Investigation of Sugar Losses at Different level through Process Analysis a Case Study at Matahara Sugar Factory

Gizacho Asfawu Tolan

A Thesis Submitted To

The Department of Mechanical Design & Manufacturing Engineering Program

School of Mechanical, Chemical and Materials Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master's In Mechanical Engineering (Manufacturing Engineering)

Office of Graduate Studies

Adama Science and Technology University

August, 2022

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Advisor Dr. Gutata Kabeto (PhD)
Assistant Professor

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Declaration

I hereby declare that this Master Thesis entitled "Investigation of Sugar Losses at Different level through Process Analysis a Case Study at Matahara Sugar Factory" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation

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Name of the student	Signature	Date

Recommendation

I/we, the advisor(s) of this thesis, hereby certify that I/we have read the revised version of the thesis entitled "Investigation of Sugar Losses at Different level through Process Analysis a Case Study at Matahara Sugar Factory" prepared under my/our guidance by Gizacho Asfawu submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Mechanical Engineering.

Therefore, I/we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Advisor	Signature	Date
Co-advisor	Signature	Date

Approval Page of MSc. Thesis

I/we, the advisors of the thesis entitled "Investigation of Sugar Losses at Different level through Process Analysis a Case Study at Matahara Sugar Factory" and developed by Gizacho Asfawu, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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Major Advisor Signature Date

We, the undersigned, members of the Board of Examiners of the thesis by Gizacho Asfawu have read and evaluated the thesis entitled "Investigation of Sugar Losses at Different level through Process Analysis a Case Study at Matahara Sugar Factory" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Mechanical Engineering.

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Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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ABBREVIATION

Acronym	Nomenclature
AFW sugar	A-Fore worker sugar (1st cured A-sugar)
C-massecuite	2nd grade boiled massecuite
COMESA	Common Market for Eastern and Southern Africa
DMAIC	Define, Measure, Analysis, Improve, Control)
D-massecuite	Last massecuite (low grade massecuite)
FMG	Food Manufacturing Group
EPA	European Productivity Agency
GM	Ground mean
GNP	Gross National Product
HVA	Handels -Vereening Amsterdam
ISO	International organization for Standardization
KPI	Key Performance Indicators
LAL	Lower Action limit
LWL	Lower warning limit
MSF	Matahara Sugar Factory
OEE	Overall Equipment Efficiency
PDAC	Plan, Do, Check, Act
PI	Preparation Index
PM	Preventive maintenance
Pol	Polarization
RPM	Revolution Per Minute
SIOPC	Supplier, Input, Process, Output, Customer
SPC	Statistical Process Control
SPSS	Statistical package for social science
TQM	Total quality management
TCD	Tons of cane Crushed per day
UAL	Upper action limit
UWL	Upper warning limit

ABSTRACT

Now a days the struggle to survive in a global market competition has become threatening and even though productivity of manufacturing industry plays significant role in enabling an industry to survive in this competition, it can be negatively impacted by the presence of bottlenecks in production system. However, production bottlenecks are uninventable, they can be a key ingredient to enhance productivity and profitability of the entire production. This study focuses on improving productivity through process analysis, evaluating and managing equipment failure and operational loss of sugar in byproducts to enhance productivity during cane processing in cane sugar factory. As case study, Matahara Sugar Factory (MSF) was used. The statistical process control (SPC) tools and Statistical Package for the Social Sciences (SPSS) were used in this work to collect, compute, and analyze data. The descriptive study was conducted to examine the impact of machineries failures and sugar losses during cane sugar processing and controlling mechanisms were suggested to minimize the effect of machinery component failure and sucrose losses with by product. The company sugar losses in bagasse, filter cake, final molasses, and undetermined were 0.725%, 0.51%, 1.78%, and 0.45% respectively. In the last five years, sugar losses with bagasse, filter cake and molasses were totaled 3.37%, or 927,512,115.03 Birr. Therefore, it has been concluded that identification and elimination of production bottleneck has great positive impact on productivity improvement and loss reduction which ultimately ensures a company's profitability.

Keywords*: bagasse, sugar, losses, sucrose, bottleneck, productivity*

CHAPTER-1

INTRODUCTION

1.1 Introduction

This chapter describes the background information, location of the sugar factories in Ethiopia, role of the sugar industry, performance of the sugar factory, the statement of the problem, objectives of the study, motivation, significance of the study, scope of the study and limitation of the study.

1.2 Back ground

The Matahara sugar factory is found in Oromia region at 200 Kilo Meters distance from Addis Ababa. Same as Wonji Shoa Sugar Factory its construction was carried out by H.V.A. Company of the Netherlands. The factory started sugar production in 1970. Formed as Share Company between the then Ethiopian government and the constructing company, it was the second sugar mill to the nation. Its sugarcane plantation filed is 10,230 hectares and has the potential to produce more than 130,000 tons of sugar per year. Through an expansion project conducted it came up with an ethanol producing plant by the end of 2010. Currently the factory's ethanol plant has a capacity of producing 12,500 Meter Cube ethanol per year. It also generates 9 megawatts of power from bagasse. This makes it self-sufficient in getting its own power supply. Merti is the head quarter of the factory in which sugar production plants (boiler and power plant, cane handling, milling, clarification, evaporation, vacuum, centrifugal) and ethanol plant found at. The factory has designed production capacity of 5000 TCD (tons of cane crushed per day). Sugar industry is one of the biggest agro-industries in Ethiopia and one of the most competitive sectors for the national economy. The country has suitable weather conditions at different areas for cane plantation and sugar production. There are three sugar factories with total production of about 3,000, 000 tons of plantation white sugar per year. Now days there are a number of projects undertaking in Ethiopia to expand the existing and to install new sugar (Metahara Sugar Factory Strategic Plan Manual, 2021).

The main goal of sugar cane factory is to have an efficient and profitable operation with the required sugar quality and maximum sugar recovery with high productivity. The problems in sugar industries is the loss of sucrose in operational process. The monetary value of the losses of sucrose is of extreme importance because of the direct impact on productivity and profitability. Generally two types of sucrose losses are existing in sugar factories, namely, known or determined and unknown or undetermined losses. The known loss consists of losses of sucrose with by-products: sucrose loss in bagasse, sucrose loss in filter cake, and sucrose loss in molasses. Undetermined sucrose loss includes chemical (inversion), biological and mechanical losses (sucrose that is unaccounted for when completing a mass balance over the mill). All of these components need to minimize to maximize sugar recovery (Rasitc, 2004).

1.3 Production process

Cane preparation

The cane carrier is the moving apron which conveys the cane into the factory and which ensures consistent feed to the mills by transporting the cane from the yard to the crusher. Since effective feeding of the crusher requires an elevated hopper, and the cane must be raised to this high level from the level of the yard, where the carrier is generally in a pit, the carrier always includes a sloping portion. The cane carrier consists of knives and hammers to break down the cane before passing it through to a crusher and shredder. The crusher is the first machine applying pressure which the cane encounters on arriving at the milling plant (Mohammed, 2017).

Juice Extraction System

The juice is extracted from the cane either by milling, in which the cane is pressed between the heavy rolls, or by diffusion, in which the sugar is leached out with water. The sugar cane bagasse produced at the extraction is delivered to the boiler plant, where it is used as fuel, producing the steam and electricity to the factory. The juice extracted from the cane is treated in the subsequent process to remove the non-sugar impurities (Merkane, 2011).

Clarification

This involves separation of impurities from the juice by adding flocculants which will react with organic material and precipitation of non-sugar debris (mud) will follow. The clarification process gives clear juice to be sent to the evaporation process and mud which juice will be filtered further (Birru, 2016).

Filtration:

This involves the filtration of the mud from the clarification process in order to separate suspended matter and insoluble salts formed (fine bagasse is entrained with these) from the juice (Birru, 2016).

Juice Evaporation

Evaporation is performed in two stages: initially in an evaporator station to concentrate the juice and then in vacuum pans to crystallize the sugar. The clarified juice is passed through heat exchangers to preheat the juice and then to the evaporator stations. Evaporator stations consist of a series of evaporators, termed multiple-effect evaporators; typically, a series of four evaporators. Steam from large boilers is used to heat the first evaporator, and the steam from the water evaporated in the first evaporator is used to heat the second evaporator. This heat transfer process continues through the four evaporators and as the temperature decreases (due to heat loss) from evaporator to evaporator, the pressure inside each evaporator also decreases which allows the juice to boil at the lower temperatures in the subsequent evaporator. Some steam is released from the first three evaporators, and this steam is used in various process heaters in the plant. The evaporator station in cane sugar manufacture typically produces a syrup with about 60percent solids and 40 percent water (Muwanika, 2017).

Syrup sulphitation

Syrup (concentrated clarified juice) from the evaporation system is sulphited to PH of about 5.5 by addition of the bleaching agent, so_2 gas, to improve the color of final product (Merkane,2011).

Sugar Crystallization and Centrifugal Separation

The massecuite from the pan is dropped in crystallizers and subsequently centrifuged in centrifugal machines for separating sugar crystals from mother liquor (molasses). The Crystals are washed, dried, cooled and sent to packaging or to storage. The mother liquor (molasses) again is sent back to pan for boiling and re-crystallization. Usually three stages of re-crystallization are adopted to ensure maximum recovery of sugar in crystal form. The final mother liquor referred to as final molasses is sent out of the factory as by-product being unsuitable for recovery of sugar under commercial conditions from economic point of view (Merkane,2011). The schematic representation of cane plantation white sugar production in MSF shown in Figure 1.1.

A major problem with productivity is that it means many things to many people. Economists determine it from Gross National Product (GNP), managers view it as cost cutting and speed up, engineers think of it in terms of more output per hour. But generally accepted meaning is that it is the relationship between goods and services produced and the resources employed in their production (Kumer and Susher, 2008).

The main purpose of this study is identify the losses area though process analyzing then after identify the area of losses find the root causes of the losses in depth and find proper solution by using statistical process control method.

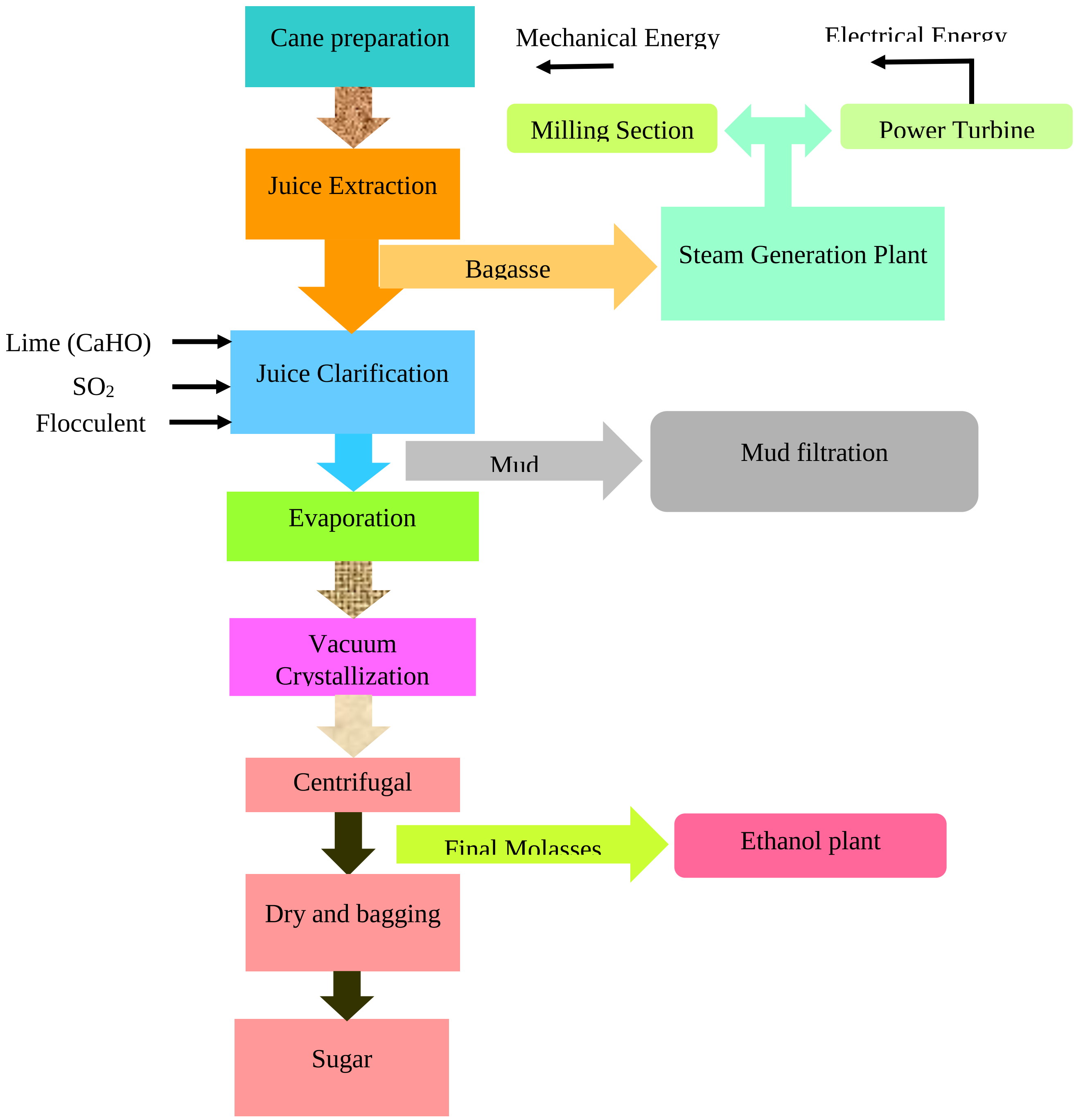

Figure 1.1 Schematic representation of cane plantation white sugar production in MSF

1.4 Location Ethiopian Sugar Factories

Currently, there are eleven large-scale sugar factory establishments in the country; four of them are in the Awash Basin (Wonji Shoa, Metehara, Kesem and Tendaho); two of them (Finchaa and Arjo Dedesa) in the Blue Nile Basin; the other three (Omo 1, Omo 2 and Omo

3) are in the southern region of Ethiopia and two sugar factories (Tana Beles 1 and Wolkayit) in the northern part of the country are under erection. These sugar companies except Omo 1, Tana Beles and Wolkayit are presently producing plantation white sugar for the local market with lower capacities due to different reasons for each factory (Tesfaye, 2020). The Geographical location of sugar factories in Ethiopia as shown Figure 1.1 below.

Figure 1.2 Geographical location of sugar factories in Ethiopia (source: Google earth)

1.5 Role of Sugar Industry

The present Sugar Corporation with a vision of executing sugar development activities at a large scale came into existence on October, 2010 by the Council of Ministers Regulation No.192/2010. It is operating under a board of directors. Currently the Corporation is accountable to Public Enterprises' Property and Administration Agency as dictated on proclamation number 1097/2018. Ever since its establishment in October 2010 Sugar Corporation has benefited communities of the areas in which the development is going on. It has made irrigation, potable water, roads, schools, health posts and other social service institutions available for the local community. It is also expanding land covered with sugarcane, increases the number of sugar factories and creates job opportunities. However; it is possible to witness that it has yet to do a lot in increasing housing construction, and sugar co-products supply. To fulfill its major goals and tackle problems faced the Corporation is implementing change management and other series of tasks. Along with this capacity building trainings are going on locally and abroad. Corporation Sugar Industry Sub Sector Sugar development sector is one among other huge projects which enables industry take a leading role in the nation's economy. Ethiopia has huge human as well as natural resources which enable the nation to broaden this export oriented manufacturing industry sector and its productivity. The nation has suitable climate, 1.4 Million hectares wide and proved irrigable agricultural land as well as abundant resource of water and ample labor resource (www.ethiopiansugar.com, 2019).

1.6 Statement of Problem

Yearly due to many problems production volume is not as planned. There are sugar losses in bagasse, filter cake, final molasses and undetermined losses. In addition to maintenance problems the escalation cost of spare parts, inventory control, raw material supply quality, quantity and COVID in resent time. Therefore, the existing Sugar factory need to improve on the recovery of sucrose, to become productive, competitive and profitable. During the crushing season 2020/21 from Oct15 to May15, the factory have a plan to crush 1,008,743.3 tons cane and crushed only 889,510.6 tons with 12.84 flied yield and plan to produce 97,163 ton of sugar and achieved 76,266.6 tons of sugar. Based on this figure the factory achieved 78.5 % of the plan and this report indicate that there is machine failures and sugar losses in the factory.

1.7 Research Question

Based on the above stated statement of problem this research will be conducted to answer and put finding for the following research questions.

