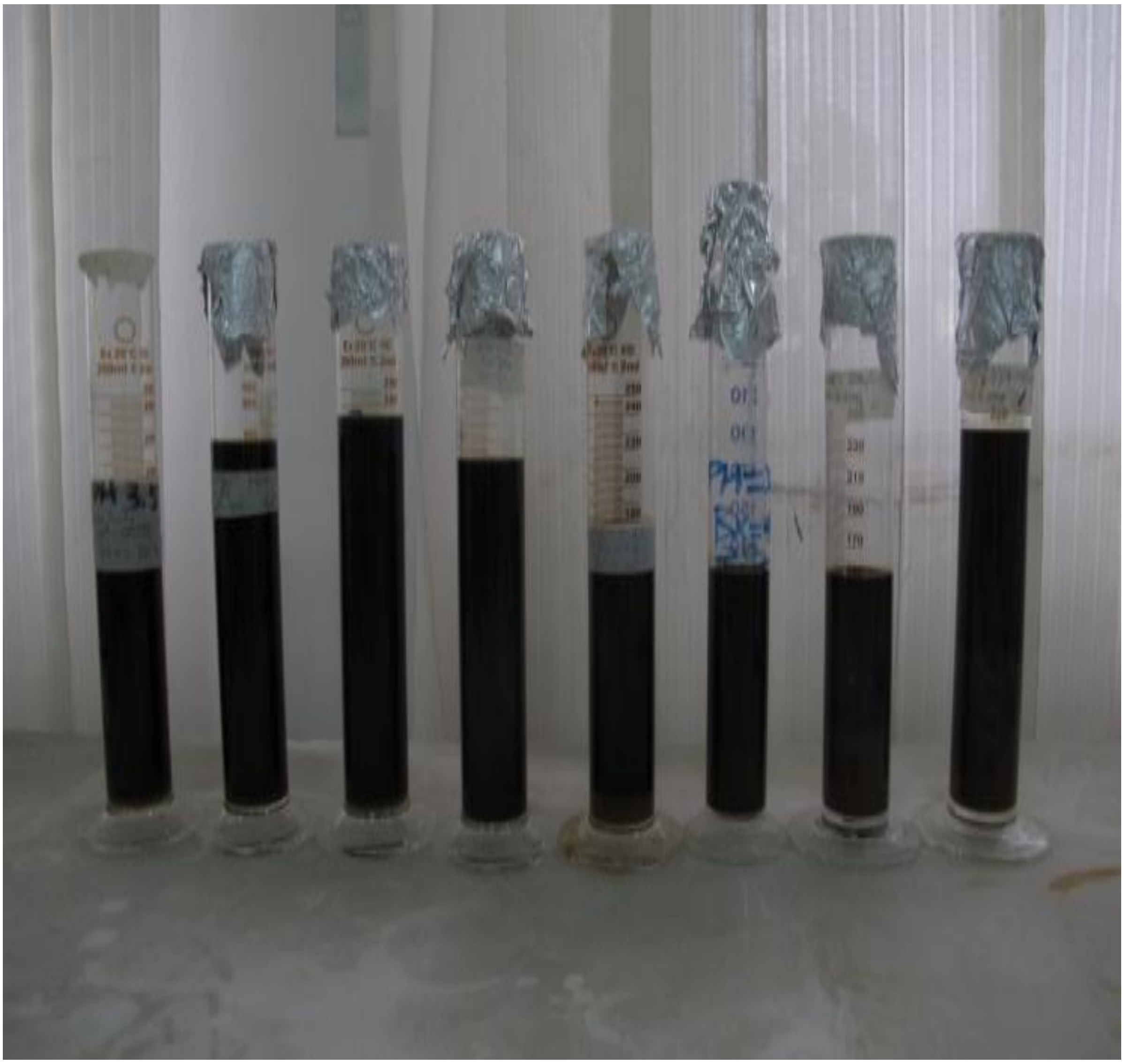

Fig 3.4 Experimental set up to determine sedimentation rate in HAT

3.3.3 Acid centrifugation Treatment

Has been carried out at various levels of these three factors, Temperature (75-90 ^{0}C),Dilution(21 – 41),Acidity (3.5-5.8 ph) each at three levels with three replicates, and one response Ca molasses in clear diluted molasses a total of 60 runs has been conducted.

Table 3.2 Experimental design using design expert (RSM of CCD)

	Std	Run	Block	Factor 1 A:Temperatu 0 C	Factor 2 B:Dilution Brix	Factor 3 C:Acidity ph	Response 1 Ca befor mg/100gm	Response 2 Ca after mg/100gm	Response 3 Ca removed mg/100gm
	1	7	Block 1	75.00	42.00	3.50			
	2	9	Block 1	90.00	42.00	3.50			
	3	4	Block 1	75.00	21.00	3.50			
	4	2	Block 1	90.00	21.00	3.50			
	5	3	Block 1	75.00	42.00	5.80			
	6	6	Block 1	90.00	42.00	5.80			
	7	1	Block 1	75.00	21.00	5.80			
	8	5	Block 1	90.00	21.00	5.80			
	9	12	Block 1	82.50	31.50	4.65			
	10	10	Block 1	82.50	31.50	4.65			
	11	8	Block 1	82.50	31.50	4.65			
	12	11	Block 1	82.50	31.50	4.65			
	13	18	Block 2	75.00	31.50	4.65			
	14	17	Block 2	90.00	31.50	4.65			
	15	14	Block 2	82.50	42.00	4.65			
	16	20	Block 2	82.50	21.00	4.65			
	17	19	Block 2	82.50	31.50	3.50			
	18	16	Block 2	82.50	31.50	5.80			
	19	13	Block 2	82.50	31.50	4.65			
	20	15	Block 2	82.50	31.50	4.65			

I. Experimental procedure for acid centrifugation processes

The experiment was conducted on a laboratory centrifuge (AAIT) which can accommodate four samples at a time. The speed of rotation of the centrifuge was assigned between 2500- 4500 rpm, and the automatic timer of the centrifuge was set at 10 min for all of the tests. Centrifugal clarification can be enhanced by addition of sulphuric acid , simply the raw molasses was first diluted using distilled water, then sulphuric acid was added drop by drop and heated, while stirring for a certain length of time prior to centrifugation. Depending on the data shown in the *Table 3.2* above, distilled water was prepared in accordance with the simple mass balance and mixed together with the molasses in order to reduce the viscosity of the given molasses ,after dilution ph was adjusted by drop by drop addition of sulfuric acid up on agitation using a magnetic stirrer ,and finally the solution was heated via water bath up to the required temperature according to the experimental design output, once when it reached the specified temperature, the solution was immediately centrifuged between 2500-4500 rpm for about 10min.

3.4 Analysis of the clarified molasses

Pre treatment effectiveness was Ca content which was determined by atomic absorption (AA) spectroscopy.

3.5 Selection of the Best Technology for Molasses Treatment

Depending on the three factors two technologies of molasses clarification methods has been discussed in the above experiments, and finally the best clarification technology has been selected among them . Parameters that have been used for selecting the best one among the clarification technologies include maximum calcium removal, minimum energy consumption, minimum utility consumption (water, electricity), minimum chemical addition, simplest processing steps.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1. Characterization of the raw material

The composition of molasses shows wide variation. Its composition is influenced by factor such as soil type, ambient temperature, moisture, season of production, variety and technology of sugar mills can control the amount of sucrose extracted. Because of this the sugar content of molasses produced in different countries will vary according to the production technology employed. According to *Curtin (*1983*)*, changes in the design of centrifuges used to separate sugar and syrup constitute one of the major advancements in the cane sugar industry. Continuous centrifugation now results in more sugar extracted with a corresponding decrease in the amount of sugar left in molasses. The obtained results shows that cane molasses composition presented in this project reflect, there was similar result from analysis presented in the following publications (*Curtin*, 1983 olibrich 2006, *John, 1954, and Ethiopian standards, 2004).*

4.1.1. Physical and Chemical properties

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A. pH

Table 4.1 pH of molasses samples

Trial no	**Methara**	**Wonji**
1	5.72	5.37
2	5.7	5.56
3	5.74	5.47
Average	**5.72 ±0.02**	**5.47 ± 0.02**

According to the literature (Olibrich 2006) and different data’s from different sources the cane molasses belongs to the acidic media range between 5.2-5.9.therefore as shown the table above the ph of the samples belong to the range. Studies have shown that the pH and temperature play a vital role in controlling contamination during fermentation process (Wang et al., 1998; Sugawara et al., 1994;Murtagh, 1999). S.cerevisiae grows better under slightly acidic conditions.

B. Density

Table 4.2 Density of molasses samples

Trial no	**Methara (kg/m^3)**	**Wonji(kg/m^3)**
1	1431.8	1453.8
2	1432.7	1452.3
3	1433.2	1454.6
Average	**1431.825**	**1453.2**

This is in line with the recommendation of E. Hugot, which says ‘true density of molasses is generally the order of 1.4 - 1.5 gm/ml. Therefore the molasses samples belong to the range.

C. Brix

Table 4.3 Brix of molasses samples

Trial no	**Methara**	**Wonji**
1	83.18	86.3
2	83.26	86.09
3	83.05	86.42
4	83.25	86.04
Average	**83.0**	**86.0**

Brix represents an approximation of total solids content . Brix is a term originally initiated for pure sucrose solutions to indicate the percentage of sucrose in solution on a weight basis. The brix of the given molasses are with the range, of commercial molasses which are inline the standard range which is 70-90 ^{0} Brix. According to (Ethiopian standard, 2004 total solids is about 85% (w/v)), (John ,1954 - 79%(w/v)),(Curtin ,1983 – 79.5%),therefore the total solids data is in line with the standards, and can be acceptable.

D. water content (moisture content)

Mo1-methara sample 1

Mo2-mehara sample2

Wo1-wongi sample 1

Wo2-wongi sample2

Table 4.4 water content of molasses samples

Batch no	**Crucible name**	**Mass of crucible(W_1)**	**Molasses Sample mass**	**Sample and crucible mass(W_2)**	**After drying(W_3)**	**(%)moisture**
1	Mo_1	22.55	5	27.55	26.62	18.6
2	Mo_2	22.53	5	27.53	26.56	19.3
3	Wo_1	22.56	5	27.56	26.57	19.77
4	Wo_2	21.73	5	26.73	25.72	20.2

The water in molasses is mostly unbound but a part is held as hydration water or hydrate water. Commercial molasses have an average water content of 20%. (MOLASSES by Hubert Olbrich, 2006), the given molasses samples are in accordance within the standard.

E. Sulphated Ash

Table 4.5 Sulphated Ash content of molasses samples

Bach no	Crucible name	sample mass	crucible mass(W_1)	Crucible +sample(W_2)	after ashing (W_3)	Ash (%)
1	Mo_1	2.50	32.17	34.67	32.48	12.4
2	Mo_2	2.50	33.86	36.37	34.17	12.4
3	Wo_1	2.49	22.39	24.88	22.74	14.05
4	Wo_2	2.52	24.46	26.98	24.80	13.49

Mo = 12.4

Wo = 13.77

According to the Ethiopian standard 2004, the sulphated ash content ranges between 8-14%, from the data the percentage for ash content is according to the standard. Ethiopian molasses contains excessive amounts of ash containing excess calcium that results in down process, colour change in the final product, even stopping the fermentation process, and resulting in lowering the concentration of Yeast biomass, therefore the molasses it must be clarified and must be free from any microorganisms.

F. Mineral Analysis

Table 4.6 Mineral content of molasses samples

No	**Sample name**	Fe(mg/100gm)	Mg(mg/100gm)	Ca(mg/100gm)
1	**MO**	28.75± 0.18	4.17 ± 0.01	488.72± 1.26
2	**WO**	24.14± 0.01	4.17± 0.04	530.02±1.89

Cane and citrus molasses contain higher amounts of calcium, copper, iron and manganese than beet molasses. Within a molasses type, the trace mineral variability can be quite high. Curtin (1983) reported that cane molasses contained an average of 297 mg/kg iron with a range of 145-640 mg/kg (14.5-64.0 mg/100gm).Both wongi and methara has the iron content which is in the range of the given standard. Cane and beet molasses are comparatively high in potassium, magnesium, sodium, chlorine and sulfur. According to Jhon 1954,the calcium ranges 0.08-5%, in our case the amount of calcium is 4.88% and 5.3% respectively which is acceptable range range ,but excessive amounts of calcium has been analyzed.