1- What are the production bottlenecks in MSF?
2- Which bottleneck contribute for the significant change of production performance?
3- What are the techniques for controlling of losses in cigarette making operations?

1.8 Objectives

1.8.1 General Objective

The main objective of this study is to enhance productivity by minimizing sugar losses during operation campaign in matahara sugar factory.

1.8.2 Specific Objectives

The specific objectives of the study are as follow:

1. Investigation of production bottle necks for consecutive five years
2. Determine the root causes of sugar losses in different sections (milling, clarification and centrifugal section).

3. Analyze the controlling mechanisms to improve productivity

1.9 Motivation

Matahara sugar factory is the oldest among the existing sugar factory and newly erupt projects in Ethiopia. The reduction of productivity and profit due to break down of machineries and operational factors that cause losses of sucrose in bagasse, filter cake and final molasses at extraction, clarification and centrifugal section respectively. The factory losses increases gradually to abnormal stage, so this motivate to plan in-depth investigation/analysis the losses of sucrose issues in this MSc thesis work.

1.10 Significance of Study

In sugar production firm, the big headache is how to minimize machinery breakdown and losses of sucrose to maximize the company's profit and sustain the system. Based on this, in MSF there is huge impact on production and productivity of sugar due high losses in bagasse, in filter cake, final molasses and undetermined, so this study was concerned to minimize the effect machine break down and losses of sugar production and bring the company to profitable. Losses are difficult to completely eliminate, but they can be minimized to levels that meet local and global acceptance. Being in the actual location where the actual problem can be easily analyzed knowledge will be gained by having a full research of this particular losses problem. Second, this thesis will lay the foundation for additional research on the subject at hand. Reducing losses at all stages and raising productivity will ultimately help the factory achieve its main objectives, which are the enhancement of the product and productivity.

1.11 Scope and Delimitation of the Study

The goal of this study is to investigate potential production bottlenecks, along with how machine failure and sugar losses affect production, production performance, and productivity. In this research continuous improvement approach has been investigated and suggested towards eliminating production bottlenecks of a MSF. This research takes MSF as a case study on identifying production bottlenecks of sugar factory. In this research only five years data of a selected as a case study company has been analyzed, since increasing the amount of data will makes the study complex and also difficult. Besides there was time and budget limitation to include more than five year data.

1.12 Organization of Thesis

The thesis work incorporates five main chapters including introduction, literature review, research methodology, data collection and analysis, and finally conclusion and recommendation. The first chapter is introduction and it briefly explains about the objectives, problem statement, significant of the study etc. and the second chapter, literature review, discusses various literature on related subjects and previous works. The third chapter proposes appropriate research methodology and under the fourth chapter, data collection and analysis, collected data has been presented as well as root-cause analysis has been conducted and discussed. In the last chapter, conclusion and recommendation has been made and presents what should be done to ensure continuous improvement of production performance and productivity.

1.13 Limitation of the Study

This thesis work may be limited to the following factors

- Data collection was challenging because of the company profile and network issues.
- There was time and budget limitation to include more than 5 years data.
- The study program was running in addition to my job and the distance limits my regular face to face contact with my advisor was a challenge.

CHAPTER-2

LITERATURE REVIEW

2.1 Introduction

The main production from sugar mill is white crystal sugar and the by-product of bagasse, molasses and filter cake. The level of sugar productivity is influenced by the quality of sugarcane and the efficiency of the factory (Gunawan et al, 2018).More than 60% of the world's sugar production is from sugar cane; the balance is from sugar beet. Sugarcane contains not only sucrose but also numerous other dissolved substances, as well as cellulose or woody fiber. Sugarcane is generally about 70% water, 15% fibrous material and the remaining is dissolved solids. The major composition of sugar cane is given below: Sugarcane: 100%, Water: 70 to 73%, Fiber: 12 to 15%, Sugar (sucrose): 11 to 14%, Dissolved non-sugar solids: 2 to 3%. In extreme cases there would be even wider variations, depending upon the age and varieties of cane and also the climatic factors like temperatures, humidity soil condition agricultural practices (Merkane, 2011).

Sugar in Ethiopia serves for direct household consumption and as an intermediate input for other industries like pastries, bottling companies and breweries. The per capita consumption in Ethiopia is one of the lowest in the world. The current level of per capita consumption is estimated to be about 3.6 kg, which is even below the world average minimum of 5 to 6 kg. The Ethiopian consumption of sugar was forecasted for the coming 10 years, taking into account the current Ethiopian population of 108 million in 2019, population growth rate per annum of 2.53 % and an annual average economic growth rate of 13.09%. It is assumed that the per capita sugar consumption could increase at the rate of the economic growth of the nation (Bocha, 2019).

Sugar factory have its own procedure to start with a cane and end with white sugar after long journey of production process. The sugar production process broadly classified in to eight main section in matahara sugar factory. Those are:-cane handling and preparation, extraction plant, clarification, evaporation, vacuum, centrifugal, bagging floor, boiler and power station.

2.2 Productivity

Production, quality performance, is a component of productivity effort. Thus, productivity is a combination of effectiveness with efficiency. The higher the predicted value of the yield, the higher the production. The high value of sugar yield shows that the performance of the sugar factory is optimal and efficient. Identification of productivity is done through efficiency assessment. Where productivity is a ratio between output and input used to produce sugar. The higher the productivity the higher the production of sugar. This is because the ratio of resource inputs such as machinery, sugarcane raw materials, additives used to produce sugar is used efficiently and effectively (Gunawan et al.,2018).

Productivity is a measure of how efficiently inputs are converted into outputs. It measures how well resources are used. For a business, the more the products made, the lower the overhead, and the higher the profits. Enhanced production lowers the cost per unit of a product which in turn, resulting in lower prices for better quality, which enhances a business' competitiveness in the market (Kanyoni et al., 2021). Factors influencing productivity can be broadly classified into two categories: controllable or internal factors and un-controllable or external factors. Under the controllable factors Product factor, Plant and equipment, Technology, Material and energy, Human factors, Work methods and Management style are listed. From the above listed controllable factors technology is one of the considered factor in this study. The various aspects of technology factors to be considered are: Size and capacity of the plant, Production planning and control, Repairs and maintenance, Waste reduction, and Efficient material handling system. Factors that are classified under the controllable are: Structural adjustments, Natural resources and Government and infrastructure (Kumar, 2008).

The efficiency of transformation of raw materials, both human and material, into useful services and goods is indicated by productivity (Singal et.al, 2016). Productivity is a broad term whose definition is different for different peoples. Productivity as a measure of the efficiency with which a company or an enterprise converts its available resources (inputs) into finished goods or services. But it can be also defined as the effectiveness of productive effort, especially in industry, a measurement of how many outputs produced from a given amount of input. In general, productivity is a term used to explain both efficiency and effectiveness of processes conducted in an economy business.

Measuring the productivity of a production line allows the managers to have a clear view of the current situation of their company. Productivity is an important input for operational management, since it helps the growth of the organization and enables them to survive in a competitive world. There are three different views to the productivity concept; (Singal et.al, 2016)

- Technological concept - describes the relationship between ratios of outputs to the inputs used in its production
- Engineering concept - the relationship between the actual and the potential output of a process
- Economist concept - the efficiency of resource allocation

Productivity is a continual effort of applying new and effective strategies to constantly adapt social, economic and environmental conditions (Singal et al., 2016). In manufacturing when productivity is taken as ratio of output to the input, it describes balance between the entire factors (input) of production that will give maximum output with the smallest effort.

There are three ways to express productivity partial productivity, multi-factor productivity and total productivity. When productivity measures use only one class of input or factors (i.e., labor) it is called partial productivity measures because the productivity is only measured partially. Whereas multi-factor productivity measures include multiple factors but all inputs and outputs are considered in total productivity measures (Li et al., 2009).

Productivity growth has a number of benefits for a firm or industry and its stake holders. When productivity improves,

- Workers will have better wages and working condition
- Shareholders will get higher profit and dividend distribution
- Customer will enjoy products with lower price
- There will be stringent environmental protection
- The government will be benefited from increase in tax payment
- Competitiveness of the company will increase which lead for better market share

Manufacturing superiority can only be achieved through productivity improvement. And this improvement can be in the form of optimizing the system, reducing variation, maximizing throughput, reducing cost, improving quality, eliminating waste, correcting ineffective processing, simplifying the process, or responsiveness and reducing set-up time. This continuous improvement has a great significance in boosting production efficiency and it can be obtained by providing a control framework. It also guarantees a sustainable growth to an organization by preparing it for flexible adaptation of market change and customer requirement of a production. If any improvement in the productivity of any individual machine cannot improve the overall system throughput a production line is said un improvable, which means the production line is said to be well designed or optimally balanced (Li et al., 2009).

2.3 Production performance

Most manufacturing firm’s focuses on improving the production performance in terms of productivity output in order to survive in the competitive market, because a high productivity performance has a direct relationship with the equipment efficiency and process control (Amir, 2015) Production performance is a capacity of a system to meet its productivity goal or its demand. It is mainly evaluated by production throughput. Better production performance can be archived by continuous improvement of a production process (Araya, 2011).

Throughput, circle time and average delay are factors affecting production performance of any production process and the variability of this factors is a key parameter for evaluating production performance. Performance of a production line plays a vital role to control the production line and make tactical decision. Therefore, production line manager uses different tools and indicators to evaluate the production performance of their line. This production performance measurement systems measure the inputs and outputs to an operation in order to determine how good or bad the operation is using them. Continuous improvements of manufacturing systems are necessary for a competitive industry (Araya, 2011).

Manufacturing firms should pay a great attention and track their key performance indicators (KPI) to measure their operational process and create a sustainable manufacturing process. Mostly used KPI’s for manufacturing industries are (Andrew, 2019).

1- OEE (Overall Equipment Effectiveness) - is a reliable quantitative metric which used in most of manufactory systems for controlling and monitoring the productivity of production equipment. This performance indicator consists of three important components which are availability, productivity and quality to measure how well (or ill) the line is performing.
2- Total cycle time – measures the time it takes for an order to start and finish the entire production process; it represents the total time it takes to convert raw material in to final product from the starting point of a line to its end. This KPI measures machine efficiency and indicates real-time machine performance.
3- Throughput (total production volume) – is an important parameter to evaluate production performance since it directly indicates the presence of issues that constrain production. It is defined as a time rate of units produced. Throughput can be improved by eliminating downtime losses, calibrating machines, improving

machine maintenance strategy, solving raw material quality issue and reduce number of steps in a cycle to reduce short stops.

4- Capacity utilization – is a ratio of actual and potential output of a production line, which indicates the available capacity and slack of the production system. This KPI is great to understand the line's ability to scale production or institute more flexible job scheduling during production.
5- On- time delivery – measures the percentage of orders delivered on time. This KPI has been the best indicator of operational efficiency of manufacturing plants.
6- Yield – the ratio of good parts produced to total unit produced. It is the best KPI to have a clear understanding of production efficiency and profitability since it is a measure of quality and performance of a production line.
7- Availability – is the basic manufacturing lines performance indicator which measures the up time and downtime of machines.

2.4 Machine down time

Downtime is serious issue in manufacturing industries since it was much related to business profitability and productivity. Machine or equipment downtime is the amount of period of time in which the machine stays idle, not operating for assigned duty due to many reasons like unplanned and planned downtime. Planned events when the operation of a machine intentionally stopped are categorized under planned down time, breaks, scheduled maintenance, and holidays are under this category. but unplanned events that causes loss of planned production time are called unplanned down time, events such as mechanical problems, operator's error, and lack of oversight are categorized under unplanned down time (Hechtman, 2011).

Machine downtime is one of the reasons behind the frequent occurrence of production disturbance leading to poor production efficiency. Unplanned downtimes are measured against plant operating time, which is total available time of the plant for operation. Therefore, plant availability can be calculated by dividing unplanned down time by planned production time. Calculating plant availability is important to understand and investigate the cause of the downtime and production disruption and take a corrective action to solve their root cause problem. Tracking and reducing downtime is the first step toward improving OEE. Tools like fish born, Five-why and DMAIC (i.e., Define, Measure, Analyze, Improve and Control) can serves as root cause analysis methods. Line operators, maintenance arcticians and also production supervisor affects downtime on their own assigned responsibility.

Tracking machine downtime is important to monitor and secure healthy production environment. Machine downtime information is vital in operations management systems to precisely adjust the maintenance operations and correct ongoing machinery deficiencies. Maximizing machine uptime has become good action taken towards reducing downtime in various production processes, including Food and Manufacturing Groups (FMG's) (Jeol and Adenkola, 2020)

2.5 Implementation of six-sigma

Competitive scenario, the markets are becoming global & economic conditions are changing fast. Customers are very quality conscious & demand for high quality product at competitive prices with product variety and reduced lead -time. Companies are facing tough challenge to respond to the needs of customer while keeping manufacturing & other related costs down (Sindha, 2017).

The Six Sigma method begins by recognizing critical elements of quality (critical to quality) of a process to provide suggestions on improvements related to defects that arise. Six Sigma has measurable improvement steps that will result in costs reduction and increased customer satisfaction to maintain the sustainability of a company as a whole (Trimarjoko, 2020). One of the elements of streamlining the production process can be the DMAIC (Define - Measure - Analyse: Improve - Control) method, rooted in the automotive industry and successfully utilised in process improvement in accordance with the Six Sigma assumptions (Michał, 2017).

When implementing the DMAIC method, a number of auxiliary quality improvement tools and methods are used. The improvement cycle using the DMAIC method consists of the following elements (Michał, 2017):

- **Define**: In this stage a team is created which will be responsible for the implementation of the method. The defining phase must identify the following elements: determining the problem (description of the problem, time of occurrence), scope of the project (elements of the process the team will work on), aim of the project (a tangible goal to achieve and sustain in the future).
- **Measure:** During the measurement stage parameters and places of measurement should be defined, i.e. the points of process quality and its costs along with a precise reflection of the actual state. Conducting measurements successfully requires a

statistical outlook on the particular production processes and problems related to them. The measurement stage employs methods such as: descriptive statistics, summary charts, the SIPOC method and the process map.

- **Analyse:** During this stage of the methodology, by analyzing the particular parameters of the process, the team will be able to determine the causes of the problem, which will then need to be eliminated or fixed. The results obtained during the measurement stage are used in order to investigate the correlation between causes of defects and process variability sources.
- **Improve**: Improvement can otherwise be understood as engagement in the course of the production process, i.e. reduction of the defect rate. It consists in searching for and evaluating potential causes of process variability and investigating their correlations. Learning the multi-factor relations allows for achieving the desired results.
- **Control:** The control stage takes place after finishing the new process implementation phase. The fundamental goal of Six Sigma is the constant observation of the improvements introduced to maintain a desired level of quality. As we can infer from the above description, based on the concepts of Six Sigma and Lean, the DMAIC method used in management systems relies on the principle of constant improvement and PDCA formulated by E. Deming (Deming, 2000) and required by the ISO 9001 series standards. A comparison of both concepts has been presented in the literature in many forms (Sokovićet al., 2010).

The DMAIC methodology is used for improving production processes, successfully contributing to the reduction of the number of non-compliant products and reducing production costs. The author of this elaboration decided to introduce this method to processes auxiliary to the production process, i.e. to the maintenance process. The maintenance process, as every other process, has its inputs, outputs, clients, suppliers and can be described using indicators, similar to the production process. The case presented pertains to the breakdown removal process.

2.6 Review of Related Research

The aim of the milling station is to extract more sugar into mixed juice with minimum loss to bagasse. For good extraction sugar (pol) % bagasse from the last mill should be <1% (0.3 pol% cane). It's this pol% bagasse which will determine how much sugar is lost in bagasse in a particular crush year (Chacha, 2020). Sugarcane milling is not based on the quality of sugarcane but on the arrival time to the factory. Under this condition, different sugarcane qualities will be milled together. As a consequence, it may not yield the optimal sugar production. In the sugar production process, equipment performance must always be monitored. Equipment failure will reduce the amount of sugar produced. Therefore, efforts to increase sugar production must consider both factors, namely the variation of input quality and monitoring of equipment performance. One approach in solving this problem is statistical thinking approach (Kustiyo et al., 2019).

The major reasons of losses in sugar are due to sugar in bagasse, final molasses, filter cake and unknown factors. The sugar losses occurred in any sugar plant in a season of crushing is one of the important term of accessing the technical performance of the sugar plant (Meles, 2019). The data that the loss of sugar in bagasse, molasses, and press-mud cake and in unknown losses is 2.07% of the total cane crushed and out of the total sugar loss at the Kaithal Cooperative Sugar Mill Ltd. sugar loss in bagasse is 25.34% while sugar loss in filter cake is 2.89 %, sugar loss in molasses is 66.94 % and sugar undetermined loss is 4.83 % respectively Chetan and Vikas, 2015). The invert sugar has several disadvantage properties that play an important role in many food applications. It has a high affinity for water and is the cause of making products retain moisture. Invert sugar also affects the caramelization process, producing a browning effect (Wasna and Chantana, 2008).

Bagasse is initial stage co-product of sugarcane industry after juice extraction. It contains nearly 45–50% water, 2–5% dissolved sugar and 40–45%fibers. Press mud is also a byproduct of the sugar industry and known to filter cake. It contains 75–80% moisture; 2–5% of sugar and 5–10% of fibers. Molasses is an additional important side product of the sugarcane processing industry. Nearly 2.5–4% of molasses were produced from one tone of sugarcane. It contains sucrose 35%, water 20%, fructose 9%, glucose 7%, reducing sugars 3%, carbohydrates 4%, nitrogenous compounds 4.5%, non-nitrogenous acids 5%, ash 12% and others 5% (Sahu, 2018). Under normal milling conditions sugar loss is estimated to be around 1.0 to 2.5 kg of sucrose per ton of cane ground between crusher juice and mixed juice depend on factory condition (Roy, 2020).

In clarification, precipitate is formed by the clarifying agent added. The separation of this precipitation or mud is done in special designed tank called clarifier. The precipitation settle at the bottom and the clear juice at the top. A good clarifier should produce good juice quality, should have short retention time and more efficient mud removed. Any accumulation of mud that is not properly scraped away will crust over rapidly and cool to temperature that permits bacterial action and souring, resulting sugar loss. Retention of juice at an elevated temperature leads to inversion and reduce sugar degradation to form organic acid, resulting in purity and PH drop. In the other hand if temperature drop below 75^{o}C, there is a chance of loss due to micro activity (Notcutt, 2017).

The Dorr clarifier consist of four compartments with separate provision for feed, overflow take off and mud withdrawal, allowing the unit to operate as four totally independent clarifiers in closed in a common housing. Juice is introduced at the top center of each compartment though a central hallow shaft. As a feed enter each compartment, it strikes the deflector baffle, and then flow out ward at a decreasing velocity, with minimum turbulence. The scraper is arranged on the rotating central shaft in each compartment, which moves the settled mud discharge boot at of the tray to be withdrawn separately. Each compartment have its own overflow piping to remove the clarified juice at multiple point around the periphery. A single overflow box collects the clarified juice from all compartments. The juice is taken off uniformly to eliminate stagnant pockets. The clear juice from each compartment is taken off by means of overflow tubes due to hydrostatic head. The overflow tubes are adjustable, in height, which enable to regulate clear juice flowrate from each compartment. The mud juice can also be taken off by means hydrostatic head. However since muddy juice is too thick and heavier than clear juice Dorroco pumps are provide to take off the muddy juice (Tawfeuk, 2017).

The filter is composed of a hollow rotating about a horizontal axis and partly submerged in the liquid to be filtered. The periphery of the drum serves as the filtering surface. It’s divided in to 24 independent suction connected individually to a vacuum system by small pipe terminating in a distributing valve situated at one end of the drum and carrying three different sectors as follow. Firstly, one without connecting to the vacuum but connected to the atmosphere. Secondly connect with low vacuum chamber of the order of 15-30 Cm of mercury. Thirdly connect with high vacuum chambers, of the order of 40-50Cm mercury (Mohammed, 2017).

Cane juice clarification aims; at forming flocs to trap all suspended matter, providing conditions of temperature, pH and ion concentration which will maximize the precipitation of soluble impurities from the juice. Producing clarified juice of high quality, with a minimum turbidity, color, and low calcium content with properly settled mud is the main target of mixed juice clarification (Tesfaye, 2020). To obtain high-quality refined sugar, it is important to remove all suspended matter from the sugar liquor which are filtered at three stages of filtration when a screen is dipped into a mud trough and to the back side of the screen, when suction is applied then juice is sucked in and a cake of solids is formed on the surface of the screen. As more suction, after removing the screen from the trough is applied, the cake became firmer and after a time flow ceases. If to this cake water is applied, fluid flow to the suction increases (Salma et al., 2014).

The majority of sugar factories use continuous clarifiers to separate solids from the first carb slurry. The overflow from the clarifier is called clarified juice, and the under flow is carbonation mud. Because of settling, about 75% of the first-carb slurry is converted into clarified juice (clarifier's overflow), which is nearly free of suspended solids, and 25% becomes mud (clarifier's underflow). The volume ratio of the mud to the slurry is called thickening ratio (Mosen, 2007).

Tesfaye, (2020) discussed that purpose of clarification process is to remove impurities from the juice as early as possible in process. This elimination has to be done to prevent the loss sucrose or reducing sugars in a considerable quantity. The juice usually contains considerable colloidal and fine suspended matters, which are removed by clarification and addition of some soluble compounds, are also done by means of chemical treatment, heating and settling.

The operation of sugar boiling house is arranged with the aim of maximum sucrose recovery or minimum sugar loss, proper quality of final product and minimum quantity of total massecuite boiled. Practically it is not possible to exhaust the crystallizable sucrose from syrup in one boiling stage. In order to meet the primary goal of an efficient sugar boiling house, the sugar coming with the evaporator syrup has to be recovered by several crystallization stages or different boiling schemes. The best boiling scheme is the one which gives the required sugar quality, minimum sugar loss with final molasses, and efficient use of the steam and the equipment available. Achieving the crystallization efficiency targets has an important effect on minimizing the use of steam and optimizing the equipment capacity: pan, crystallizers and centrifuges (Rein, 2007).

The loss of sucrose in final molasses is the biggest loss which has to suffer by a Sugar factory. This loss has a significant impact on the profitability of a Sugar Mills directly or indirectly. It is essential to obtain a reliable data on final molasses exhaustion to minimize sucrose loss. Many operating factors, such as the character of the crystals and density of the final massecuites, the extent of the cooling in the crystallizers, and the after treatment of massecuite, effect the purity of final molasses.

Viscosity is also of great importance in exhaustion of molasses, since it is one of the factors that limit the concentration of the massecuite and the super saturations of the molasses (Areeba, 2019).

Undetermined loss is not measured directly as molasses loss but it is primarily determined as the difference between sucrose input and sucrose output. This method of estimating a small quantity from the difference between two large quantities is notoriously imprecise. Small percentage errors in each of the large quantities translate into a large percentage error in the quantity estimated by difference. Maximizing sucrose recovery in a factory can then be pursued as a process of minimizing these sucrose losses, using the weekly performance reports to benchmark the factory against performance achieved elsewhere in the factory and to track improvement with time (Love et al., 2010).

2.7 Research gap

Many researches have conducted several studies on production bottleneck identification and elimination methods and various approaches have been recommended for manufacturing companies. As noted from literature, several researchers have focused their studies on methods for bottleneck identification and elimination of only a production line and machines neglecting the over whole production process. Many research works tend to focus only on the production performance and efficiency analysis but not on the cause of continuous disturbance in production performance and efficiency of a production. There is also a limited research conducted in food processing and sugar production with a case study. Many sugar industries are working in Ethiopia but no one researcher has done research work related to investigation of sugar losses at different level through process analysis in sugar industries in Ethiopian working environment.

CHAPTER -3

MATERIALS AND METHODOLOGY

3.1 Introduction

To achieve the study's goal, the research design of this study was built on the reduction of losses and downtime through the use of statistical process control tools. Therefore, the case study line was used to implement this methodology in research design and study how to improve production by eliminating down time and losses. The investigative method used was described as follows in Figure 3.1. The frame work of the study was analytical, descriptive, and prospective study, because collecting and analyzing data and information with the aim of proposing improvements strategies based on statistical process control tools.

3.2 Data Collection Methods

Data collection was critical factor when studying complex production processes. Therefore, it was vital to collect recent and long-term precise data from reliable sources. To do so, it was necessary to have better understanding of the overall production process and observe the production performance of the production process. Therefore, it was necessary to study the process flows of sugar production, the different activities performed in the process, and the working principles of machines in detail. Reading related research works and documents related to this production system, such as journal articles and books, where also important for gaining better understanding of the general characteristics and new information in the field of productivity.

After gaining deeper comprehension of the production process, the tools needed to carry out the research were determined. For this study, primary data where from real-time production systems, and historical data has been collected from maintenance log sheet, quality management department, and production report books. Survey questions, field observation, focus group discussion, and interviews were also used as source of primary data for the research.

3.2.1 Survey questionnaires

Semi-structured questionnaires were used to enable the researcher to obtain primary quantitative data in order to provide complete picture of machine break down and sucrose losses in each process sub-section. The questionnaires were divided into three categories. Part one captures general information about the respondents' current job positions and length of service in that function, among other things. Part two captures information in relation to total quality management, SPC and the challenges they face in their application. The third part was the specific knowledge related to machine failures and operational losses in factory.

3.2.2 Documentation

From the method of data collection categories documentation was the secondary data collection method that widely used in this study. In addition to maintenance log sheet, operational process manual, Laboratory data and other related document were used.

3.2.3 Focus group discussion

In this suction, mechanical maintenance and production groups were formed to discuss relevant information about machineries break down and production processes that are used to collect information and how minimize machine failure and sucrose losses. The group discussed the root causes of downtime, sucrose losses, and how to reduce the production bottlenecks.

3.3 Data analysis methods

After all the data collected from Matahara sugar factory analyzed, compared, and summarized with mathematical calculation results, then interpretation of the data was held by using SPC, SPSS and Qi-Microsoft tools.

3.3.1 Statistical Process Control

Statistical process control (SPC) is a statistical method of separating variation resulting from special causes from variation resulting from natural causes in order to eliminate the special causes and to establish and maintain consistency in the process, enabling process improvement (Davis, 2014). Although SPC is normally thought of in industrial applications, it can be applied to virtually any process. Everything done in the workplace is a process. All processes are affected by multiple factors. For example, in the workplace a process can be affected by the environment and the machines employed, the materials used, the methods (work instructions) provided, the measurements taken, and the manpower (people) who operate the process the Five M’s. This means that there are no special causes adversely affecting the process’s output. Special causes are (for the time being, anyway) eliminated. Does that mean that 100% of the output will be perfect? No, it does not. Natural variation is inherent in any process, and it will affect the output. SPC does not eliminate all variation in the processes, but it does something that is absolutely essential if the process is to be consistent and if the process is to be improved (Davis, 2014).

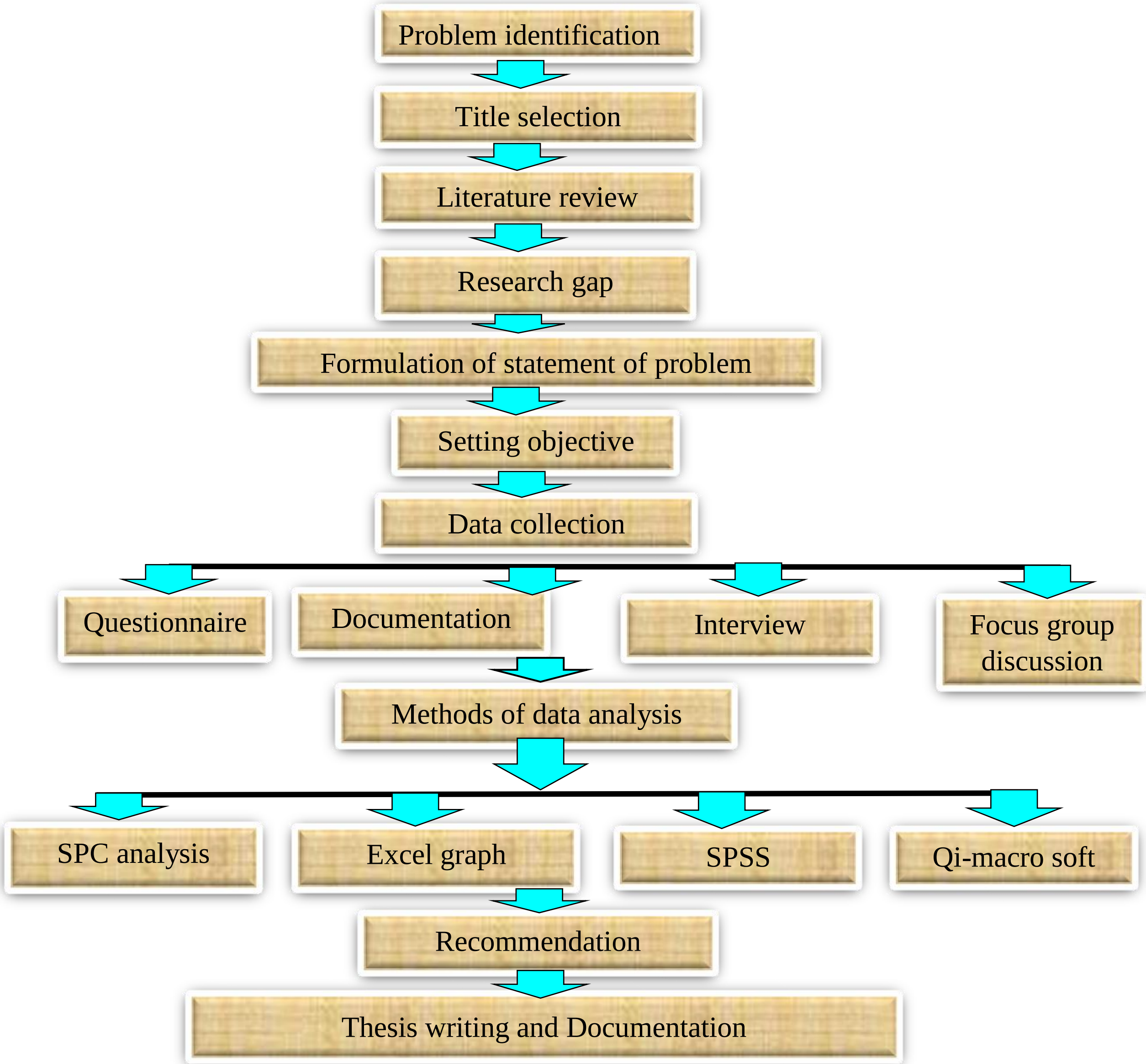

Figure 3.1 Frame work of the methodology

3.3.2 Pareto analysis

A bar graph where the bars are arranged in descending order of height, starting at the left is called a Pareto chart, it also contains lines to represent the total cumulative values. This chart is a vital tool to perform Pareto analysis. A Pareto analysis is a technique which helps the identification of major problems, according to Pareto analysis, 80% of problems can be traced to 20% of the cause. The main advantage of Pareto analysis is that it helps to identify and determine main cause or root causes of defects or problems by prioritizing them in descending order. It also provides a common knowledge based on facts, instead of hunches, which results in gaining the cooperation of all problems involved. Therefore, in this study Pareto chart was chosen to identify the 20% predominant downtimes that caused around 80% of total filler downtime so that it can be easier to study root cause of major problems causing a highest downtime loss (Varsha at al., 2014).

3.3.3 Five why analysis

Five why method is referred as ultimate root cause analysis tool which helps a production team to focus on finding the root cause of any problem. This analysis is done in a brainstorming session where team members are sharing ideas to eliminate recuring failures and problems caused in a production line. This method is originated in Japan, developed by a Japanese inventor and industrialist Sakichi Toyoda. It has become an integral part of a lean philosophy and also used in Toyota production system for the first time and it is suggested by many scholars to be an effective tool taken as a problem elimination step in complex production system (Olivier, 2017).

Five why method is structured by an iterative interrogative question to explore the cause-and-effect relationship underlying a particular problem, and its primary goal of this technique is to determine the root cause of a problem by repeating the question “why?”. There are two primary techniques are used to perform a five why analysis; the fish bone (Ishikawa) diagram and tabular format. These two techniques allow the analysis to be branched so that multiple root causes could be provided (Serrat, 2017)

CHAPTE -4

RESULTS AND DISCUSSION

4.1. Introduction

The analysis of this research work starts from studying current production performance of the case study MSF sugar production. Since reliable quantitative metric which was used in most of manufacturing systems for controlling and monitoring the productivity through statistical process control tools and form that, cause and effect were chosen as tool.

Matahara sugar factory were productivity problem due to sucrose losses at milling, clarification, and centrifugal sections and machine failure. There was loss of sucrose with bagasse, filter cake, and final molasses. When it comes to the milling section, the problem of sucrose losses was due to failures of machinery components, operational parameters, human factors, and others. The objective of the milling section were to extract the sucrose from cane to the maximum and reduce the loss of sucrose and moisture in bagasse to satisfy the process house and power generation plant, respectively. The aim of the clarification section were to clarify the juice and filtrate the sucrose from mud, and the centrifugal section was the area to separate mother liquor from molasses. The main problem of the centrifugal section was the loss of sucrose with molasses.