G. Nitrogen and Protein

Table 4.7 Nitrogen and Protein

Sample no	Sample name	%N	Protine=6.25*N
1	MO	0.42±0.02	2.625
2	WO	0.40±0.02	2.5

According to John, 1954 the amount of nitrogen is about 0.15 – 8 % in range, therefore our molasses belongs to the range and both the molasses samples have a lower value of nitrogen content. Cane and beet molasses are not rich in basic elements like nitrogen, phosphors, calcium and magnesium which are vital for the growth of yeast strains. Nitrogen is the basic nutrient in enhancing yeast growth. According to (Gutierrez et al) nitrogen deficiencies are one of the main causes of stuck or sluggish Fermentations. Thus, addition of nitrogen sources is needed; generally in the form of ammonium salts, aqueous ammonia, soluble proteins or urea in addition to the amino acids present in molasses

H. **Total Reducing Sugar**

Table 4.8 Total Reducing Sugar of molasses samples

Trial	Wongi(T)	TRS
1	41.7	47.96
2	40.9	48.89
3	42.1	47.5
Average		48.2

Trial	Methara	TRS
1	36.5	54.79
2	38.7	51.67
3	39.2	51.28
Average		52.58

According to the Association of American Feed Control officials (AAFCO, 1982) Cane molasses is a by-product of the manufacture or refining of sucrose from sugar cane .It must not contain less than 46%total sugars expressed as invert..Therefore the total reducing sugars for methara and wongi are 48.2 and 52.58 respectively which are more than 46% and fit the given standard.

4.2 Molasses Treatment Results

4.2.1 Hot acid treatment Results

From the final step of molasses treatment by HAT ,the molasses sample after acidification was followed by sedimentation, and the given molasses solution was allowed to settle by the action of gravity and finally the clear molasses solution (supernatant) was collected by decantation and analyzed for Ca content and the following results has been obtained.

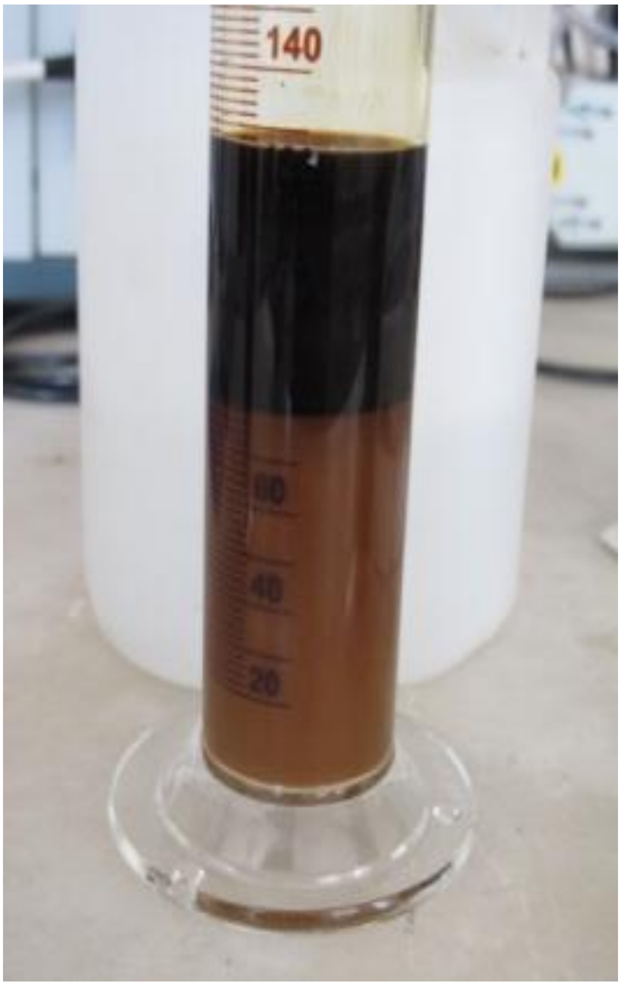


Fig 4.1 Sedimentation process in HAT

The laboratory results of the given experiment has been collected depending on the run order recommended by the software and tabulated in the table 4.9 below, the amount of calcium removed from the given molasses samples given by (mg/100gm), and the ash content of the supernatant is given in the table 4.10 below, given the sample code name of H_n

Table 4.9 Present Ca removed after molasses treatment by HAT

Std	Run	Block	Factor 1 A:Temperatu 0 C	Factor 2 B:Dilution Brix	Factor 3 C:Acidity ph	Response 1 Ca befor mg/100gm	Response 2 Ca after mg/100gm	Response 3 Ca removed mg/100gm
1	10	Block 1	80.00	30.00	3.50	488.72	40.67	448.05
2	17	Block 1	95.00	30.00	3.50	488.72	31.06	457.66
3	19	Block 1	80.00	50.00	3.50	488.72	148.41	340.31
4	7	Block 1	95.00	50.00	3.50	488.72	123.33	365.39
5	14	Block 1	80.00	30.00	5.50	488.72	194.59	294.13
6	15	Block 1	95.00	30.00	5.50	488.72	199.93	288.79
7	16	Block 1	80.00	50.00	5.50	488.72	196.5	292.22
8	13	Block 1	95.00	50.00	5.50	488.72	290	198.72
9	5	Block 1	80.00	40.00	4.50	488.72	309	179.72
10	8	Block 1	95.00	40.00	4.50	488.72	238.1	250.62
11	3	Block 1	87.50	30.00	4.50	488.72	293.59	195.13
12	20	Block 1	87.50	50.00	4.50	488.72	297.02	191.7
13	11	Block 1	87.50	40.00	3.50	488.72	26.96	461.76
14	18	Block 1	87.50	40.00	5.50	488.72	252.23	236.49
15	1	Block 1	87.50	40.00	4.50	488.72	230.43	258.29
16	2	Block 1	87.50	40.00	4.50	488.72	235.86	252.86
17	9	Block 1	87.50	40.00	4.50	488.72	250.87	237.85
18	12	Block 1	87.50	40.00	4.50	488.72	281.69	252.9
19	6	Block 1	87.50	40.00	4.50	488.72	251.02	237.7
20	4	Block 1	87.50	40.00	4.50	488.72	250.1	238.62

Table 4.10 Ash content for hot acid treatment

Exp no	Exp name	Ash (%)
1	H1	3.2
2	H2	2.78
3	H3	6
4	H4	5.98
5	H5	4.78
6	H6	4.75
7	H7	6.35
8	H8	6.32
9	H9	5.58
10	H10	5.58
11	H11	5.17
12	H12	6.4
13	H13	4.36
14	H14	5.5
15	H15	5.2
16	H16	5.17
17	H17	5.17
18	H18	5.13
19	H19	5.2
20	H20	5.18

From table 4.9 maximum calcium was removed at the experiment named by $H_{2,}$experiment nomber 2,and operated at Temperature of 95 ^{0} C,Dilution of 30 ^{0} Brix,and ph of 3.5,calcium removed (457 mg/100 gm). Simillarly minimum calcium was removed by the experiment named by $H_{9,}$and has been operated at temperature of 80, dilution of 40 ^{0} Brix,ph of 4.5 ,calcium removed (179.72).The minimem ash content was obtained in experiment number 2, therefore maximum calcium removal can be achived at low ash contante and has a direct relationship.the higher the ash content the higher calcium content.Therefore lowering the ash content resultes maximum calcium removal.one of the factor affecting the yeast production regarding the molasses quality is its high ash content and calcim ,therefore at the given ponits,there was a minimum ash content ,and maximum ca removal .Higher temperature ,lower brix,low acidity resultes maximum calcium removal.

4.2.2 Acid Centrifugal Clarification

Clear molasses solution (supernatant) was collected from the centrifuge and analyzed for Ca content.

Table 4.11 Present Ca removed after molasses treatment by acid centrifugal clarification

	Std	Run	Block	Factor 1 A:Temperatu 0 C	Factor 2 B:Dilution Brix	Factor 3 C:Acidity ph	Response 1 Ca befor mg/100gm	Response 2 Ca after mg/100gm	Response 3 Ca removed mg/100gm
	1	11	Block 1	75.00	42.00	3.50	488.72	26.86	461.86
	2	4	Block 1	90.00	42.00	3.50	488.72	62.76	425.96
	3	2	Block 1	75.00	21.00	3.50	488.72	80.27	408.45
	4	12	Block 1	90.00	21.00	3.50	488.72	81.31	407.41
	5	1	Block 1	75.00	42.00	5.80	488.72	269.72	219
	6	6	Block 1	90.00	42.00	5.80	488.72	178.13	310.59
	7	3	Block 1	75.00	21.00	5.80	488.72	280.82	207.9
	8	9	Block 1	90.00	21.00	5.80	488.72	37.31	451.41
	9	10	Block 1	82.50	31.50	4.65	488.72	176.86	311.86
	10	7	Block 1	82.50	31.50	4.65	488.72	176.86	311.86
	11	5	Block 1	82.50	31.50	4.65	488.72	176.86	311.86
	12	8	Block 1	82.50	31.50	4.65	488.72	176.86	311.86
	13	18	Block 2	75.00	31.50	4.65	489.01	304.21	184.8
	14	13	Block 2	90.00	31.50	4.65	489.01	260	283.01
	15	19	Block 2	82.50	42.00	4.65	489.01	192.83	296.18
	16	15	Block 2	82.50	21.00	4.65	489.01	208.16	280.85
	17	17	Block 2	82.50	31.50	3.50	489.01	188.75	300.26
	18	16	Block 2	82.50	31.50	5.80	489.01	208.79	280.22
	19	20	Block 2	82.50	31.50	4.65	489.01	176.86	312.15
	20	14	Block 2	82.50	31.50	4.65	489.01	176.86	312.15

Table 4.12 Ash content for Acid Centrifugal clarification @3500 rpm

Exp no	Sample code	Ash content
1	S1	4.37
2	S2	4.35
3	S3	2.38
4	S4	2.15
5	S5	5.95
6	S6	6.23
7	S7	2.76
8	S8	3.57
9	S9	3.6
10	S10	3.44
11	S11	9.52
12	S12	3.1
13	S13	7.56
14	S14	3.58
15	S15	3.77
16	S16	3.75
17	S17	3.75
18	S18	3.81
19	S19	3.71
20	S20	3.71

From table 4.11 ,maximum calcium was removed at experiment number one,operating at the process conditions of temperature at 75 ^{0} C , dilution of 42 brix,acidity of 3.5,calcium removed was 461 mg/100gm.simillarly the minimum calcium was removed at experiment number 13,operating at temperature 75 ^{0}C ,dilution of 31 brix,acidity of 4.65,and calcium removed was 184.4 mg/100gm.

The results in the given table 4.12 describes that there is a variation in the ash content of the given experment in comparision with hot acid treatment ,because acid centrifugation reduce the sedimentation rate through a centrifugal force ,there has been maximum sludge concentration,since centrifugation resulted ,the agglumration of the solid particles,and suspended materials

,components,which are risponsible for the colour formation in case of molasses. In addition the supernatant which was obtained through centrifugation of the given molasses at 4500 rpm,was clear,totally free of any suspended matter.