4.2 Data collection

These input data can be obtained from both historical records and real time production observation. For this study primary data of real time production system and historical data has been collected from mechanical maintenance log sheet of the company and production report books. Machine operating and user manuals, books and interviews were also used as a source of secondary data for the research. The data attached in appendix have been collected from historical database and directly from the production system.

Real time production data collected through observation are; overall company production system, planned and actual output of total production, machine downtime data, failure of every machine and their frequency, and planned and unplanned down time. Secondary and historical data collected from company mechanical maintenance log sheet and production report books, data sheets.

4.3 Data presentation

MSF crushing was from 220-240 days per year, 7 days per week and 24 hours per day in three shifts. Except from unplanned stoppages the factory have planned preventive maintenance in 1 ½ month minimum of four times in crushing campaign. Even though the crushing and production operation was 24 hours per day, it may not be always producing well due to inheritance failure. The machine was not producing due to component or other failure problem of the machine it-self; the failure duration can be for short or long time.

4.4 Actual and planned production data of MSF

The production plan for each year may vary due to a variety of variables, mostly because of planned and unplanned maintenance in every production year. The graph shown in Figure 4.1 was the comparison between the plan and the actual ton of cane crushed in the past five consecutive years. The data taken from Appendix A shows that the tone of cane crushed and sugar produced in MSF from 2016/17 to 2020/21 crushing season.

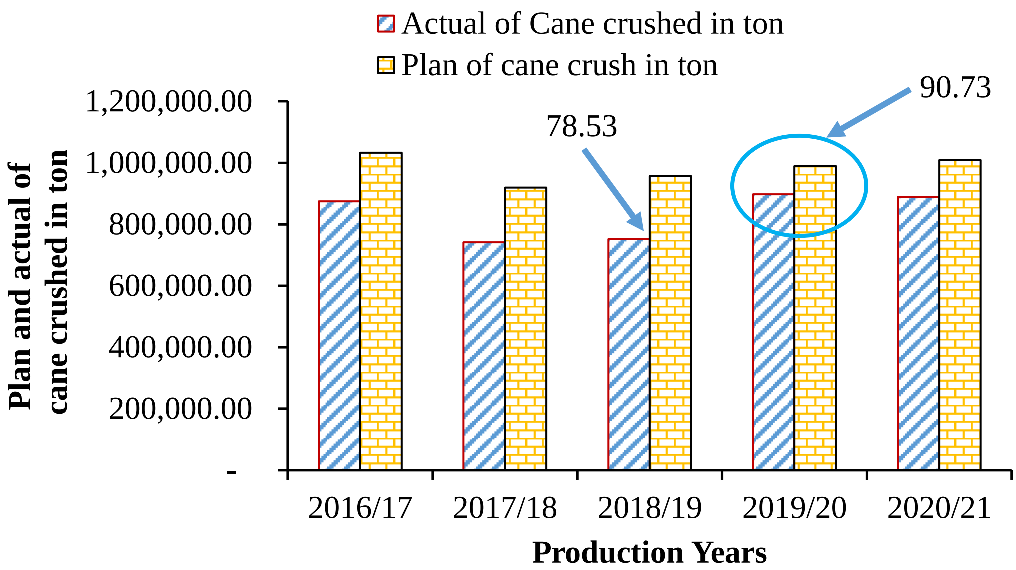

Figure 4.1 Plan against actual of cane crushed (Appendix A)

Based on this data, the following graph was drawn. In the graph there was difference between the plan and the actual cane crushed in all years. However, the variation between cane crushed plan and actual was due to the low performance of the cane preparation section and milling house. Good performance of crushing were observed in 2019/2020 season 90.73 % and lowest performance were in 2018/2019 season. Mechanical, electrical and instrument machinery component failure are the suspected cause of down time. In addition to operation problems, pressure drop were another factor. Hence, there was clear variation in cane crushed plan and actual in all operational campaigns due to the existence of machine failures. Especially in season 2018/19 GC, the variation were very high.

Machine failures such as mechanical, pressure drop, electrical, instrument, boiler, lack of cane, preventive maintenance, and others are the main causes of variation between crushed cane plan and actual. The following pie chart in Figure 4.2, shows which factors have the most influence on crushing.

Table 4.1 Causes of factory down time

Cause of down time	Down time duration (hrs)	Frequency of failure (year)
Process house	10.25	11
Others	21.5	8
Instrumentation	28.25	24
Preventive maintenance	299.25	17
Electrical	369	370
Blockage	631	717
Boiler	682	208
Lack of cane	1163.5	299
Pressure drop	1836	599
Mechanical	2823	1890

Using the above Table 4.1, pie chart analysis has been conducted, and the pie chart below shows that mechanical, pressure drop and lack of cane are the causes of 59 % of the total down time.

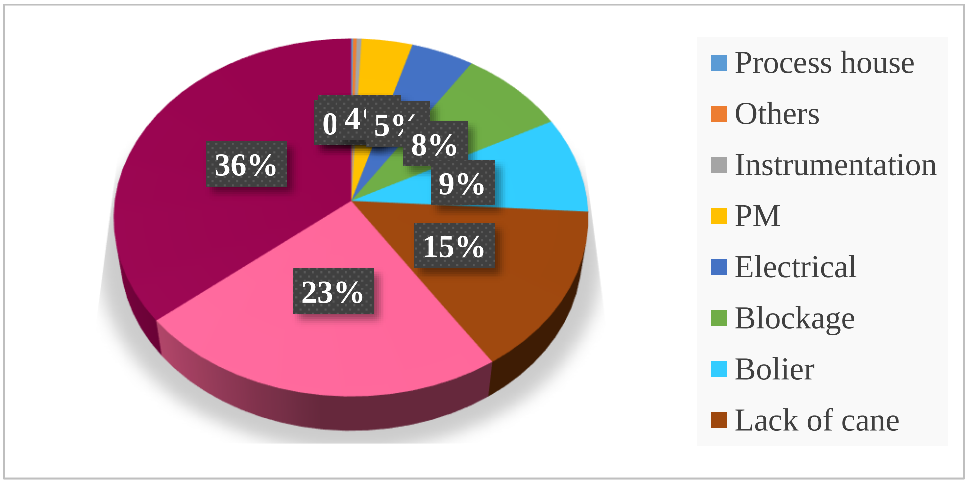

Figure 4.2 Pie chart of downtime due to machineries failures.

To know the section of machine failures, it needs to collect additional downtime of machineries and draw Pareto chart from Table 4.2 shown below.

Table 4.2 Mechanical machinery causes down time

Down time causes	Stoppage hours
Cane handling plant A (CHA)	229.75
Cane handling plant B (CHB)	338.75
Milling Plant A (MPA)	919.75
Milling Plant B (MPB)	683.75
Pumps Compressors And Gear Boxes (PC&GB)	129.75
Steam Boiler Plant and Power Turbines (SGP& PT)	215.75

Using the above table 4.2, Pareto analysis has been conducted, and the Pareto chart below shows in Figure 4.3, that milling plant A, and milling plant B are the causes of 63.5 % the total down time.

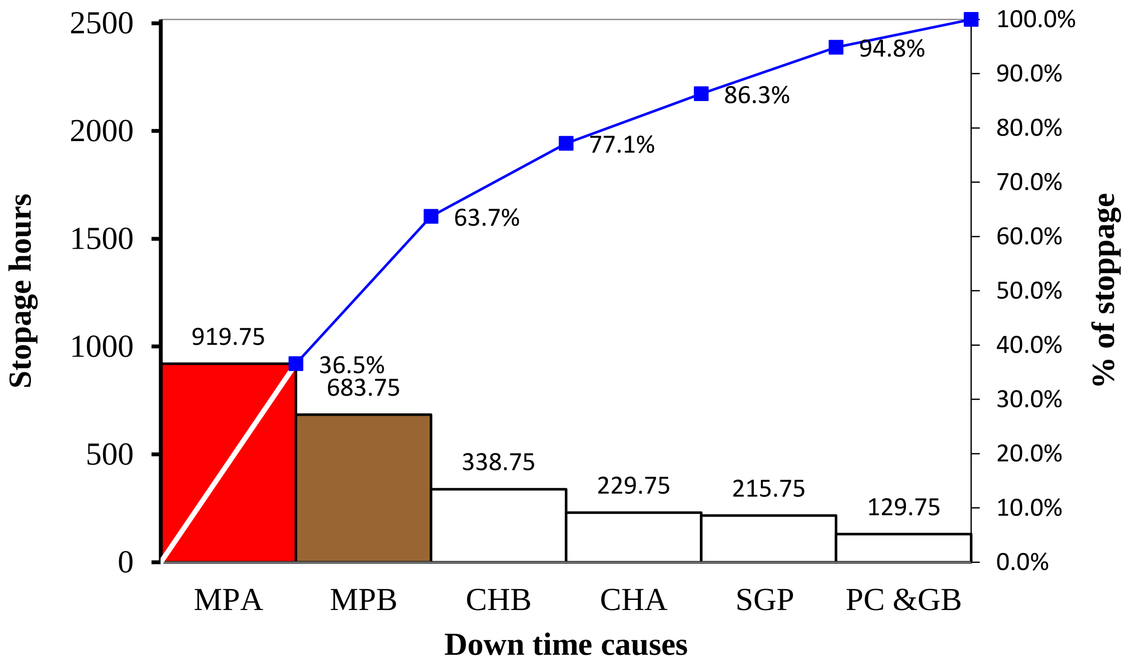

Figure 4.3 Pareto analysis machineries down time

To know the individual effect of mechanical machine break down it need to do anther Pareto chart. The above Figure 4.3 was general factory section wise of mechanical machineries failures downtime analysis. From milling section machineries component failure identify which takes the height percentage described in Figure 4.4 shown below.

Table 4.3 Specific machineries failures

Down time causes	Stoppage hours(hrs)
Feed roller chain and sprocket assembly	0.25
Mill Turbines and accessories	5.25
Mill Turbine # 3	23.75
Mill Turbine # 1	30
Mill # 2	40
Intermediate bagasse carrier # 2	56
Intermediate bagasse carrier # 1	60.75
Milling Plant A	79
Mill # 1	102.25
Mill turbine # 2	207.5
Mill # 3 shaft journal worn out	315

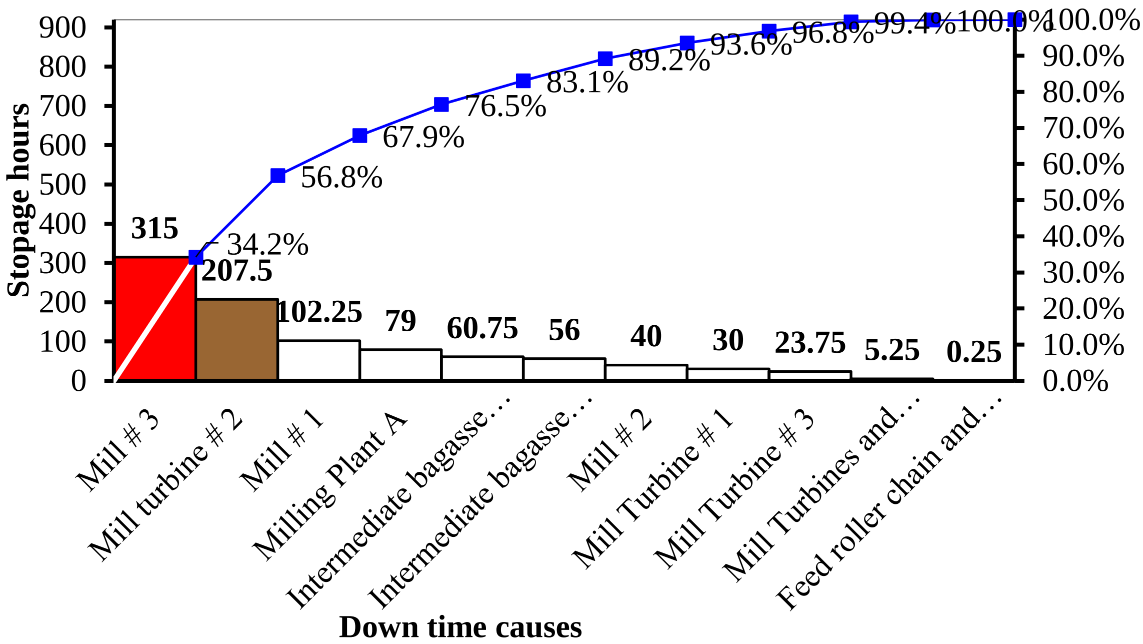

Figure 4.4 Pareto analysis of downtime due to mechanical machine failures

According to the Pareto analysis in Figure 4.4 above, milling #3 accounts for the biggest percentages of downtime in the mechanical segment. Wear on the mill shaft on (journal) bearing seat was the main issue with milling #3. The 5W technique was employed to pinpoint the root causes of the issue as shown in Figure 4.5 below.

The 5W technique were employed to pinpoint the root causes of the issue.

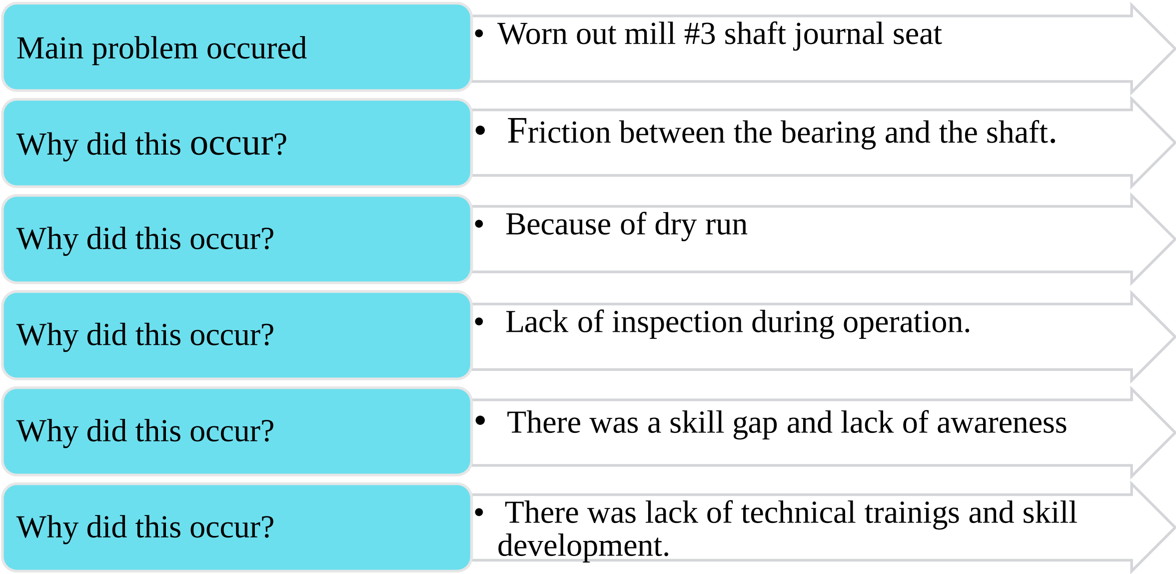

Figure 4. 5 5 Why analysis of Milling #3

4.5 Losses of sugar in process due to the presence of bottleneck

The contrast between the percentage of sugar produced and the amount of cane crushed was

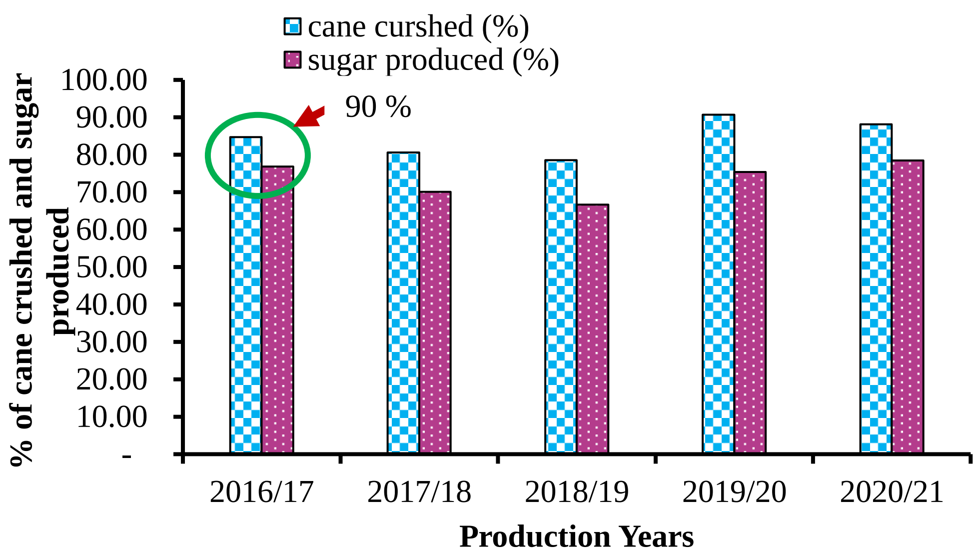

Figure 4.6 Percentage of cane crushed and sugar produced (Appendix A)

displayed in the graph below in Figure 4.6. Based on this, the chart demonstrates that sucrose losses occur during each operational season, with the biggest variation being observed during the operational campaign for 2019/20 GC.

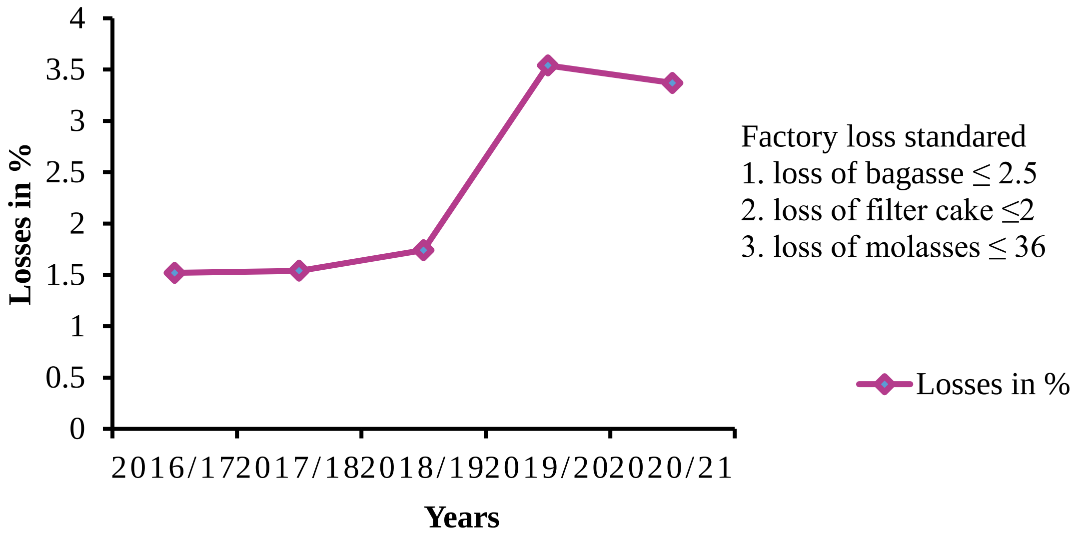

Figure 4.7 Losses of sucrose in factory (Appendix A)

As described in the Figure 4.7 the percentages of sugar losses in the factory were gradually increase for three years and dramatically raised in 2019/20 GC that was very hard for factory and shows a little downward that was promising, but it was far from the company losses standard. The reason were discussed in analysis section below. The graph were drawn from Appendix A.

Interpretation of data

Following the discovery of losses, it was necessary to determine if the losses in the plant were under control or not. To do this, statistical process control tools, which were extensively utilized in these studies, were applied. The gathered data of sugar loss in bagasse, filter cake, and final molasses are presented in Appendices B, C, and D, respectively. These data are used to determine the mean, range, and grand mean for bagasse, filter cake, and final molasses shown in Table 4.4.

Mean $\bar{x}$

$$\bar{X} = \sum_{i=1}^{n} \frac{x_i}{n} \tag{4.1}$$

Mean sample range ($\bar{R}$)

$$\bar{R} = \sum_{i=1}^{n} \frac{R_i}{n} \tag{4.2}$$

$$\bar{R} = \sum_{i=1}^{n} \frac{R_1 + R_2 + R_3 + \cdots + R_n}{k} \tag{4.3}$$

Process mean ($\bar{\bar{X}}$)

$$\bar{\bar{X}} = \sum_{j=1}^{k} \frac{\bar{x}_j}{k} \tag{4.4}$$

Standard deviation (σ)

$$\sigma = \frac{\bar{R}}{d_n} \; or \; \frac{\bar{R}}{d_2} \tag{4.5}$$

where; d_n or $d_2 = hertely'sconstant$

$$From\ Appendix\ B, for\ a\ sample\ size\ n = 5; d_n = d_2\ @\ n, 5 = 2.326$$

And

$$\text{Upper Action Line} = \bar{\bar{X}} + 3\sigma/\sqrt{n} \tag{4.6}$$

$$\text{Upper Warning Line} = \bar{\bar{X}} + 2\sigma/\sqrt{n} \tag{4.7}$$

$$\text{Lower Warning Line} = \bar{\bar{X}} - 2\sigma/\sqrt{n} \tag{4.8}$$

$$\text{Lower Action Line} = \bar{\bar{X}} - 3\sigma/\sqrt{n} \tag{4.9}$$

Range chart

$$\text{Upper Action Line at } D' = 0.001\bar{R} \tag{4.10}$$

$$\text{Upper Warning Line at } D' = 0.025\bar{R} \tag{4.11}$$

$$\text{Lower Warning Line at } D' = 0.9751\bar{R} \tag{4.12}$$

$$\text{Lower Action Line at } D' = 0.999\bar{R} \tag{4.13}$$

The table in Appendix C provides four constants; $D'_{0.001}, D'_{0.025,}D'_{0.975} and\ D'_{0.999}$

For the loss in bagasse, the sample size is five and the constants are thus:

$D'_{0.001} = 2.34$ $D'_{0.025} = 1.81$ $D'_{0.975} = 0.37$ $D'_{0.999} = 0.16$

Table 4.4 Calculated data of production losses

Losses /Required	Bagasse	Filter cake	Final molasses
Range($\bar{R}$)	1.437	1.85	4.492
Process mean($\bar{\bar{X}}$)	3.23	2.51	37.981
Standard deviation (σ)	0.619	0.863	2.131
Mean UAL	4.06	3.586	40.481
UWL	3.783	3.282	39.645
LWL	2.67	1.738	35.912
LAL	2.39	1.417	34.979
Range UAL	3.037	3.975	9.484
UWL	2.601	3.634	8.787
LWL	0.532	0.743	1.796
LAL	0.229	0.321	0.777

Figure 4.8 shows mean chart for losses of pol. % in bagasse that describe the presence of special causes of variation and interpreted in the below Table 4.5. The reason for the presentation of spatial causes of variation was explained well in the table for both graph shown in Figure 4.9 which was the represent range chart for losses in bagasse.

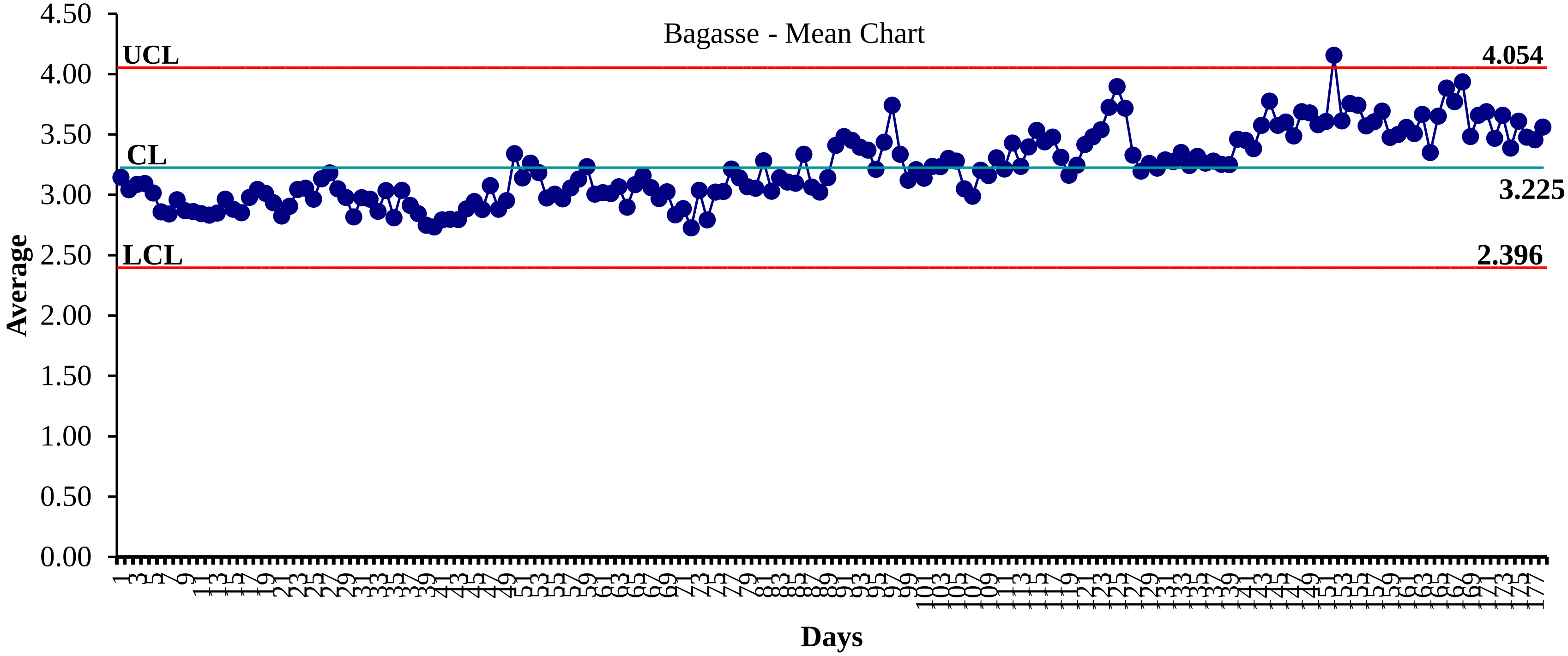

Figure 4.8 Mean chart of losses in pol. % of bagasse.

Following the computation of the mean, range, and grand mean, the graph in Figure 4.8 for the mean, was drawn to determine whether the process was under control or whether there were special causes of variation. Table 4.5, which was shown below, provides an interpretation based on the previously mentioned chart.

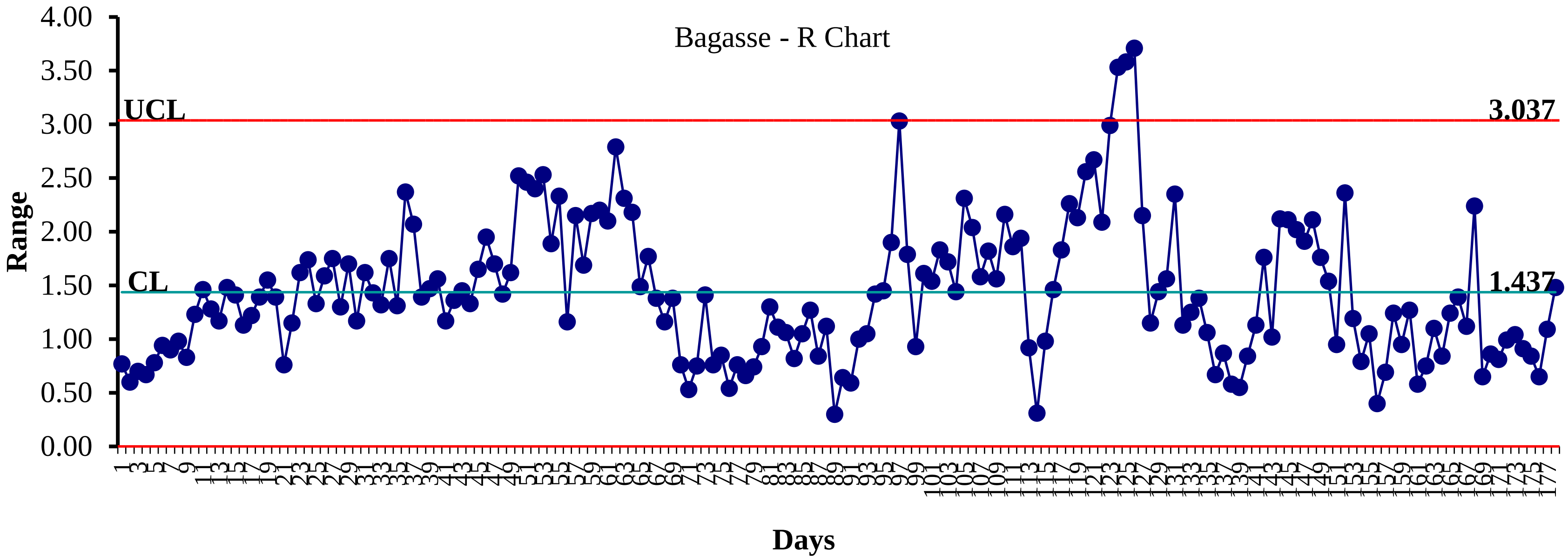

Figure 4.9 Range chart of losses in pol. % of bagasse

Following the computation of the mean, range, and grand mean, the graph in Figure 4.9, was drawn to determine whether the process was under control or whether there were special causes of variation. Table 4.5 shown below, provides an interpretation based on the previously mentioned chart.

Table 4.5 Interpretation of graph

Sample number	Chart	Observation	Interpretation
62	Range	Upper warning limit	Acceptable on its own, resample is required.
90	Range	Upper warning limit	Acceptable on its own, resample is required.
97	Range	Upper warning limit	Acceptable on its own, resample is required.
121	Range	Upper warning limit	Acceptable on its own, resample is required
123	Range	Upper warning limit	Acceptable on its own, resample is required.
124	Range	Upper action limit out of control	Obtaining further information is a potential course of action, but other actions include determining whether the mill has been bypassed, whether the hydraulic pressure is within acceptable limits, and whether the mill's setting is appropriate. Note that the mean chart shows no issues.
125	Range	Upper action limit out of control	Possible action could be involve obtaining additional information, but some possible action could be; (a) check if mill was bypassed (b) Is hydraulic in standard (c) check the mill setting as per the required. Note: mean chart indicate problem, take action.
125	Mean	Upper warning limit	Two warning must be in the same warning zone to be an action, resampling required.
126	Range	Upper action limit out of control	Possible action could be involve obtaining additional information, but some possible action could be; (a) check the imbibition volume used (b) Is hydraulic in standard (c) check the mill setting as per the required. Note mean chart indicate no problem.

144	Mean	Upper warning limit	Acceptable on its own, resample is required.
152	Mean	Upper action limit out of control	Possible action could be involve obtaining additional information, but some possible action could be; (a) check if mill was bypassed (b) Is hydraulic in standard (c) check the mill setting as per the required (d) check imbibition flow rate. Note range chart indicate no problem.
164	Mean	Upper warning limit	Acceptable on its own, resample was required.
168	Mean	Upper warning limit	Acceptable on its own, resample was required.

The histogram graph shown in Figure 4.10 below was summarized as follow:

1. The graph has one peak point at that center that implies unimodal data distribution.
2. The graph skewed to the right with 0.51 confirmed skewed to the left for the factory due to its losses not product defect.
3. The losses found in the graph was 15.8% that above and below specification limit. Below the specification is not defect, only upper specification limit were the losses that 7.9%.