4.3. Selection of the Best Technology for Molasses Treatment

There is now a wide range of situations where centrifugal force is used in place of the gravitational force in order to effect separations. The resulting accelerations may be several thousand times that attributable to gravity. Some of the benefits include far greater rates of separation; the possibility of achieving separations which are either not practically feasible, or actually impossible, in the gravitational field; and a substantial reduction of the size of the equipment. Some of the areas where centrifuge is extensively used are as follows, For separating particles on the basis of their size or density. This is effectively using a centrifugal field to achieve a higher rate of sedimentation than could be achieved under gravity, For separating immiscible liquids of different densities, which may be in the form of dispersions or even emulsions in the feed stream. This is the equivalent of a gravitational decantation process, For filtration of a suspension. In this case centrifugal force replaces the force of gravity or the force attributable to an applied pressure difference across the filter.

Depending on the three factors two technologies of molasses clarification methods has been discussed in the previous sections, and finally the best clarification technology has been selected among them. Parameters that have been used for selecting the best one among the clarification technologies include maximum calcium removal, minimum energy consumption, minimum utility consumption (water, electricity), minimum chemical addition, simplest processing steps.

Table 4.13 Best Technology Selection mechanism

No	parameters	Treatment Methods	
		Hot Acid Treatment	**Acid Centrifugation**
1	**Calcium removal**	fair	maximum
2	**Energy consumption**	high	minimum
3	**Utility consumption (water, electricity)**	high	minimum
4	**Chemical addition**	fair	minimum

Depending on the above data ,in the case HAT their was fair calcium removal, in the case of acid centrifugation maximum calcium removal has been achived this is due to the fact that the hot acid treatment mechanisem follows the given procedures,the given brix of the molasses has been reduced using a distiled water,once there was a complet dilution of the given molasses sample but some of undisolved components of the molasses samples remains at the botom of the dilution tank in our case 500 ml beaker has been used as a dilution tank. During the process of dilution the viscosity of the given molasses has been lowerd and the molasess disolves completely ,and there has been a suspended componentes insoluble to the water.Acidification processes,resulted in precipitation of salts of calcium,waxs,gums,colouring matters etc.it a very rapid reaction in which once the sulphric acid feed in to the given diluted molasses sample it starts to form an agglumeration of components ,in this case the acid acts as a flocculant .When veiwing the given solution the pricipitate forms a brown colour,and there is also some suspended matters that can’t react with the sulpheric acid ,and remains in suspended form ,finally the given molasses solution has been tranfered in to measuring cylinder for settling process(sedimentation process),settling of the given components of molasse due to the effect of gravity and it takes long time for all components ,in addition Using longer retention time of settling increases the size of the equipments to be used in the treatment plant and may results in unnecessary initial investment cost.

Energy consumption, in case of hot acid treatments there are about 8 unit operation process (Mixing tank, Heat exchanger, acid tank, sedimentation, decanter, sterilizer ,pumps,) ,while for the case of acid centrifugal clarification the dilution, heating and acidification can be done in a single unit and has a minimum of energy consumption in comparison with hot acid treatment . Regarding to the utility consumption (water, electricity), both hot acid treatment and acid centrifugal treatment consumes water and electricity. Water used for the dilution purpose, for heat exchanger unit, other cleaning purpose. Electricity has been used for starting dilution process; heat exchanger (water bath) requires electricity to start on.

Therefore acid centrifugation is the simplest and best treatment technology, and it can be used for treatment purpose of molasses that is used as a row material for the bakery plant. Depending on the results obtained in the previous experiments performed through acid centrifugation can be used to determine the optimum process condition for molasses treatment.

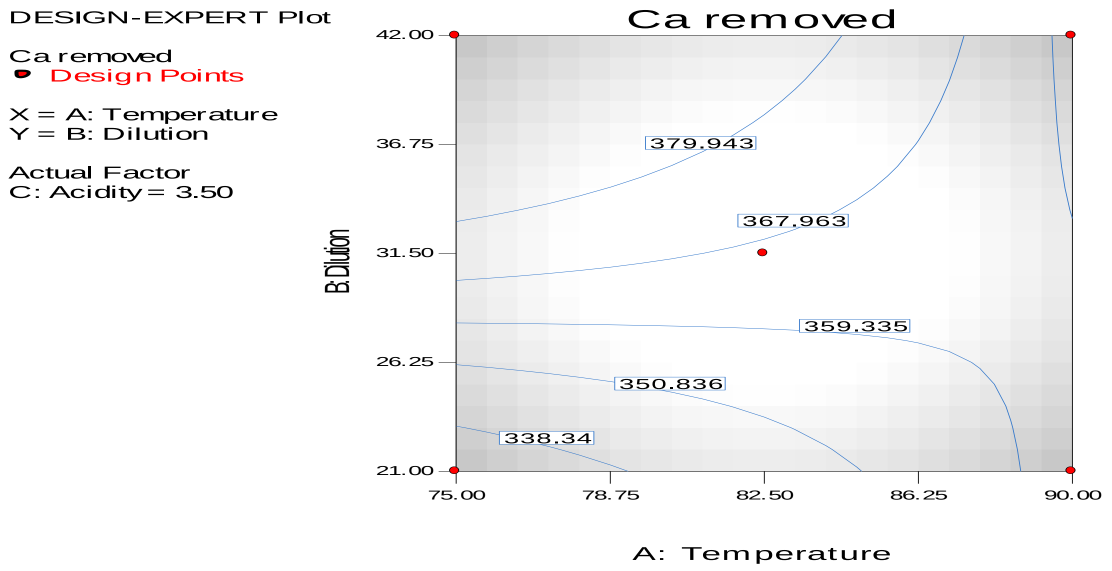
4.4 Discussion

We have choosen the acid centrifugation, as best technology, depending on that our discussion has been based on the results obtained from the acid centrifugation method. By over viewing the results from the table 4.11 the maximum removal of Ca has been obtained at temperature of 75^{O} C,brix of 42 ^{0}Brix , pH of 3.5 at which Ca removed becomes 461mg/100gm. In other case, the minimum removal of Ca has been recorded at temperature of 75 ^{O}C, brix of 31.5 and pH of 4.65 at which Ca concentration after treatment becomes about 184.8 mg/100gm.

In order to determine the optimal levels of each variable for maximum Ca removal, response (Ca removed , mg/100gm) contour plots and 3-D response surfaces of the results obtained were constructed by plotting the response (Ca removed) on the Z-axis against two independent variables, while maintaining other variables at their optimal levels which is helpful for understanding both the main and the interaction effects of these two factors. The response surfaces can be used to predict the optimum range for different values of the test variables and the major interactions between the tests variables can be identified from the circular or elliptical nature of the contours. The contour plots and 3-D response surfaces plots based on independent variables were obtained using the software package design expert 6.0.0 as follows.

Model Graphs

A)



B)

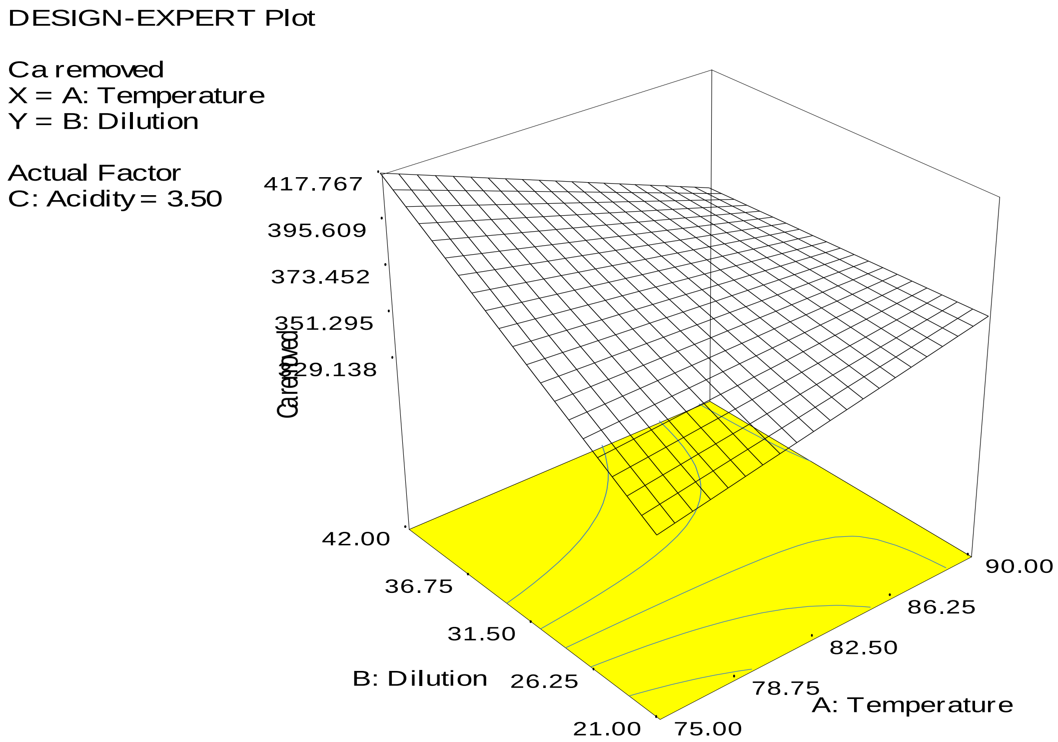
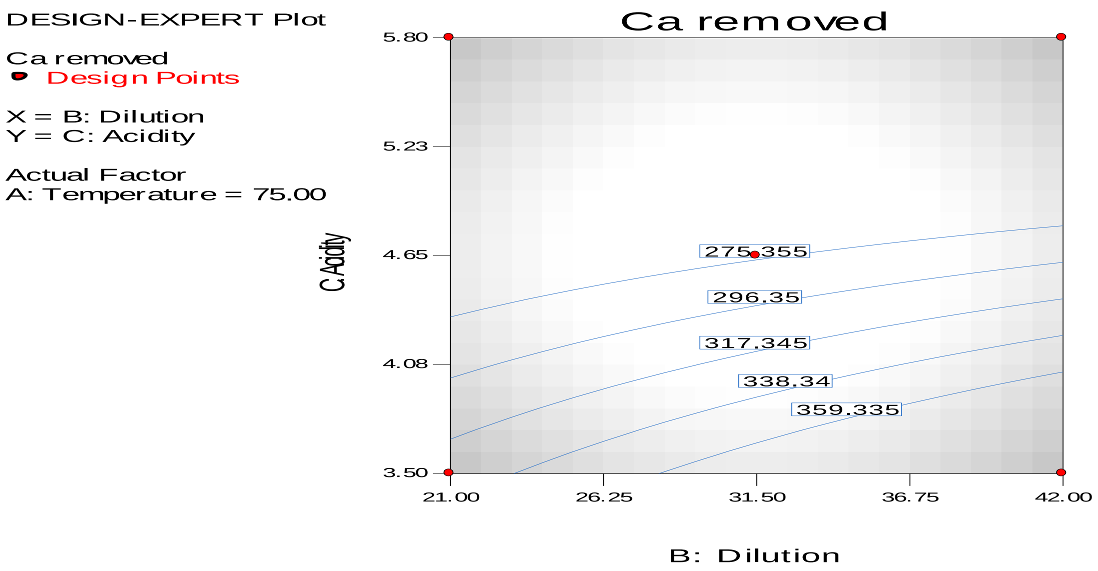


***Figure 4.2:** - The effect of temperature and Dilution on Ca removed (mg/100gm) from molasses at 3.5 pH **a)** Contour plot b**)** 3-D surface plot*

A)



B)

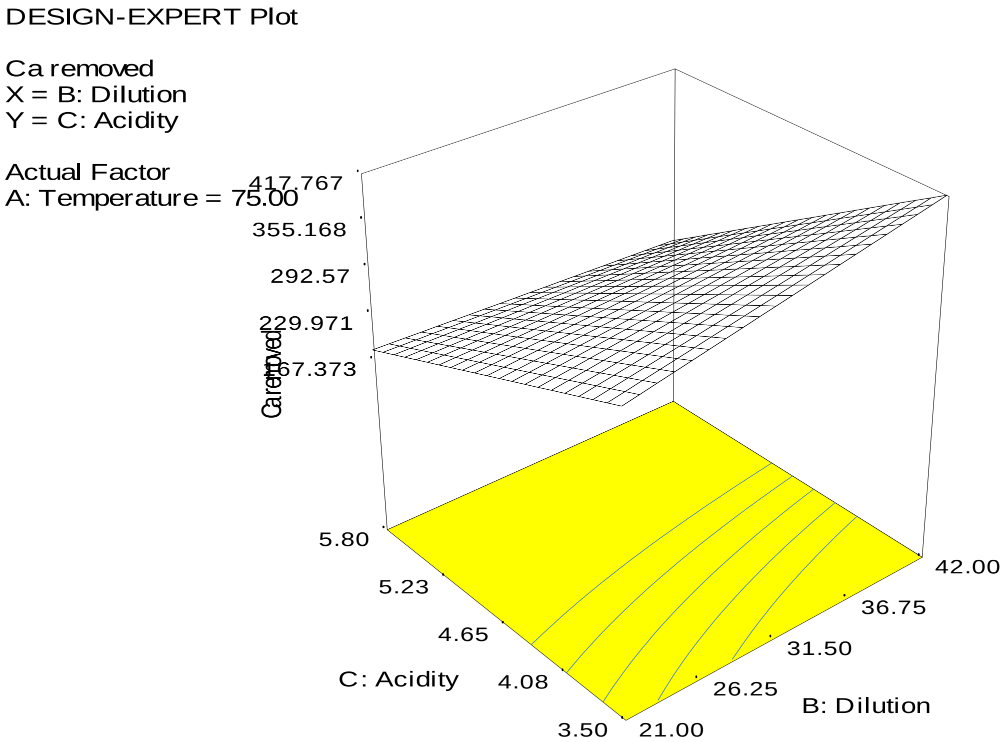


***Figure 4.4: -** The effect of acidity and dilution on Ca removed (mg/100gm) from molasses at 75 ^{0}C*
***a)** Contour plot b**)** 3-D surface plot*

The above Figs. a) contour and b) 3-D plots show interaction effects of temperature, pH and brix on the response variable of present Ca after treatment . The circular natures of the contours shows that the interaction effects between the test variables are not significant and therefore optimum values of the test variables can be easily obtained.

At lower ph, higher brix, there is low effect of temperature, as shown in the table above at temperature of 75 ^{0} C, brix of 42,ph of 3.5 there is maximum ca removal comparing with experiment operated at temperature of 90 ,brix of 42 ,ph of 3.5 and experiment operated at 82.50 C, brix of 42 ,ph of 3.5.therefore at higher brix there is only ph effect. At lower brix ,and higher ph value there was a temperature effect, at 21 brix, 5.8 ph, similar experiment operating at different temperatures at 75 and at 90 ,there is higher calcium removal difference .therefore at higher ph value and lower brix we noticed the effect of temperature, in addition lowering the brix, requires dilution of the given molasses and resulting in higher mass transfer rate but affecting the reaction between the acid and precipitation forming components.

Low brix, low ph value there was no significant difference between the result obtained at 75 ^{0} C, 90 ^{0}C. There is a rapid reaction between the acid and the components of molasses which are responsible for precipitate formation .once the reaction starts further increasing the temperature will not increase the amount of calcium removed. Even further heating results in the formation of colors, formation of reducing sugar. Higher brix, higher ph, there is a significant effect of temperature, because the experiment which has been operated at 75 ^{0} C,42 ^{0} Brix ,ph of 5.8 has a calcium removal of 219 mg/100 gm , similarly at 90 ^{0} C ,42 ^{0} Brix , ph of 5.8 has a calcium removal of 310 mg/100 gm . Therefore at higher brix there is an effect of viscosity resulting mass transfer problem ,for the reaction between the acid and calcium compounds, therefore temperature lowers the viscosity of the molasses and facilitates the reaction between sulfuric acid and calcium compounds. Temperature has both reaction effect and viscosity reduction effect. Therefore optimum condition for calcium has been found at a temperature of 75^0 C, brix of 42, ph of 3.5. It can be seen that as one goes from lower temperature to higher temperature within the given range of temperature, but at higher pH the amount of calcium removed from molasses also increased, indicating that Ca removal at high temperature is superior to that at lower temperature incase of higher pH value. The result indicates the increment of temperature of the molasses favors removal of ca, through facilitating the reaction between the sulfuric acid and calcium compounds, in addition temperature also lowers the viscosity of the molasses so as facilitating mass transfer effect of the given molasses.

Dilution of final molasses reduce its viscosity, which will lead to enhanced efficiency of hot acid centrifugal separation of precipitated solids One. On the other hand, increased dilution tends to dissolve more precipitated solids, so that the benefits of viscosity reduction are counteracted by the increased solution of solids and it is expected that at higher brix less Ca is removed even the temperature is high. At higher brix and higher temperature less precipitate is formed in this case Ca compounds are more soluble, while at lower brix predominantly a solubility effect will be there. So, at the higher brix one would expect a solubility effect (if significant) as well as a significant viscosity effect, whereas at the lower brix one would expect predominantly a solubility effect. If viscosity is the overriding mechanism then the difference between the Ca content at the high temperature, compared with the low temperature, should be greater at the higher brix.

As one move from lower pH to higher pH within the given range, Ca removed highly decrease, which shows that increasing pH of the molasses negatively affects Ca removal from molasses. through adding drop by drop of the given sulphuric acid ,the ph of the given solution had been adjusted, meaning increasing the concentration of the acid will lowers the ph of the given molasses solution, resulting fast reaction within complex compound of calcium that belongs within the given molasses solution, so the precipitation of calcium will be significant. These show that, unlike temperature, the effect of pH and brix on molasses treatment is inversely proportional that lowering pH and brix favors Ca removal from molasses. Therefore from the given results of above, at 42 ^{0}Brix, temperature of 75 ^{0} C, and lower ph of 3.5 the maximum ca has been removed. In some cases lowering the brix, at low temperature also favors maximum ca removal.

i. Development of Regression Model Equation

The model equation that correlates the response (Ca after treatment) to the molasses clarification process variables, temperature, pH and brix in terms of coded factors **and actual factors** was given below.

Final Equation in Terms of Coded Factors:

Ca removed =
+313.10
+39.64 * A
-4.24 * B
-53.48 * C
-23.35 *A*B
+46.51 *A*C
-25.21 *B*C

Final Equation in Terms of Actual Factors:

Ca removed =
+1098.26315
-10.44833 *Temperature
+33.76339 *Dilution
-425.57130*Acidity
-0.29648*Temperature*Dilution
+5.39188*Temperature*Acidity
-2.08778*Dilution*Acidity

From this model equation it can be seen that both temperature and pH negatively affect Ca removal where as dilution affects positively. Even if their effects are relatively different, the individual effects of all factors are significant.

iii. Effect of Individual Process Variables

a. Effect of temperature on Ca removal

At the given optimum condition having a temperature of 75 ^{0}C, pH of 3.5 ,the graph shows that at a lower temperature ,there has been a maximum calcium removal ,temperature has only a function of facilitating the reaction between the acid and the calcium in the given molasses ,once it reach the optimum temperature the reaction is very fast and there is a fast formation of precipitation, but at higher pH and higher brix ,temperature has both a function of reducing the viscosity of the given molasses and facilitation of the reaction between the acid and calcium compounds, and resulting a higher steam cost .as one goes from 75 ^{0}C to 90 ^{0}C.

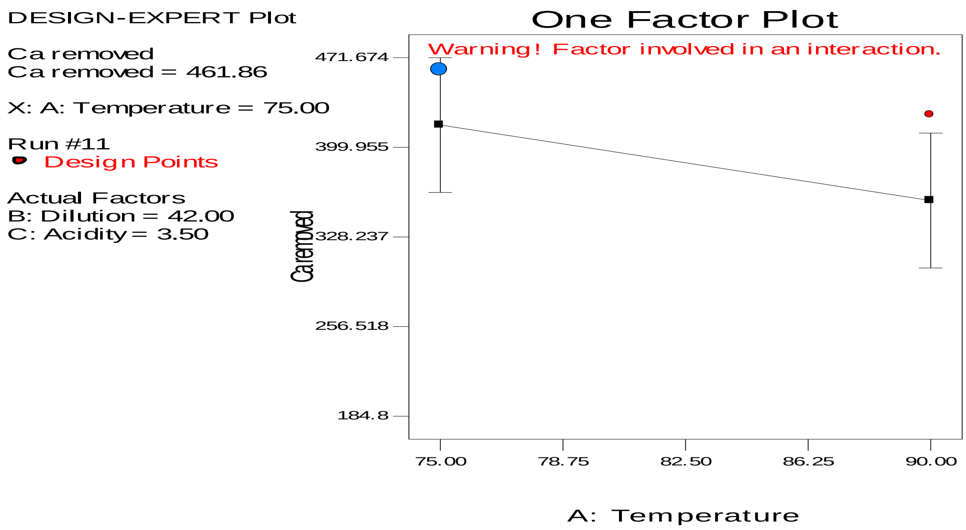


Figure 4.5: -Effect of temperature on present Ca removed from molasses.

b. Effect of brix on Ca removal from molasses

From the graph as we goes from 21 Brix to 42 Brix ,there has been a maximum calcium removal at 42 brix. This shows that at a lower ph value there has been a maximum calcium removal at higher Brix. At a Brix of 21 and ph 3.5 there has been a minimum calcium removal, resulting solubility of calcium components ,so we have observed a solubility effect at a higher dilution ,so as the formation of precipitation will be lower. In addition further dilution results larger equipment size and resulting extra cost of equipment.

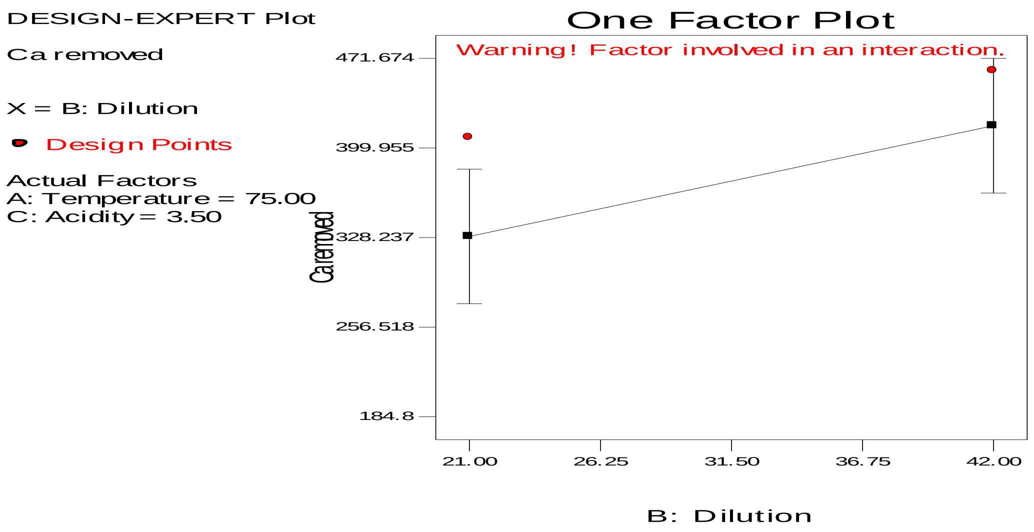


Figure 4.5: -Effect of brix on present Ca removed from molasses

C. Effect of pH on Ca removal from molasses

Ca removed from molasses is inversely proportional with pH that it increases with decreasing pH. This shows that using excess acid consumes the maximum Ca in the molasses. Similarly, as it can be seen from figure below, there is a maximum calcium removal at pH of 3.5. Therefore lowering the ph of the given molasses favors a maximum calcium removal. Processes which has been operated at a higher brix and at lower temperature has achieved a maximum calcium removal .this shows that the operation can be done at lower temperature with a minimum of steam consumption ,and reduces the cost of equipment which occurs due to further dilution of the molasses resulting a larger equipment size.