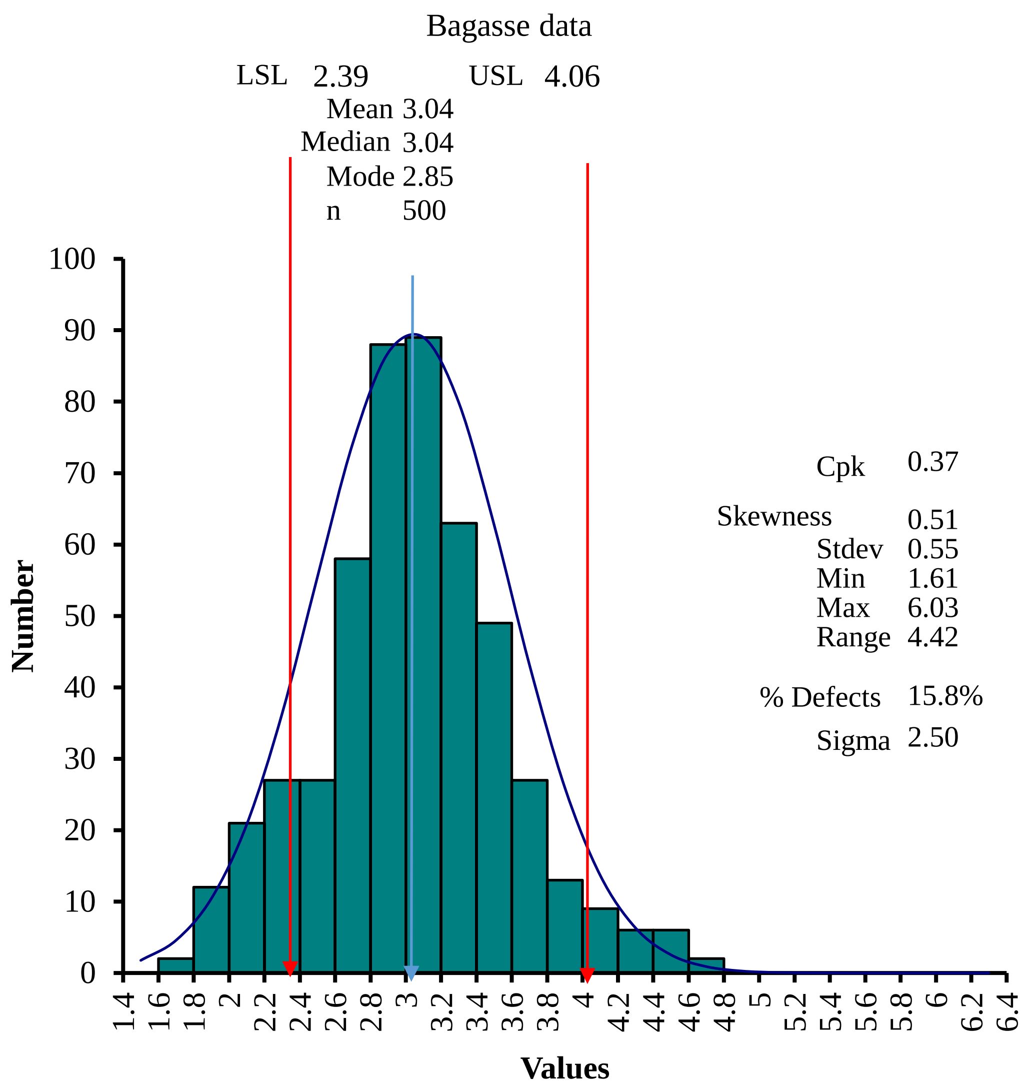

Figure 4.10 Histogram bar for losses of pol. % in bagasse

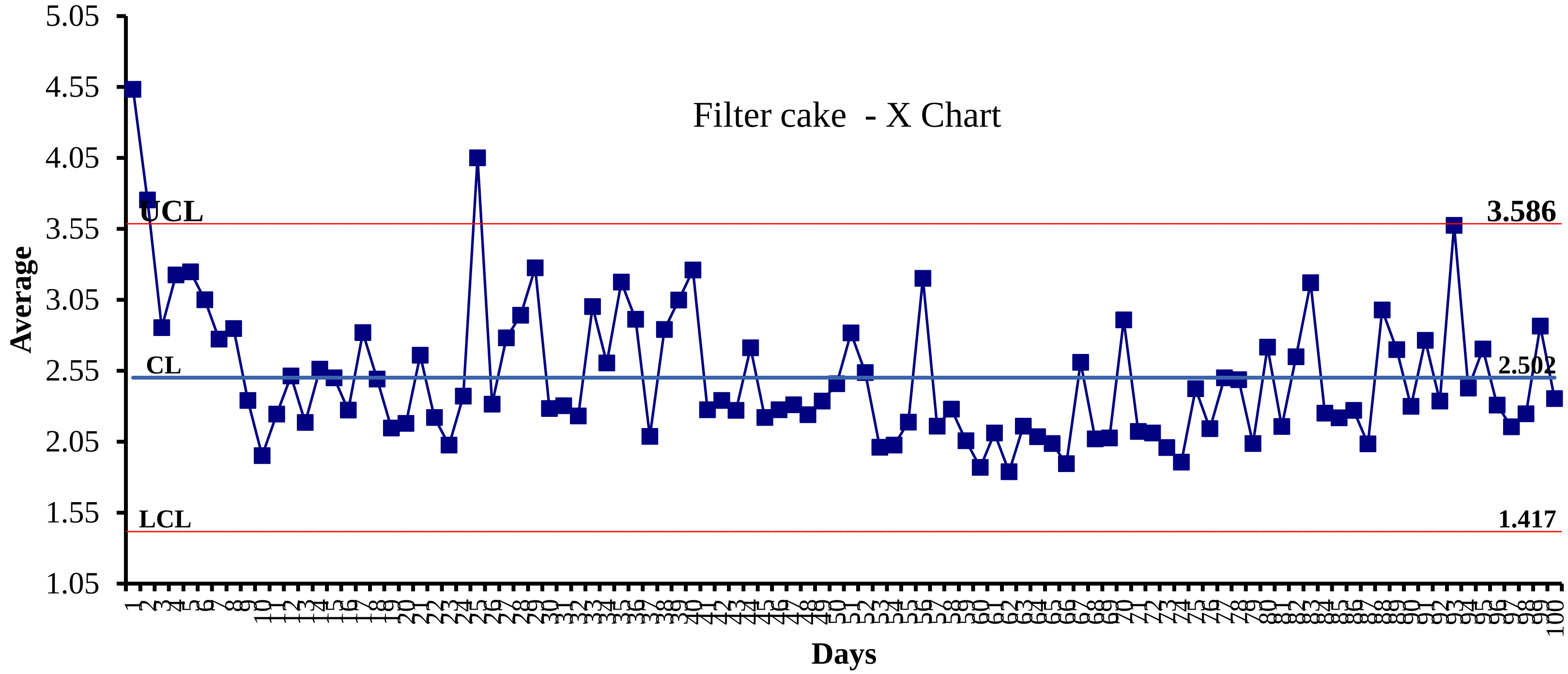

Figure 4.11 Mean chart of losses in pol. % of filter cake

After calculating the mean, range and grand mean the above graph shown in Figure 4.11 drawn to know does the process was control or there was special causes of variation. Based on the above chart the interpretation were given in table 4.6 shown below.

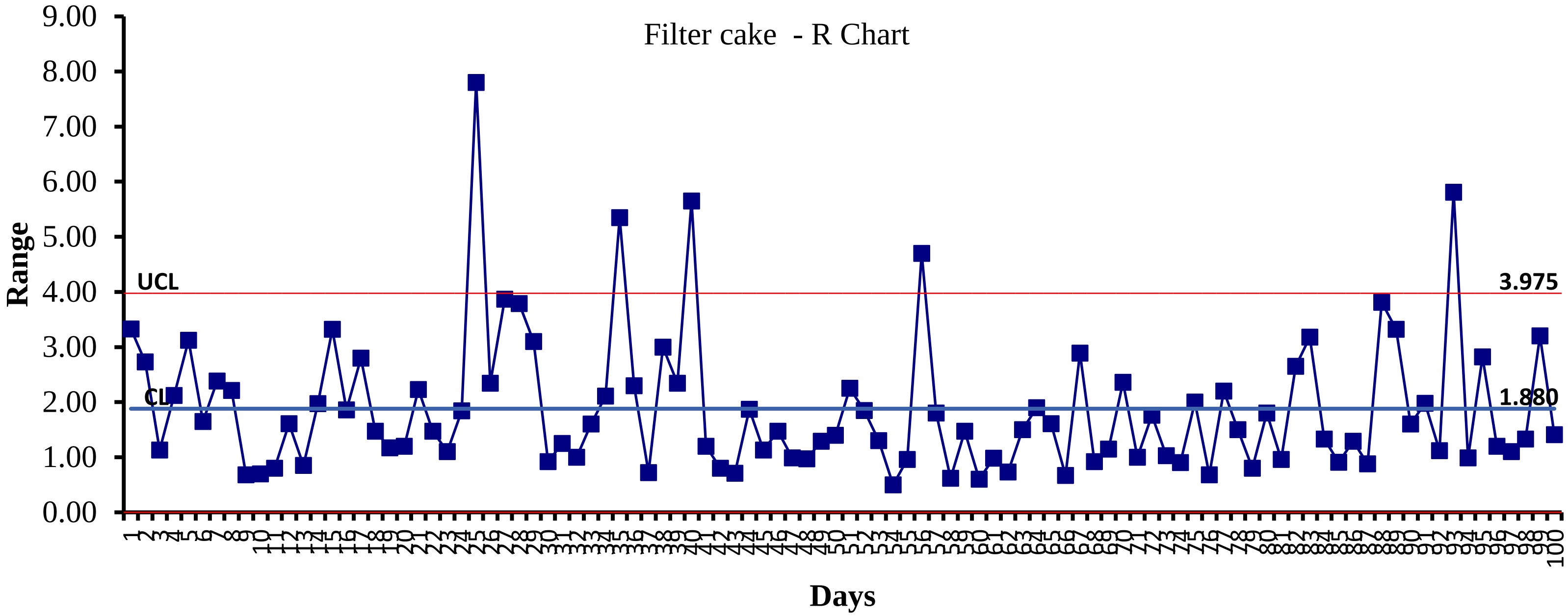

Figure 4.12 Range chart of losses in pol. % of filter cake

After calculating the mean, range and grand mean the above graph shown in Figure 4.12 drawn to know does the process was control or there was special causes of variation. Based on the above chart the interpretation were given in table 4.6 shown below.

Table 4.6 Interpretation on the above mean and range chart

Sample number	Chart	Observation	Interpretation
1,2	Mean	Upper action limit out of control	Obtaining further information is a potential course of action, but other options include checking for sieve cracks, evaluating the functioning of the Nash vacuum pump, and checking for leaks in the high- and low-vacuum lines. (d) Determine whether the mud is in the proper state. These was may be due to factory start up Note that the range chart shows no issues.
25	Range	Upper action limit out of control	Possible action could be involve obtaining additional information, but some possible action could be; (a) check if sieve crack (b) check the performance of Nash vacuum pump (c) check high and low vacuum line if any leakage (d) check mud conditioning as per the required.
25	Mean	upper action limit out of control	Possible action could be involve obtaining additional information, but some possible action could be; (a) check if sieve crack (b) check the performance of Nash vacuum pump (c) check high and low vacuum line if any leakage (d) check mud conditioning as per the required.
27,28	Range	Upper warning limit	Acceptable on its own, resample is required.

35	Range	upper action limit out of control	Possible action could be involve obtaining additional information, but some possible action could be; (a) check if sieve crack (b) check the performance of Nash vacuum pump (c) check high and low vacuum line if any leakage (d) check mud conditioning as per the required. Note mean chart indicate no problem.
39	Mean	Upper warning limit	Acceptable on its own, resample is required.
40	Range	upper action limit out of control	Possible action could be involve obtaining additional information, but some possible action could be; (a) check if sieve crack (b) check the performance of Nash vacuum pump (c) check high and low vacuum line if any leakage (d) Check mud conditioning as per the required. Note mean chart indicate no problem.
56	Range	upper action limit out of control	Possible action could be involve obtaining additional information, but some possible action could be; (a) check if sieve crack (b) check the performance of Nash vacuum pump (c) check high and low vacuum line if any leakage

			(d) Check mud conditioning as per the required. Note mean chart indicate no problem.
88	Range	Upper warning limit	Acceptable on its own, resample is required.
92	Mean	Upper warning limit	Acceptable on its own, resample is required.
93	Range	Upper action limit out of control	Possible action could be involve obtaining additional information, but some possible action could be; (a) check if sieve crack (b) check the performance of Nash vacuum pump (c) check high and low vacuum line if any leakage (d) check mud conditioning as per the required. Note mean chart indicate no problem.

The summary of the histogram graph in Figure 4.13 shows:

1. The graph's single peak point in the middle suggests a unimodal data distribution.
2. Although the graph were skewed to the right with value of 2.6, the factory would want it to be slanted to the left due to its losses rather than product defect.
3. The losses shown in the graph was 11.6% higher than the allowed range. Because there are no losses below the specification limit, the company pays special attention to minimizing the overall losses from appearing in the upper specification limit.

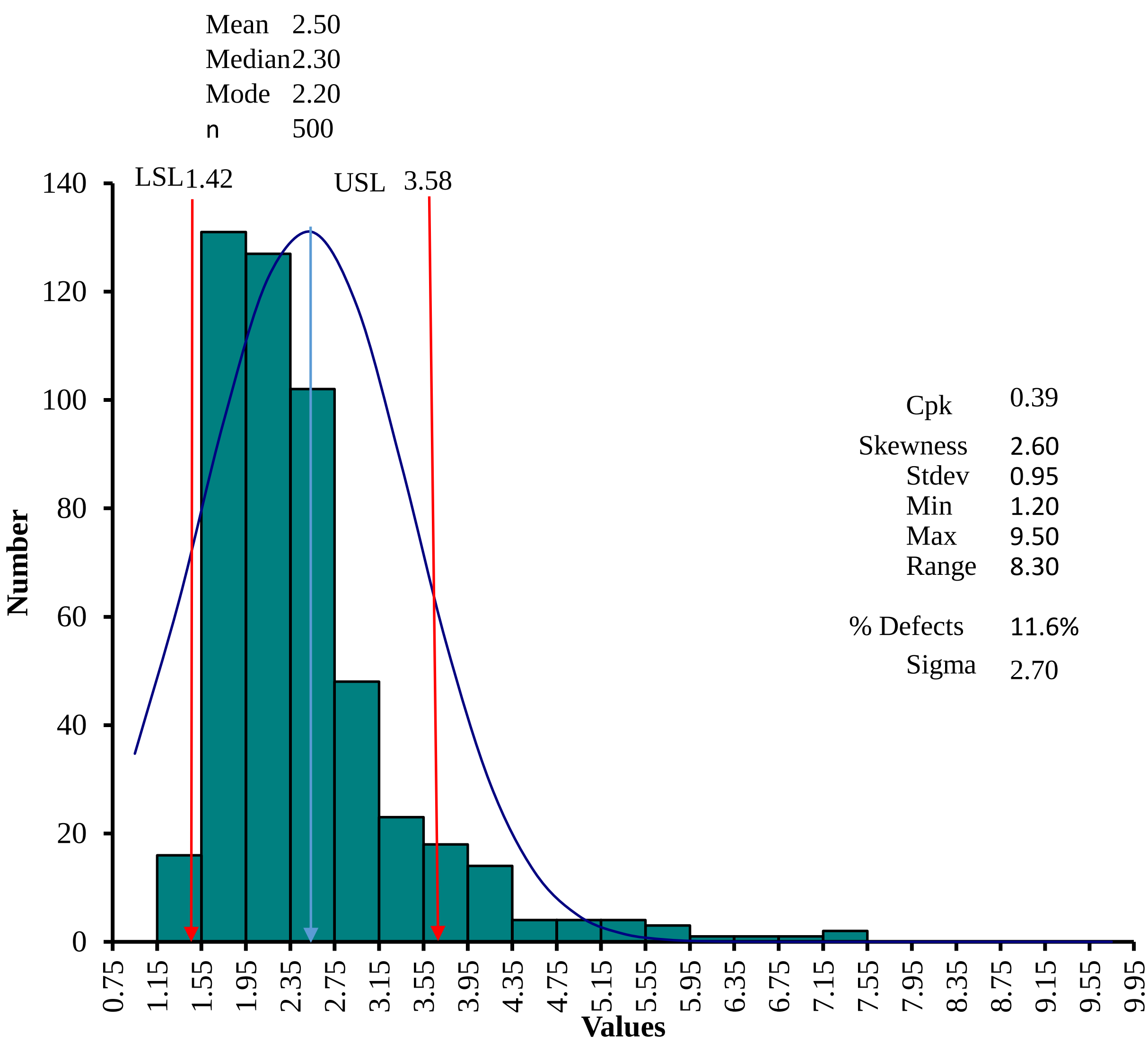

Figure 4.13 Histogram bar for filter cake.

The graph shown in Figure 4.12 was the distribution of the mean for molasses losses, more of the distribution were in the grand mean and there was small appearance of special causes of variation that need rearrangements.