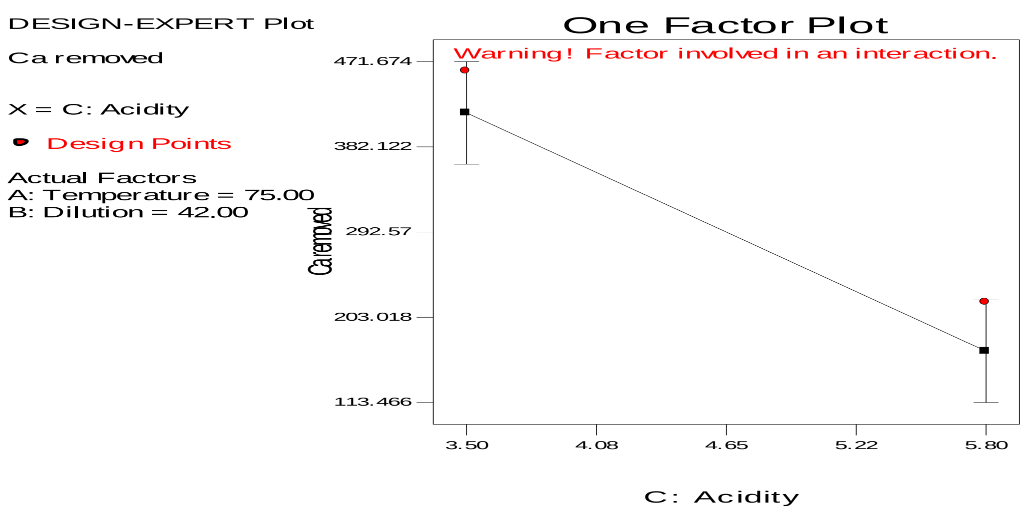


Figure 4.6: -Effect of pH on present Ca removed from molasses

ii. **Interaction Effect between Process Variables**

Interaction between Process Variables can affect the performance of clarification plant.. In this section, these effects are going to be seen statistically and graphically as follows:-

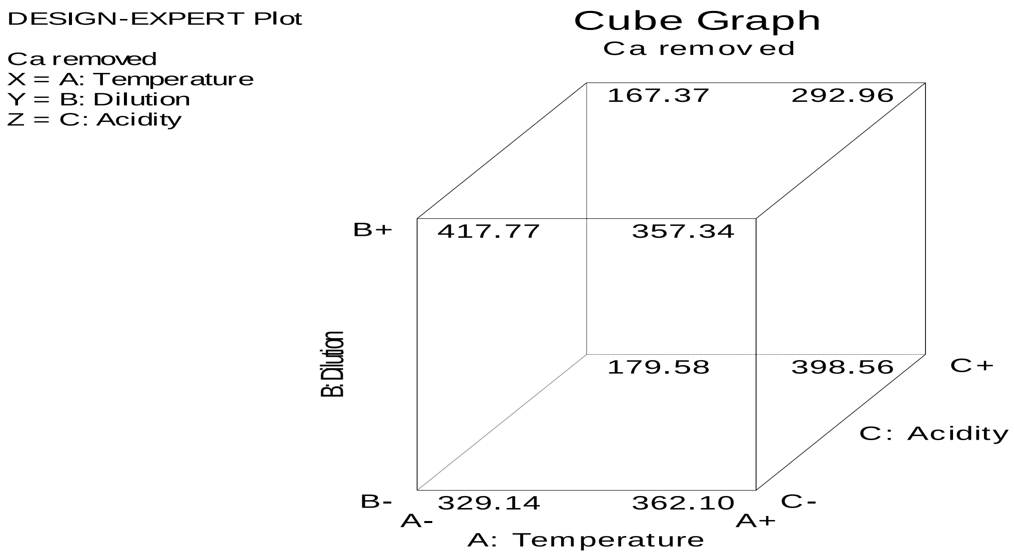


Figure 4.7- Cubic representation of interaction effects of temperature, pH and brix on present Ca removed from molasses.

a. **Temperature - pH interaction effect**

$$=\frac{1}{4*2}\ (\mathbf{398.56 - 179.10 - 362.10 + 329.14 + 292.98 - 167.37 - 357.34 + 417.77}) = \mathbf{372.06}$$

The result shows that temperature – pH interaction has effect on calcium removal. This is shown graphically in the figure below .From the graph,it can be seen that the lines are going to meet at some point this shows that there is significant interaction effect between temperature and pH of the molasses.

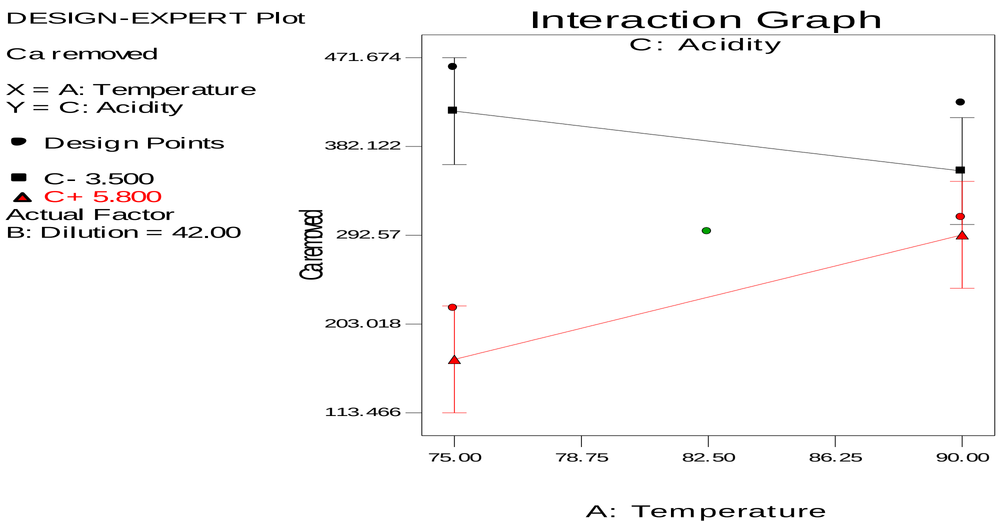


Figure 4.8: - Temperature-pH interaction effect on percent Ca removed

b. Temperature-brix interaction effect

$$=\frac{1}{4*2}\ (\mathbf{398.56 - 179.10 - 362.10 + 329.14 + 292.98 - 167.37 - 357.34 + 417.77}) = \mathbf{-186.78}$$

Temperature–brix interaction has a negative effect on calcium removed from molasses. This is shown graphically in the figure below. In this graph the lines are meeting together and this shows that there is an interaction effect between temperature and brix of the molasses.

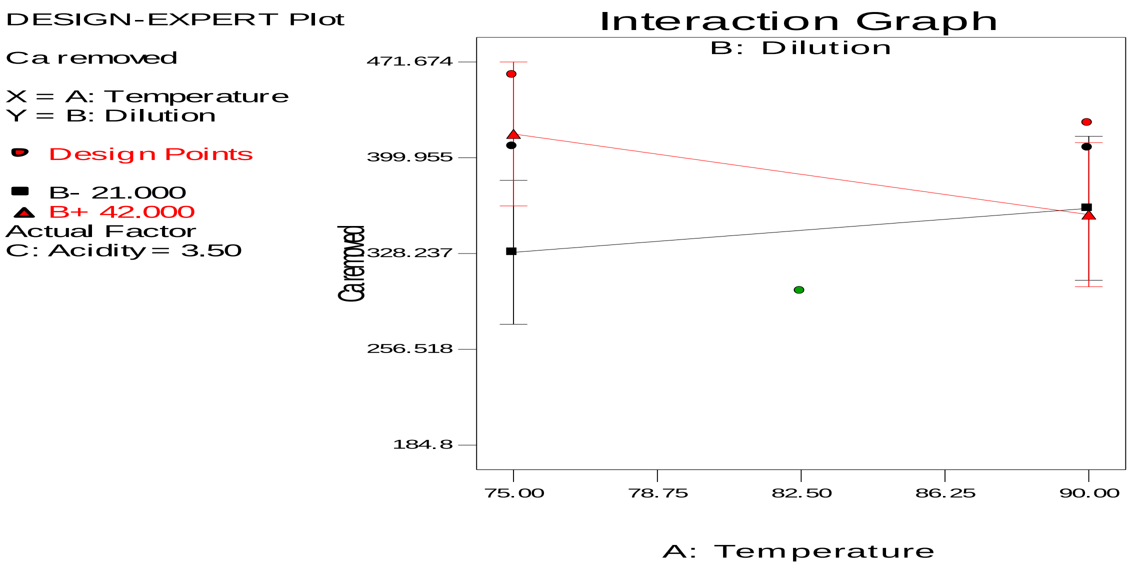


Figure 4.9: - Temperature-dilution interaction effect on percent Ca removed

c. **pH –brix interaction effect**

$$=\frac{1}{4*2}\ (329.14 + 362.10 - 179.58 - 398.56 - 417.77 - 357.34 + 167.37 + 292.96) = -201.68$$

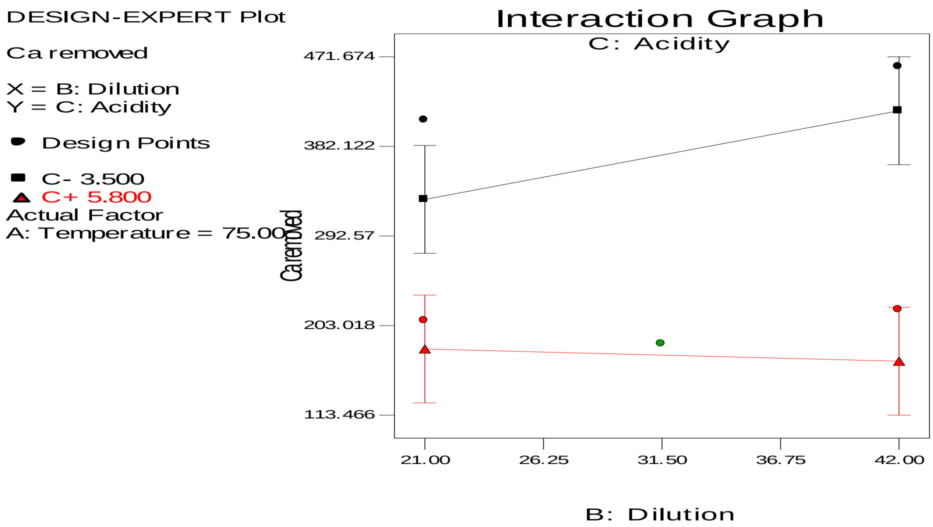


Figure 4.10: -pH-brix interaction effect on percent Ca removed from molasses

CHAPTER FIVE

DESIGNING OF THE CLARIFICATION PLANT

5.1 Processes Description

The raw material, molasses contains nutrients, carbon, nitrogen, vitamins and minerals that boost the growth of the fermenting micro-organisms, yeast. However, alongside these, the raw molasses contains substances that inhibit the micro-organisms' growth and can lead to difficulties in the downstream process. Among these are Calcium, sand and proteins derived from the sugar production process. It is possible to eliminate the bulk of these unwanted substances from the molasses. In this way high yield from fermentation process is assured and the reliable protection of downstream plant and equipment is maintained. To overcome these problems, these impurities must be clarified from the molasses as much as possible through different techniques, such as hot acid treatment, centrifugal clarification, and acid centrifugation. Among the given technologies, acid centrifugation has been selected as the best technology for molasses clarification. Acid centrifugation processes contains the following procedure, in order to reduce its high viscosity, the raw molasses is first diluted with water in a mixer and then preheated via heat exchanger ,the molasses must then be acidified with sulphuric acid ,as a result of acidification the calcium is precipitated as calcium sulfate and can therefore be easily separated during the subsequent separation process(Centrifugal separator).

The first step in the given process is dilution of the raw molasses from 84 ^{0} brix to 42 ^{0} brix. Dilution has many functions such as reducing the viscosity of the raw material, help the heat transfer process, and finally aid proper mixing with sulfuric acid. The given molasses solution is preheated to temperature of 75 ^{0}C in the heat exchanger. The molasses must then be acidified with sulphuric acid to pH of about 3.5. As a result of the acidification, the calcium in the molasses react with sulphuric acid and form precipitates of calcium sulfates which can easily be separated during the subsequent centrifugation process. In addition to facilitating clarification process, acidification and preheating of raw molasses helps to deactivate some undesirable microorganisms, especially bacteria. Acidification also facilitates inversion (hydrolysis) of sucrose in to glucose and fructose which are fermentable forms of simple sugars.

The clarification process is a continuous process, mixing of the raw molasses with treated water is done in a mixer, which is a simple cylindrical shape vessel fitted with an agitator., then the given solution is pumped in to the heat exchanger and heated to the optimum temperature, then the hot molasses solution is fed in to acidification tank (mixer) and acidified with sulphuric acid, as a result of acidification, the calcium is precipitated as calcium sulfate and the impurities in the molasses are separated by the aid of centrifuge. The clear molasses obtained from the centrifuge is called supernatant. Finally the treated molasses is sterilized and cooled to 32 ^{0}C using plate heat exchanger. The cooling water used in the heat exchanger going to be used as dilution water in dilution tank (mixer).

The proposed simple process diagram of the molasses clarification plant has been given in figure below.

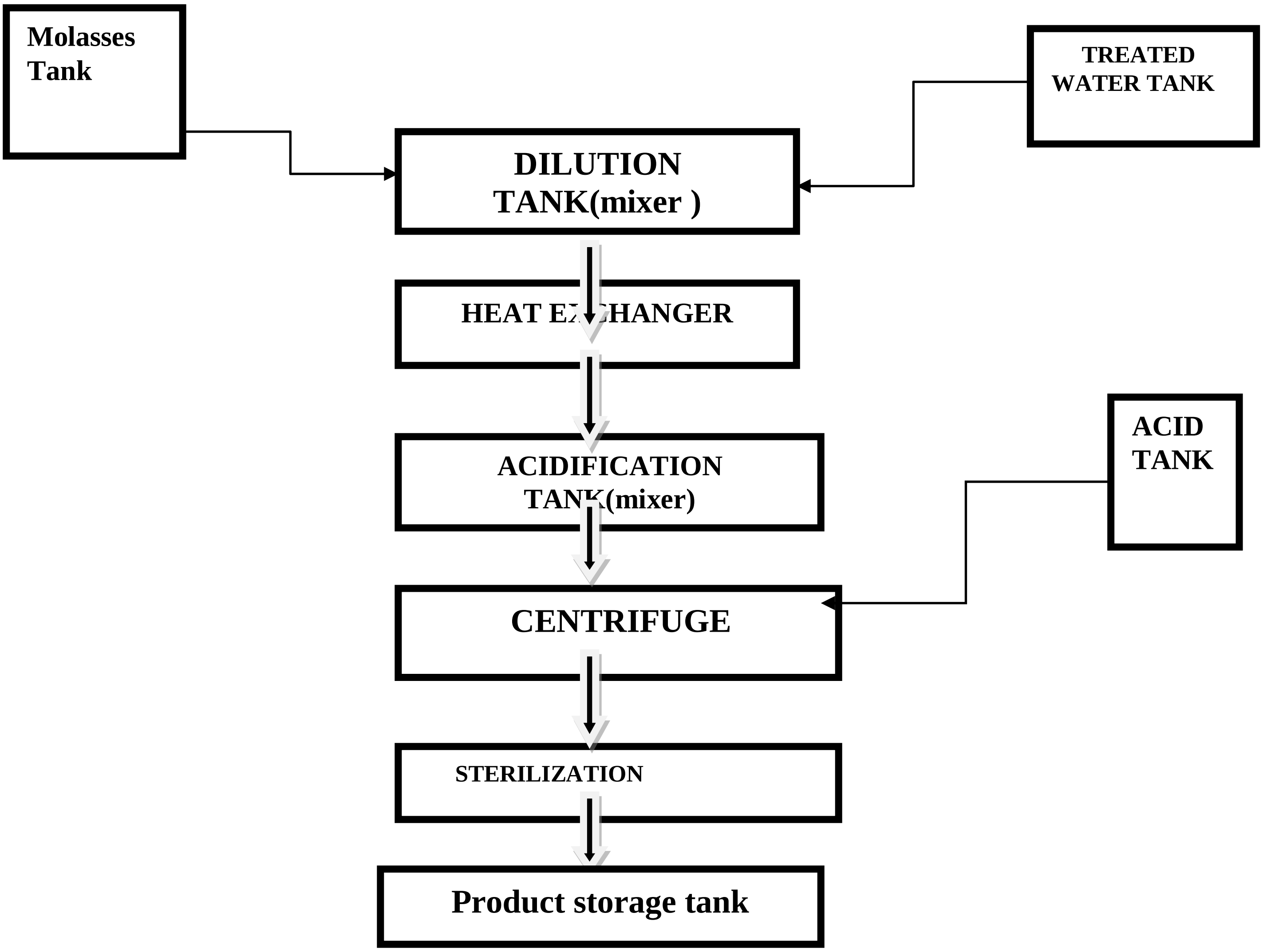


Figure 5.1: - Proposed molasses treatment plant

5.2. Equipment Design

Equipment design has been done by using the design method in *chemical engineering design* by *Coulson and Richardson's volume 6*. But, the equipments that cannot be fabricated locally have been specified and are to be purchased from abroad. No detailed design has been included for these equipments.

5.2.1. Dilution (mixer)

Mixing vessels fitted with some form of agitator are the most commonly used type of equipment for blending liquids and preparing solutions. Mixer is used for blending of, the raw material molasses and water, for the reduction of viscosity of the given molasses, makes it easy to flowing. Mixing occurs through the bulk flow of the liquid and, on a microscopic scale, by the motion of the turbulent eddies created by the agitator. Bulk flow is the predominant mixing mechanism required for the blending of miscible liquids and for solid suspension. Molasses and water are miscible liquids therefore the mixing mechanism will be bulk flow. This can be achieved through using a cylindrical shape vessel fitted with an agitator for creating uniform flow. According to the given brix of the raw molasses the reduction in brix is done by using water through a simple calculation. Initial molasses brix from laboratory result is 86 brix, reduced to the brix of 42,by using 95.5 % water .

i. Material Balance Dilution tank (mixer)

Proposed production capacity of baker yeast production is about 10 tone/day(10000 kg/d).Raw materials for production purpose are clarified molasses solution and ammonium sulfate, the given molasses is used as a source of sugar for the given plant .amount of molasses solution is determined through the given calculation .

From theoretical equation of the alcohol to yeast substance transformation theory as shown in the equation

$$\underset{(180)}{C_6H_{12}O_6} \longrightarrow \underset{(92)}{2C_2H_5OH} + \underset{(88)}{2CO_2}$$

The carbon from 180 parts of hexose will yield 92 parts of alcohol, which will be transformed into yeast substance. Four carbon atoms from the six in the original hexose will go to from yeast substance carbon – that is 180 parts of sugar yield 48 parts of yeast carbon. The average carbon content of yeast dry matter is about 47%, so that 48 parts of carbon from 180 grams of hexose sugar will form (48*100)/47 = 102.1 part of yeast dry matter. Maximum yield obtainable from 180 part of hexose sugar be 102.1 part of yeast dry matter, and 100 parts of hexose sugar would yield 57 parts of yeast dry matte. Theoretical annual baker's yeast production has been calculated 57% * Amount of hexose sugar used from *John (*1954*)*.

Theoretical baker yeast production = 57% * Amount of hexose sugar

The required amount of hexose sugar used for producing 10,000kg/d of baker yeast is determined Using the given equation

10,000kg/d = 57%* Amount of hexose sugar

$$\textbf{Amount of hexose sugar} = \frac{\mathbf{10{,}000kg/d}}{\mathbf{0.57}}$$

= **17,543.85 kg/d**

17,543.85 kg/d of fermentable sugar is required for producing the given 10,000kg /d of baker yeast, therefore the required molasses for obtaining the given fermentable sugar can be determined through using the given equation below. The molasses concentration of the fermenter is often standardized to between 5 and 7.5 percent sugar. Based on this 7% sugar concentration molasses has 13 % pole.

The amount of fermentable sugar is determined using

Mass of fermentable sugar = (Mass of molasses/d – Mass of (NH4)2SO4 /d)*0.13

17,543.85 kg/d = (Mass of molasses/d -10,497)*0.13

17,543.85 kg/d / 0.13= Mass of molasses/d - 10,497

134952.7 = Mass of molasses/d - 10,497

Mass of molasses sol /d = 134952.7 + 10,497

=**145,449.7 kg/ d**

After clarification of molasses through the given technique we obtain the 145,449.7 kg/ d , feed for centrifuge is determined by, considering 17.17% is sludge .

Feed of centrifuge = **145,449.7 kg/ d** + 17.17% Feed of centrifuge

(1- 0.1717) Feed of centrifuge=**145,449.7 kg/ d**

0.8283 Feed of centrifuge = **145,449.7 kg/ d**

$$\text{Feed of centrifuge} = \frac{\mathbf{145{,}449.7\ kg/\ d}}{0.8283} = 175{,}600.3\ \text{kg/d}$$

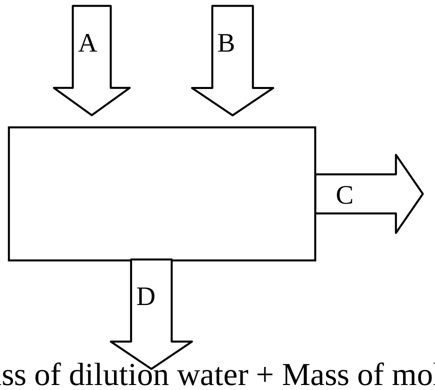
Molasses solution feed of centrifuge = 175,600.3 kg/d , **Sludge** = 30,150.6 kg/d

Material balance on mixer

A= molasses D= some un dissolved components

B= water

C= Diluted Molasses



Mass of dilution water + Mass of molasses = Molasses solution + some un dissolved materials

A + B = C + D

C = 175,600.3 kg/d

D = 1% **of C =** 1756.003 kg/d

Mass in =Mass out

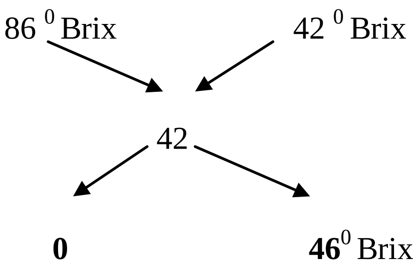
Mass out = C + D

Mass out = 175,600.3 kg/d + 1756.003 kg/d

= **177356.303 kg /d**

=177356.303 kg/d * 1d/24 hr **= 7389.84 kg/h**

From laboratory analysis result brix of the raw molasses is 86 ^{0} Brix , and it's going to be reduced to the 42 ^{0} Brix.



42 /46* 100= 95.5 % part is water

Let A = mass flow rate of molasses

B= mass flow rate of water

B = 0.955A

A + B = 7389.84 kg/h

A + 0.955A = 7389.84 kg/h

1.955 A = 7389.84 kg/h

A= 3779.97 kg/h

B = 3609.87 kg/h

Q $_{solution}$ **=** 7389.84 kg/h/(ρ_1X1 + ρ_2X $_2$)

= (7389.84 kg/h)/(0.51*1453 + 0.49*1000)

= (7389.84 kg/h)/(1231.03kg/m^3

Q $_{solution}$ **= 6 m^3 /h**

Dimension of the mixer

Let the tank holds the given diluted molasses solution foe 30 min, then the volume of the tank is determined

Volume of mixing tank = **Q** $_{solution}$ * **Time** ……….. …………………. **(5.1)**

= 6 m^3 /h *(**30** min)*(1h/60min)

=**3 m^3**

Assuming 7%safty factor

3*0.07= 0.21 m^3

Total volume of the tank = 3 m^3 + 0.21 m^3

V $_t$ = 3.21 m^3

From geometry of the tank, it is cylindrical shape therefore

V= $2\pi r^2$H ……………………………… **(5.2)**

= (πD^2 /4) H

There is a relationship between the diameter and height of the mixing tank ,it is called aspect ratio, in most cases 1.2-1.3 are most preferable ratios , choose 1.2 and it is the most economical ratio.