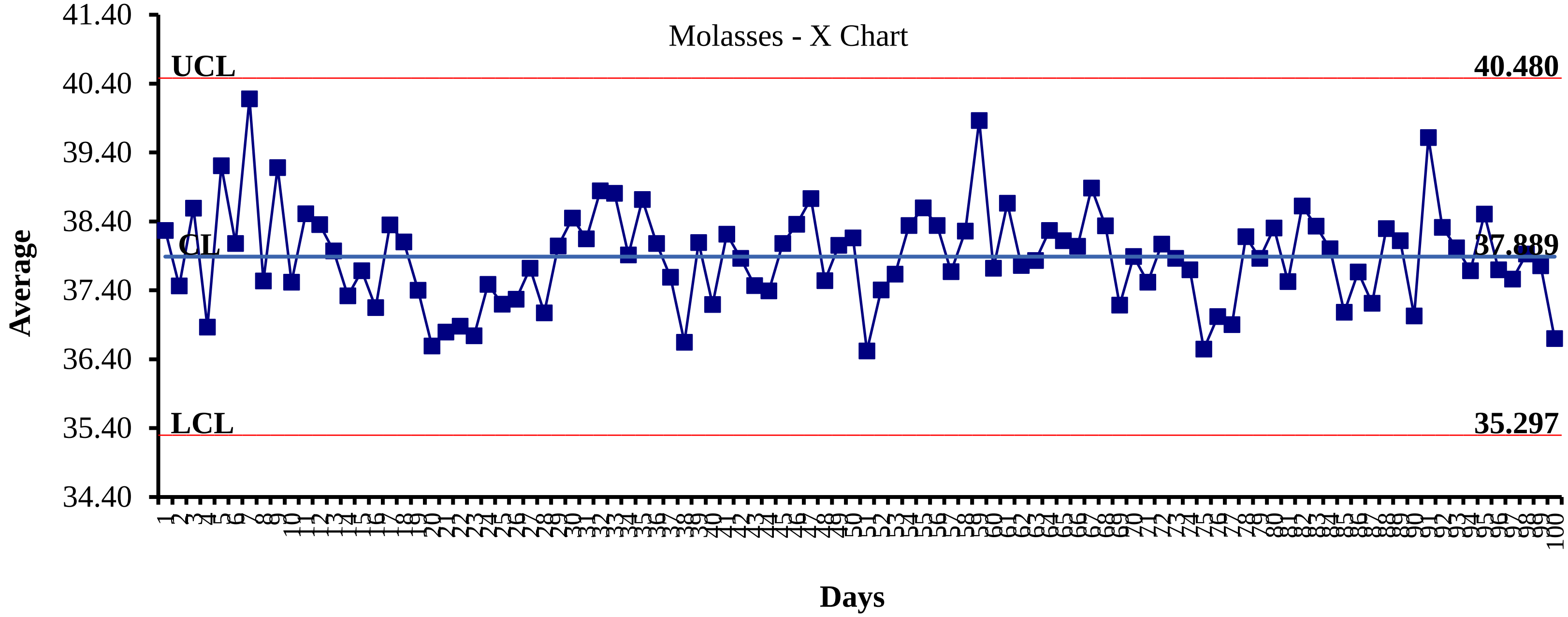

Figure 4.14 Mean chart of losses sucrose with final molasses

After calculating the mean, range and grand mean the above graph shown in Figure 4.14 for mean drawn to know does the process was control or there was special causes of variation. Based on the above chart the interpretation were given in table 4.7 shown below.

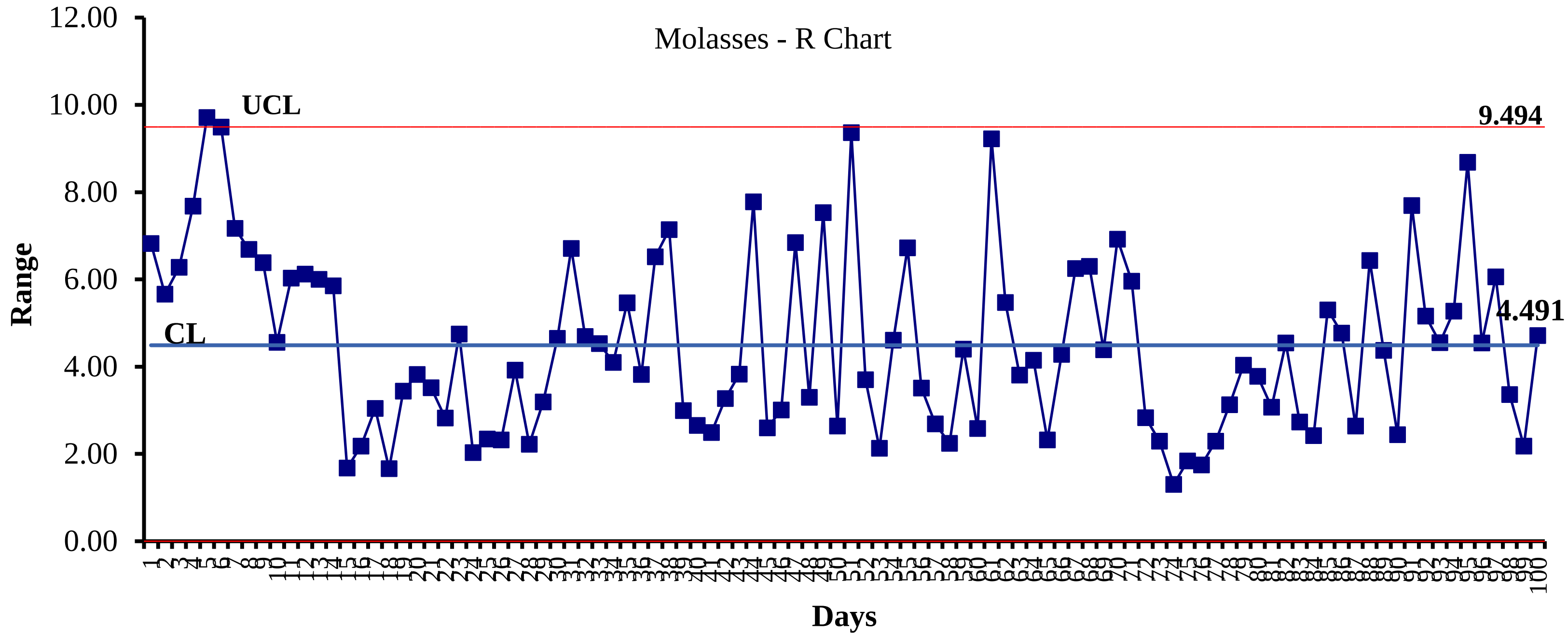

Figure 4.15 Range chart of losses sucrose with final molasses

After calculating the mean, range and grand mean the above graph shown in Figure 4.15 to know does the process was controlled or there was special causes of variation. Based on the above chart the interpretation were given in table 4.7 shown below.

Table 4.7 Analysis of above mean and range chart

Sample number	Chart	Observation	Interpretation
5,6	Range	upper action limit	Possible action could be involve obtaining additional information, but some possible action could be; (a) check low purity of the incoming juice (b) check if improper hot water inter into centrifugal machine (c) check massecuite conditioning as per the standard. (d) Check crystallizer cooling disk leakage (e) check if the working screen worn out.
7	Mean	upper warning Limit	Acceptable on its own, resample is required.
51,61	Range	upper warning limit	Possible action could be involve obtaining additional information, but some possible action could be; (a) check low purity of the incoming juice (b) check if improper hot water inter into centrifugal machine (c) check massecuite conditioning as per the standard. (d) check crystallizer cooling disk leakage (e) check if the working screen worn out
74, 96	Range	Lower warning	Acceptable on its own, resample is required.

The histogram graph shown in Figure 4.16 below is summarized as follow:

1. The graph have one peak point at that center that implies unimodal data distribution.
2. The graph is skewed to the right with 0.45 % it is better to skewed to the left for the factory rather than the right due to its losses not final product defect.
3. The losses found in the graph is 14.8% that above and below specification limit. There is no losses below the specification limit that means the total losses can appear in upper specification limit that he factory give attention to minimize.

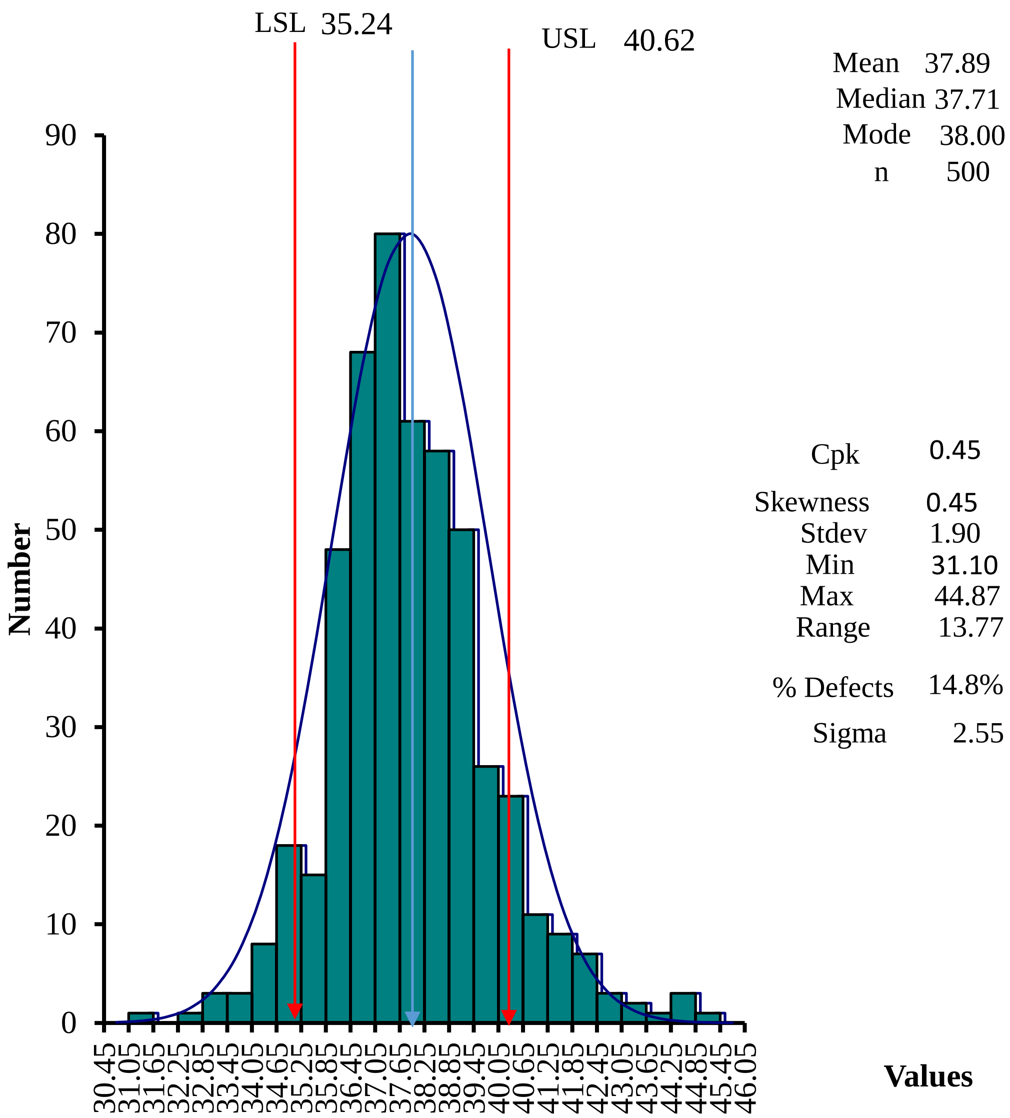

Figure 4.16 Histogram chart for final molasses

From the above chart and analysis table of bagasse, filter cake, and molasses, were concluded that there was losses for past five years of the operational campaign. It described the level of losses in Figure 4.17 Shown below and from the losses type, sucrose losses in final molasses take the highest percentage, which was 51.34%. In past five years the recored of losses in bagasse, filter cake and final molasses was very high. When the value of losses converted to the cost it was 927,502,840.03 Birr.

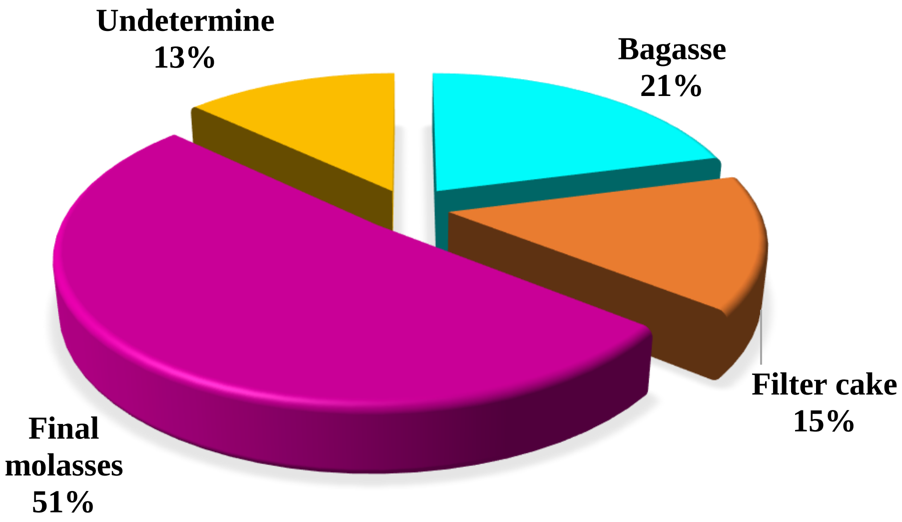

Figure 4.17 Losses sucrose in MSF factory (Appendix A).

The losses of sucrose in sugar factory are depicted in Figure 4.17 of the graph above. Final molasses represents the largest proportion of those losses. The second biggest losses at the factory were bagasse losses. The cause-and-effect diagram were analyzed to find the underlying causes.

4.6 Factors of loss in final molasses

One of the biggest problems in the sugar industries which challenge their profitability is the loss of sucrose with bagasse, with filter cake and with final molasses. At present, in Metahara Sugar Factory (MSF) 9.1 to 9.3 % of the sugar that enters the factory with the cane are lost with final molasses. This is a big loss which should be minimized. The company is losing sugar that is expected to be recovered and there is a need to increase the efficiency of sugar factory. The causes of the high sucrose loss with final molasses are not clearly identified for MSF (2019). The sugar in the final molasses is 1 % to 1.30 %. The loss in final molasses depend on the cane quality and process achieved (Sharma, 2015). There was significant loss that has to be reduced. There was need to improve the sugar factory's efficiency because the company losing sugar that should be recovered. The loss of sugar to final molasses accounts for 45-47% of the total sugar loss (Paul, 2014). The factors to be considered for the losses of final molasses are listed below. These are- low performance of boiling house, crystallizer cooling disc leakage, performance of perforated sieves, crystallizers battery leakage, perforated hole of basket wide, C-seed preparation, D-massecuite boiling, purity of molasses, poor operation(feeding), centrifugal machine speed, low bleed, steam chest steam leakage, and improper conditioning as listed in cause and effect diagram shown in Figure 4.18.

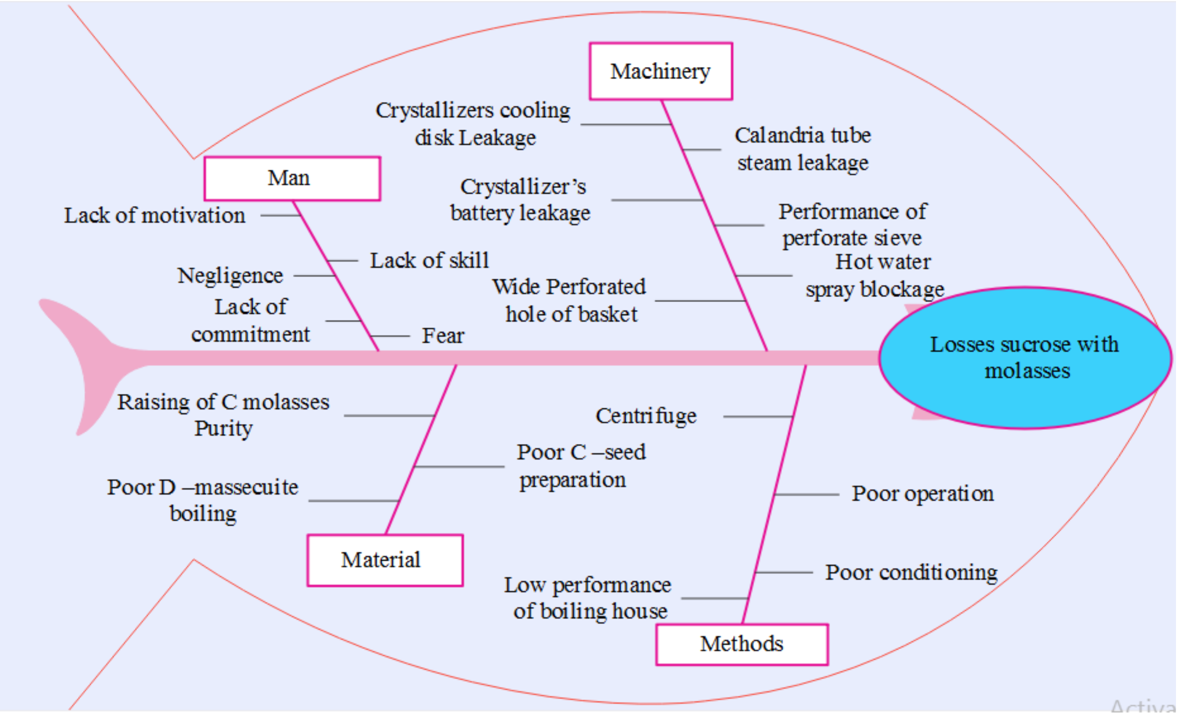

Figure 4.18 Cause and effect diagram for molasses

4.6.1 Centrifugal separation

Due to sucrose crystal will always pass through centrifugal perforated screen holes and some crystal will dissolved by the wash water purity rise across curing was to some extent it's expected. In order to minimize and improve the sucrose loss with final molasses through screen it was regularly inspection and repair shall be expected.