Therefore, H= 1.2 D

$$\mathbf{V}_t = (\pi D^2/4)\ 1.2D$$

$$3.21\ m^3 = 1.2\ (\pi D^3/4)$$

$$10.7\ m^3/\pi = D^3$$

$$3.41 = D^3$$

$$\sqrt[3]{3.41} = D$$

$$D = 1.5\ m$$

D = 1.5 m

H = 1.2*1.5= 1.8 m

Height can be approximated to 2 m

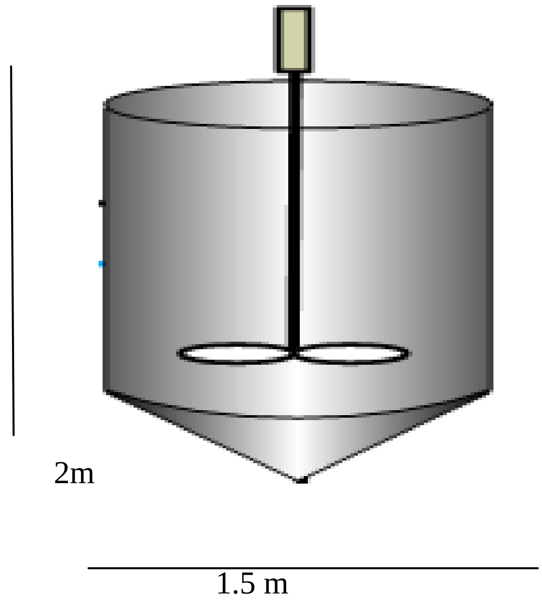


Figure 5.2 Mixer (dilution tank)

5.2.2 Molasses Heater

Shell and tube heat exchangers in their various construction modifications are probably the most widespread and commonly used basic heat exchanger configuration in the process industries. The reasons for this general acceptance are several. The shell and tube heat exchanger provides a comparatively large ratio of heat transfer area to volume and weight. It provides this surface in a form which is relatively easy to construct in a wide range of sizes and which is mechanically strong enough to withstand normal shop fabrication stresses, shipping and field erection stresses, and normal operating conditions. There are many modifications of the basic configuration, which can be used to solve special problems. The shell and tube heat exchanger can be reasonably easily cleaned, and those components most subject to failure gaskets and tubes can be easily replaced. Finally, good design methods exist, and the expertise and shop facilities for the successful design and construction of shell and tube exchangers are available throughout the world. It can be easily fabricated locally in ordinary fabrication shops of the sugar factories. This most commonly used type of heat transferring equipment, *i.e*., shell and tube heat exchanger, is to be used in this process to heat the molasses for facilitating the reaction between sulfuric acid and calcium components of the given molasses solution. Therefore the given molasses is pumped in to the heat exchanger through using a centrifugal pump in to the tube side of the given heat exchanger configuration.

i.Mass Balance

The material flow in = material flow out

Flow rate of diluted molasses entering in to HE = flow rate of molasses solution leaving the HE

Flow rate of molasses solution leaving the dilution tank =175,600.3 kg/d (7316.7 kg/h) = 2.03 kg/s.

M.= 7316.7 kg/h = 2.03 kg/s

The mass flow rate = 7316.7 kg/h = 2.03 kg/s

ii. Energy Balance

Properties of hot fluid

Type = saturated water

Pressure = 1 atm = 1.0133 bar

Temperature@1.0133 bar = 373.15 ^{0}K=100 ^{0}C (from steam table in perry page 349)

Assuming the approach temperature of the heat exchanger to be 80 ^{0}C .

C_p = 4.217 kJ/kg.k

Properties of molasses solution

Molasses solution initial temperature= 21.5 ^{0}C

Molasses solution final temperature to be = 75 ^{0}C

Specific heat of molasses taken from (book of Robert olibrich page 44, table 44) @ 42 ^{0} brix ,can be obtained by interpolation C_p = 0.71kcal/kg = 2.975 kJ/kg.k

$$\dot{\mathbf{q}} = \dot{\mathbf{m}} * \dot{\mathbf{Cp}} * \Delta T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(5.3)}$$

Heat load = mass flow rate*specific heat capacity*change in temperature

= 2.03 kg/s*2.975 kJ/kg.k (75^{0}C – 21.5^{0}C)

=**323.099 W**

$$\dot{\mathbf{q}} = \dot{\mathbf{m}} * \dot{\mathbf{Cp}} * \Delta T$$

Heat load = mass flow rate of hot water *specific heat *change in temperature

Mass flow rate of hot water = (Heat load)/ (specific heat *change in temperature)

= (323.099)/(4.217 kJ/kg .k *20 ^{0}C)

$\dot{\mathbf{m}}$ =**3.83 kg/s**

$$\text{Log mean temperature}=\frac{(100-75)-(80-21.5)}{ln\frac{(100-75)}{(80-21.5)}} = 34.2\ ^{0}\text{C}$$

Use one shell path and two tube path *(Appendix C)*

$$R= \frac{(100-80)}{(75-21.5)} =1.37$$

$$S= \frac{(75-21.5)}{(100-21.5)} = 0.55$$

From graph of temperature correction factor for one shell path and two tube path at *R=1.37* and *S=0.55* approximately *(Coulson & Richardson's, volume 6, page-657)*

Ft=0.96

Log mean temperature ΔTlm =0.96*34.2 ^{0}C = 32.83 ^{0}C

III. Dimension of the Heat Exchanger

$$\dot{q} = (UA\Delta Tlm) \qquad \text{…………………. ……….} \quad \textbf{(5.4)}$$

Total heating area, A = $\frac{\dot{q}}{(\Delta Tlm\ U)} = \frac{\mathbf{323.099\ W}}{(\mathbf{32.83 * 0.37})}$ = 26.599 m^2

From tube standard (coulson & Richardson's, volume 6, page-654) choose:

Pipe of: - 20 mm outer diameter

16 mm internal diameter

2 mm wall thickness

2.44 m long

Surface area of one tube = πDL $= \pi * 0.02 * 2.44 = 0.153$m^2

$$Number\ of\ tubes = \frac{total\ heating\ area}{surface\ area\ of\ one\ tube} = \frac{26.599}{0.153} = 173.85 = 174$$

$Tube\ per\ path\ = \frac{174}{2} = 87$ tubes per path

As the shell-side fluid, water, is relatively clean and cleaning not required use 1.25 Triangular pitches.

Bundle diameter, Db= $do\left(\frac{Nt}{K1}\right)^{\frac{1}{n1}}$ …………………………. **(5.5)**

Where **Nt = number of tubes,**

Db = bundle diameter, mm,

do = tube outside diameter, mm.

K1 and n1 read from table for 2-tube pass as : **K_1=0.249**

n_1=2.207

$$Db = 20\left(\frac{174}{0.249}\right)^{\frac{1}{2.207}} = 388.614 \text{ mm}$$

Use outside packed heat and from graph, shell-bundle clearance =38mm

Shell diameter= 388.614 mm + 38mm = **426.614 mm**

The most common material of construction for heat exchangers is carbon steel, Stainless-steel construction throughout is sometimes used in chemical-plant service and on rare occasions in petroleum refining. Many exchangers are constructed from dissimilar metals. Such combinations are functioning satisfactorily in certain services. Stainless-steel is selected as a construction of materials.

5.2.3 Molasses Acidification unit

The molasses must then be acidified with sulphuric acid to pH of about 3.5. As a result of the acidification, the calcium, magnesium and other inorganic salts in the molasses react with sulphuric acid and form precipitates as calcium and magnesium sulphates which can easily be separated during the subsequent settling process.

i. Material balance

Mass flow in = mass flow out

Flow rate of molasses solution leaving the heat exchanger =175,600.3 kg/d (7316.7 kg/h) = 2.03 kg/s. the given hot molasses is pumped in to the acidification unit operation, therefore mass flow in to the acidification tank = mass flow out of the tank = 175,600.3 kg/d (7316.7 kg/h)

ii. Energy balance

Energy balance equation

$$dQ = WCp\,\Delta\,Tt \qquad \textbf{.......................... (5.6)}$$

Where: - dQ = the increment of heat transferred in the time interval dt,

W = mass of molasses in the tank,2.03 kg/s

Cp = specific heat of molasses solution@ 42 brix = 0.71 cal/kg ^{0}c (2.43kJ/kg)

t = heating time (seconds) = 10min = 600 s

$Q = WCp\Delta Tt$

Q =2.03kg/s *2.43kJ/kg *(75-25)600 s = **147,987 J**

iii. Dimension of the Acidification unit

Molasses solution entering in to acidification unit =175,600.3 kg/d *(1/1231.03kg/m ^{3}) = 142.6 m ^{3}/d = 6m^3 /h * 20 min = 2 m ^{3}

Taking bases of 1 h , the volume of the given tank = 2 m ^{3}

Assuming 5% safety margin = 0.05*2 m ^{3} = 0.1m ^{3}

Therefore total volume of the tank = 2 + 0.1 = 2.1 m ^{3}

From the geometry of the tank, volume, V= = πr^2h = (πD^2 /4) H .... **(5.7)**

There is a relationship between the diameter and height of the mixing tank ,it is called aspect ratio, in most cases 1.2-1.3 are most preferable ratios , choose 1.2 and it is the most economical ratio.

Therefore, H= 1.2 D

$\mathbf{V}_t = (\pi D^2/4)\ 1.2D$

$2.1\ m^3 = (\pi D2\ /4)\ 1.2D$

$2.23 = D^3$

D =1.36 m = 1.4 m

H = 1.2 D = 1.68m= 1.7 m

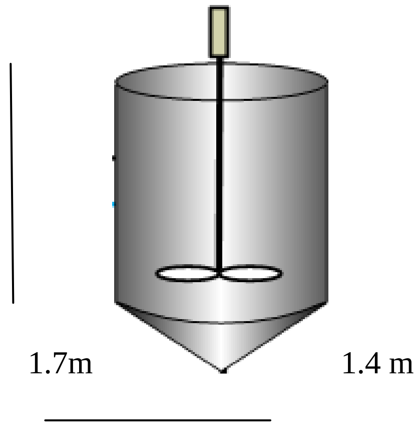


Figure 5.3 Mixer (acidification unit)

5.2.3 Molasses Centrifuge

Centrifuge is used for separation of heterogeneous mixtures in to components varying by density. Separation is achieved by spinning a vessel containing material at high speed; the centrifugal force pushes heavier materials to the outside of the vessel. The given molasses solution which reacts with sulpuric acid is transferred in to the centrifuge, and then separation between clarified molasses and sludge takes place. Disc stack centrifuge is a high speed, mechanical centrifuge used for separation and purification of mixtures comprising solids and liquids .These machines can be used in a wide range of applications. for example ,it can be used in extracting procedures for oil, for basic oil and water separation, and for filtration or removal of impurities of any solid or liquid product. it has a series of conical discs which provides a parallel configuration of centrifugal space. The disc centrifuge is used to remove solids (usually impurities) from liquids or to separate two liquid phases from each other by means of an enormously high centrifugal force. The denser solids or liquids which are subjected to these forces move outwards towards the rotating bowl wall while the dense fluids move towards the center. The special plates known as disc stacks increase the surface setting area which speeds up the separation process .The concentrated denser solid or liquid is then removed continuously manually or intermittently, depending on the design of the conical plate centrifuge. The given centrifuge rotates at high speed with many rotations per minute (rpm). This rotation introduces a centripetal force inward, and a relative centrifugal force outward. This relative centrifugal force is hundreds of times greater than the force of gravity. We know from everyday experience that a heterogeneous mixture of solid in liquid, when given enough time will separate due to gravity and result in sediment at the bottom of the container. The same principle is at work inside the high centrifugal force causes the separation to occur within minutes. In this section selection of centrifuge has been made rather than designing it.

i. **Material balance**

Mass flow rate in of molasses solution = mass flow out molasses solution

Feed into the centrifuge = clarified molasses + mass of sludge

Acidified molasses solution = mass of clarified molasses + mass flow rate of sludge

175,600.3 kg/d = 145449.7kg/d + 30,150.6 kg/d

Selection criteria for centrifuge is dependent on the throughput of the given solution which is given by a volumetric flow rate, the volumetric rate of the given feed is determined by dividing the given mass flow rate of the solution by mixture density.

175,600.3 kg/d *(1/1231.03 kg/m^3) = 142.7 m ^{3}/d = 5.94 = 6 m ^{3}/h

We have selected disc stack centrifuge having throughput of 6 **m ^{3}/h**

Through put capacity6 m ^{3}/h

Bowl speed 4600rpm


+

Figure 5.4 Disc stack centrifuge

5.2.4. Clear Molasses Receiving Tank

Clarified molasses from the centrifuge is transferred in to the molasses receiving tank. The dimension of the given tank is given below .once the clarified molasses pumped in to the storage tank; it will stay for certain period of time.

Molasses leaving the centrifuge = 145449.7 kg/ d = 118.15 m ^{3} /d *1/24 = 4.92 m ^{3} /h

Taking bases of 1 h , the volume of the given tank = 4.92 m ^{3}

Assuming 5% safety margin = 0.05*4.92 m ^{3} = 0.25 m ^{3}

Therefore total volume of the tank = 4.92 + 0.25 = 5.17 m ^{3}

From the geometry of the tank, volume ,V= $(\pi D^2/4)$ H

There is a relationship between the diameter and height of the mixing tank ,it is called aspect ratio, in most cases 1.2-1.3 are most preferable ratios , choose 1.2 and it is the most economical ratio.

Therefore, H= 1.2 D

$\mathbf{V}_t = (\pi D^2/4)\ 1.2D$

$5.17m^3 = (\pi D2\ /4)\ 1.2D$

$4.31*4 = D^3$

D = 1.76 m = **1.8 m** H = 1.2 D = 2.16 = **2 m**

CHAPTER SIX

FINANCIAL ANALYSIS OF MOLASSES TREATMENT PLANT

The capacity of the proposed project is processing cane molasses a bout **27,240 tone/annum**. The given molasses is going to be used as a raw material for the production of bakery yeast which is about **10tone/day (30,000ton/annum),** and evaluates the economic viability of the plant.

6.1. Investment Cost Estimation

The capital needed to supply the necessary manufacturing and plant facilities is called the fixed capital investment, while that necessary for the operation of the plant is termed the working capital. The sum of the fixed-capital investment and the working capital is known as the total capital investment.

Total Capital Investment = Fixed Capital Investment + Working Capital

Whereas **F.C.I =** 85- 90 % **of T.I.C**

W.C=15 -20 % **F.C.I**

I. Fixed Capital Investment

Fixed capital investment is the total cost of processing installations, building, auxiliary services, and engineering involved in the creation of new plant. About 85 to 90 percent of total capital is comprised generally of fixed capital. Typical percentages of fixed-capital investment values for direct and indirect cost segments for multipurpose plant or large additions to existing facilities. Fixed capital investment can be estimated by summation of the direct cost and indirect cost. There are several methods for determination of fixed cost of the plant; among them the first method this method requires initially that the cost of purchased process equipment. All components of direct cost are then estimated individually as equivalent to percentages of the equipment cost.

Table 6.1 Percentage of Fixed capital Investment (Peters, 1990)

Typical percentages of fixed-capital investment values for direct and indirect cost segments for multipurpose plant or large additions to existing facilities	
Component :	Range, %
Direct costs	
Purchased equipment	15-40
Purchased equipment installation	6-14
Instrumentation and controls (installed)	2-8
Piping (installed)	3-20
Electrical (installed)	2-10
Buildings (including services)	3-18
Yard improvements	2-5
Service facilities (installed)	8-20
Land	1-2
Total direct costs	
Indirect costs	
Engineering and supervision	4-21
Construction expense	4-14
Contractor's fee	2-6
Contingency	5-15
Total fixed-capital investment	

In the given cost estimation some costs like land moving, building cost and other minor costs have not been included, because the given plant is going to be installed in the given sugar plant aiming to have the clarification plant .in order to reduce the investment cost we proposed the plant to be installed in Wongi sugar mill. Therefore some civil work costs like foundation works of tanks and pumps and floor works has been included. Therefore based on the given platform the given cost estimation can be done by determining the purchased equipment cost of the given plant which is given in the table 6.2.

Table 6.2: - purchased equipment cost molasses clarification plant

Equipment cost				
Description	**Material of construction**	**Quantity**	**Unit (birr)**	**Total cost (birr)**
Dilution Tank (mixer)	Carbon steel	1	V= 3.21 m^3 =850 gallon	931500
Heat exchanger	Stainless steel	1	Area=27 m^2 =287 ft^2	1382400
Acidification unit (mixer)	Carbon steel	1	V=2.1 m^3 = 554gallon	607118.82
Centrifuge	Stainless steel	1	1061100	1061100
Centrifugal pump	Carbon steel	7	54900	384300
Gear pump	Carbon steel	4	54900	219600
Clarified molasses tank	Carbon steel	3	425000	1275000
Purchased Equipment Cost				**5861018.82**

PURCHASED EQUIPMENT COST=E=5861018.82

A.DIRECT COST

Direct cost can be determined based on purchased equipment cost .cost of purchased equipment is the basis of several pre design methods for estimation of capital investment. Estimating by percentage of delivered equipment cost is commonly used for preliminary and study estimates. it yield most accurate results when applied to a project . E=5861018.82 Birr

Table 6.3 Direct Cost

No	COMPONENTS	%E	COST
1	Purchased equipment installation	47%E	2754678.8454
2	Instrumentation	12%E	703322.2584
3	Piping	3%E	175830.5646
4	Electrical	11%E	644712.0702
5	Building (including Service)	18%E	1054983.3876
6	Yard improvement	10%E	586101.882
7	Service facilities	8%E	468881.5056
8	Land	1%E	58610.1882
		Total	**6,447,120.702**

B.INDIRECT COST

Table 6.4: Indirect Cost

No	COMPONENT	%E	COST
1	Engineering & Supervision	10%E	586,101.882
2	Construction Expense	14%E	820,542.6348
3	Contractor's Fee	6%E	351,661.1292
4	Contingency	10%E	586,101.882
Total			**2,344,407.528 Birr**

FIXED CAPITAL INVESTMENT = DIRECT COST + INDIRECT COST

= 6447120.702 + 2344407.528

= **<u>8791528.23 Birr</u>**

T.C.I = F.C.I + W.C

W.C=15-20% F.C.I

T.C.I= F.C.I + 0.2 F.C.I

T.C.I =1.2F.C.I

=1.2*(8791528.23)

=**10,549,833.876 Birr**

6.2. Operating Cost Estimation

Cost that encored due to day to day operation of the given clarification plant is called operating cost . Production costs are generally expressed in terms of cost per unit of output. These costs includes cost of raw materials which are costs of chemical feed stocks, cost of operating labor which includes the personnel required for plant operation, cost of utilities which includes costs for utilities depending on the amount of consumption.

Table 6.5: Raw material cost

No	Description	Unit	Quantity	Cost/ Unit (Birr)	Total Cost (Birr)
1	Molasses	Ton	27,240	69	1,877,407.2
2	Acid	Ton	50,063	7425	371,717.8
Total					**2,249,125**

Table 6.6: Utility cost

No	**Description**	**Unit**	**Quantity**	**Cost/ Unit (Birr)**	**Total Cost (Birr)**
1	Steam	Tone	99,273	4359.9	432,822.96
2	Water	m^3	51,969.6	5.6	291,029.76
	Sub total				**723,852.73**

Table 6.7: Operating labor

No	Description	Quantity	Cost/ Unit (Birr)	Total Cost (Birr)
1	Chemical Engineer	1	7500	7500
2	Operator	3	2000	6000
3	Assistant Operator	3	1300	3900
Sub Total				**17,000*12=214,800**

6.3. Total Production Cost

Table 6.8: - Total production cost of molasses clarification plant

No	Component	Percentage	Basis	Birr
Manufacturing Cost				
Direct Cost				
1	Raw material			2,249,125
2	Operating labor	214,800		214,800
3	Direct supervisory &Clerical labor	15%OL		32,220
4	Utilities			723,852.73
5	Maintenance &repair	6%FCI		527,491.69
6	Operating supplies	15% M&R		79,123.75
7	Laboratory charges	10%OL		21,480
8	Patents & royalties	1%sales		90,000
	Fixed charges			
9	Local taxes	2%FCI		175,830.6
10	Insurance	1%FCI		87,915.28
11	Plant overhead cost	50%(OL + M)		371,145.8
General Expenses				
12	Administration cost	20 % OL		42,960
13	Distribution and selling cost	7% sales		630,000
14	Research and development	2%sales		180,000
15	Financing	10%TCI		1,054,983.38
Total production cost				**6,480,928.2**

6.3. Profitability Analysis

Price of product = 300 birr/ton

Revenue = Capacity *unit cost

=30000ton/annum *300 birr/ton

= 9,000,000 birr

Gross Profit = Main product revenue - Total production cost

= 9,000,000 birr - 6,480,928.2Birr

= **2,519,071.8 birr**

Net profit = Gross Profit- taxes

=2,519,071.8 birr - 175,830.6

=2,343,241.2 birr

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATION

7.1. Conclusion

Molasses is regarded as a waste product by the sugar industry; it is understandable why the sugar manufacturers are not interested in altering their processes to produce a by-product, which is of minor value, with a composition especially suitable for another industry. Certain steps within the usual sugar manufacturing process resulting in an improvement in the molasses quality can be looked on as a realizable objective. Of all industries processing molasses the manufacture of yeast makes the highest demands on the quality of commercial molasses .Clarification of molasses is one of the beneficiary plants, which helps bakery plants and sugar mills. Since bakery plant requires for good raw material for bakery production. in addition the process is simple and cost effective. The study was investigated primarily aimed to characterize and clarification of cane molasses for the production purpose of bakery yeast. This would help to analyze the raw material cane molasses, through identifying the basic biochemical compositions and some inhibiters that affect bakery yeast production .calcium was considered as the major inhibitor among the other inhibiters ,different techniques has been used for removal of the given inhibitors(calcium), hot acid treatment ,centrifugal clarification ,acid centrifugation were used for clarification purpose. Among the technique acid centrifugation has been selected as the best clarification method .The result obtained through using this technique shows the raw material molasses which has been operated at the process condition of brix 42, ph of 3.5 ,and temperature of 75 ^{0}C has given the best calcium removal . About Production scales 10tone/day (30,000ton/annum) other technical and economical parameters specified in the thesis. Therefore we can conclude that the raw material cane molasses can be a potential cheap source of sugar and other nutrients for yeast production if it is treated well, Ethiopian cane molasses can be used as a raw material for yeast production .the compositions of the molasses good enough for the production purpose, clarification can be done in different way ,among the techniques acid centrifugation was the best technology for treatment purpose.

7.2. Recommendation

Ethiopian molasses can be used as a potential raw material for production of baker yeast, and, it is better to incorporate these clarification plants within the sugar mill factories ,once it reduce the transportation cost, contamination of the raw material .in addition if bakery plants are established for future , further techniques and advanced clarification can be adapted by incorporating the given proposed technology. Ethiopian cane molasses also faces a shortage of basic elements for yeast growth such as nitrogen, phosphors, magnesium; among them the most useful one is nitrogen that can be supplied as aqueous ammonia. In addition Ethiopian molasses has high calcium and ash content .Therefore further treatment of Ethiopian molasses and addition of other supplement will enhance the possibility of utilization of cane molasses for production purpose of bakery yeast.

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