4.6.2 Cooling Crystallization

Sugar crystallization start in vacuum pan and complete in cooling crystallization. Cooling crystallization is used to finalize molasses exhaustibility by removing all sugar possible from the last mother liquor (molasses) the decrease in temperature of massecuite cause the in the mother liquor to hold less sugar (solubility decrease with decreasing temperature. When massecuite is cooled in cooling crystallizer excess sugar crystalize as temperature drops. As we cool the massecuite in the cooling crystallizer to about 45 ºC (the usual temperature of the cooling crystallizer) its solubility decrease, and consequently molasses with lower purity produced after the massecuite centrifuged (Mohamed, et al., 2018).

Cooling crystallization was play important role in final stage of massecuite processing that minimize the recovery of sugar from final molasses. The main purpose of cooling crystallization to increase the sucrose recovery through depositing the massecuite on the surface of crystals. The massecuite on leaving the pans was at temperature of 70 -75°C (160 - 165°F). Cooling of final massecuite is usually done in the temperature range of 40-50 ^{0}C depending on the nature of the massecuite. Based on this fact, cooling experiment was aimed to be done in continuous crystallizers at massecuite temperatures of 40 –50 ^{0}C by controlling the cooling water flow rate (Goli, 2016). Crystallizer has shaft driven by an electric motor and worm gear which used to agitate the massecuite for exhaustion and cooling through the assembled cooling disc that allows the water circulation inside the disc.In operational period there was friction between massecuite and crystallizer's disc. Due to that the disc were easily worn out and create leakage. When the disc leaks there was contact between water and massecuite which cause dissolve of the crystals of sugar that easily discharge though the perforated sieve with molasses. The Figure 4.19 shown below was crystallizer cooling disc. The area pinpoint where the leakage was found at the most, so timely inspection and repair was better.

4.6.3 Crystallizes heater (battery) tube and body leakage

To get the greatest results in the centrifugal, massecuite must be consistently at the ideal temperature. Given the extremely high consistency of low-grade massecuite, this was especially crucial. Having re-heaters at least on the C massecuite in raw mill and on low-grade refinery recovery boiling was standard procedure (Rein, 2007). If the mixture was too viscous to handle at the centrifugal, it could be reheated before centrifuging.

Two batteries or heaters are present in the MSF's low-grade massecuite. Heat were exchanged as the hot water pass through the tube and the massecuite outside the tubes surface. Hot water and massecuite in direct contact with each other when the heat exchanger deteriorates due to wear on the joint or surface of the tube causes the erosion of the massecuite grain, which was easily discharged through the perforated sieve with molasses and increases the purity of molasses across the centrifugal section. The maintenance of heat exchangers was difficult due to all the joints being fixed with permanent joints and bulky in size. Most of the time, it's bypassed due to leakage and it takes time to repair and put in line.

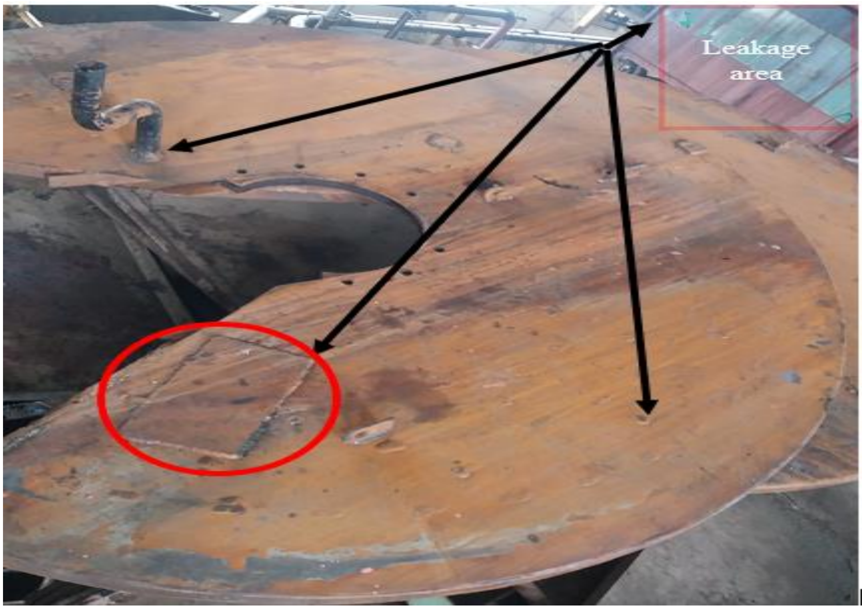

Figure 4.19 Crystallizer cooling disc

4.6.4 Performance of Perforated Sieve

Once the mother liquor exhausted to the practical limit, it remains only to separate the crystals in order to obtain the sugar in the commercial form. The operation carried out in centrifugals was known as purging. For A- massecuite Batch machines were used for C and D- massecuite Continuous machines were used. One of the centrifugal machine component which play important role for separate sugar from molasses was perforated sieve. It made up of brass or stainless steel with fine holes. During operation perforated sieve were damaged in two ways. The first one was though aging/ worn out of sieve and the second was when foreign material enter the basket and damages the sieve. The screens need to be inspected routinely to look for damage and wear. If the chrome layer were lost, the underlying nickel wears very quickly. Wear was seen mostly just above the clamp ring as the massecuite flows onto the screen. If the screen of the centrifugal machine is torn, there is high final molasses purity, hence sugar loss (Paul, 2014). Purity rises across the centrifugals will give an indication of wide holes in the screen or when worn screens not replaced. To achieve the best performance daily screen inspections, removal and caustic washing of dirty screens because of the buildup of scale, and replacement if damage were evident.

4.6.5 Skilled Man Power

It was resource that strong enough but lacks awareness of tasks and responsibilities, this was what makes human resources into one part that often became significant constraint. Employee saturation due to the monotonous work cycle and lack of supervision on employee performance during the production process affect the employee one of them decreasing the level of discipline in carrying out production activities that affect the resulting product.

4.7 Factors Affecting Juice Extraction at Milling House

According to the cause-and-effect diagram in Figure 4.20 improper imbibition, machine component failures, lack of standard hydraulic pressure, poor mill settings, poor messchaert groove/juice drainage, poor messchaert knife arrangement, an unproportioned feed and delivery set opening, and poor preparation index (PI) are all expected to be the main causes of sucrose losses in bagasse.

4.7.1 Poor Cane Preparation

After the cane were harvested and arrives at the cane yard, preparation of the cane was the primary objective of the factory. There are several machine components integrated to prepare the cane as per the request preparation index. The main machinery in this section was cane unloader, cane table, cane carriers, cane knives, and fibrizer. In MSF, there are three types of cane-cutting mechanisms. The first was roughing, the second was first finish and the third were fibrizer. Roughening and first finishing are used to rough cane through the use of the knife, and the second one were the fibrizer. It was the final step of cane preparation area and that used domi tip to initiates the activity of fiberizing as per the standard preparation index. Arrival of cane at the mill section without adequate preparation as needed was the issue in the cane preparation section. This was caused by number of issues, including maintaining the distance between knives and carriers for both knife roughening and first finishing, the opening of anvil board intake and discharge at the fibrizer, and maintaining the gap between the carriers to prevent the passage of not hammered cane. The cane cutters' constructional issues were the other issue. Due to shortage of replacement components and the scarcity of hard currency, MSF now uses homemade cutters. Poor cane preparation results from the home made cane cutters' lower level of durability and ease with which they wear out, prior to scheduled preventive maintenance. The loss of percentage in bagasse was directly correlated with the poor performance of cane cutters. The stress on the mills was reduced and the extraction process was made easier by having high cane preparation index. The MSF preparation index standard > 85, but when it comes to the actual values of PI, it was below the standard due to the reason mentioned above.

With an optimum preparatory index, the permeability of bagasse increases & juice cells were opened, holding free juice. Therefore, extraction becomes easier. As bagasse approaches the neutral plane, the permeability of bagasse reduces and density increases, causing low juice extraction.

4.7.2 Juice Extraction

The main objective of juice extraction plants was to separate the sucrose from bagasse by the integration of the following list of machineries: mill turbine, different types of speed reduction gear boxes, torque transmitter coupling, self-align mills, intermediate bagasse carriers, Donnelly chutes, cush-cush screw conveyor, vibrating screen, central oil pumps, and mill hydraulics. The failure of single machine affects the whole operation and raises the percentage of losses during the operation.

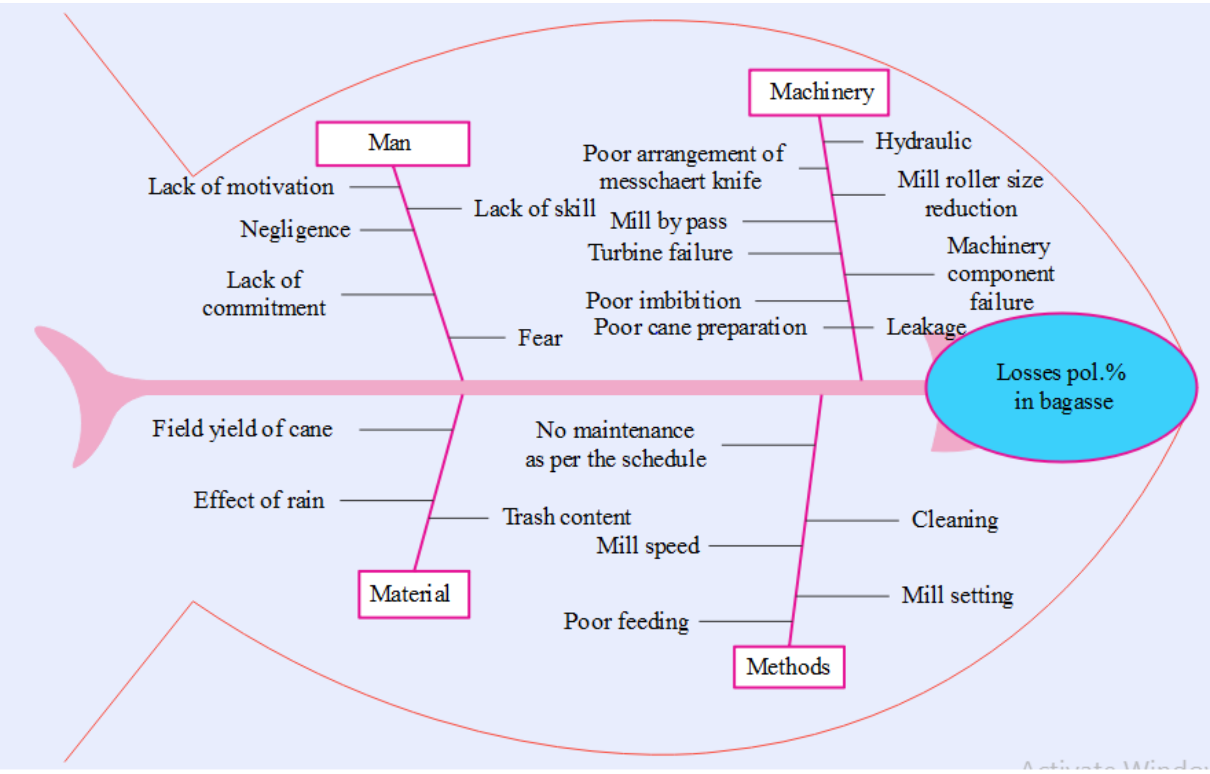

Figure 4.20 Cause and effect diagram losses of pol. % in bagasse

4.7.3 Mill Turbine

The main objective of the mill turbine were to drive the mill roller at the required mill roller speeds. The turbine was driven by steam generated from power generation plants. Due to redundancy of failure, it was one of the bottlenecks of the factory. While in operation, the mill turbine fails due to poor inspection, improper preventive maintenance, lack of spare parts, and the scarcity of steam. When one mill turbine fails, the mill were bypassed to continue the operation and the factory was obligated to run with the remaining four mills. During this, the factory recorded high loss of pol. % in bagasse, and high moisture-containing bagasse were transported to boiler, which affects the boiler operation highly. To minimize the failure of mill turbines, it was better to do preventive maintenance, timely inspection, and deliver good quality steam.

4.7.4 Mills hydraulic

In the milling process, the juice was extracted by squeezing canes under rollers, with the help of high hydraulic pressure (Ravindra et. al., 2021). The other piece in the juice extraction puzzle were mill hydraulics. Mill hydraulics was the equipment used to press the top roller at optimum pressure to extract juice. Working without hydraulic was not only losses, but extraction of juices was impossible and also puts the top roller in dangerous position. When bagasse mate feeds to mills, the top roller were lifted above the limit, and damage happens in the absence of proper hydraulic use, so proper use of hydraulic were essential.

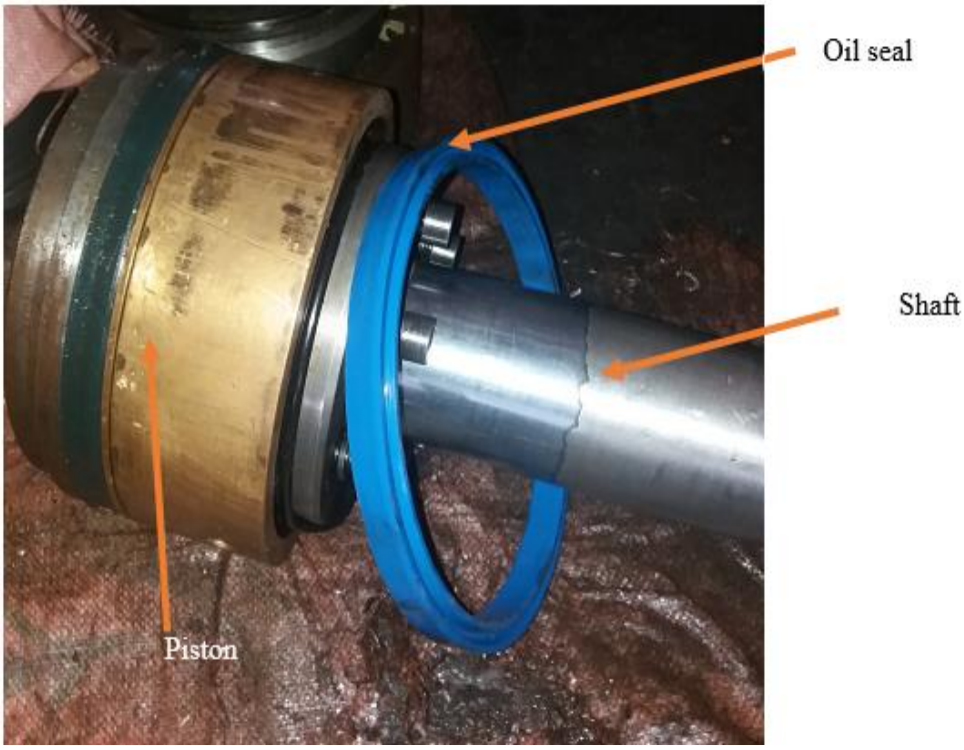

Figure 4.21 Mill hydraulic piston with accessories

The hydraulic was not working without an oil seal and hydrogen accumulator. Those two pieces of equipment are necessary for the hydraulic as spare. The accumulator was filled with oil and nitrogen gas at the top of the cylinder and used to push the oil into the piston stroke and to lift and push the top roller. Pressure were supplied by oil accumulation containing oil under pressure and also used to keep the movement of the hydraulic piston during operation.

The piston can move up and down because the oil inside the piston were kept under pressure by the oil seal, which also serves to prevent oil leaks. The indications was hydraulic failures brought on by worn-out piston shafts and pistons, as seen in Figure 4.21. Once the shaft was worn down, oil were leak outside and it becomes challenging to press the rollers. No more extraction would be possible without the use of hydraulics, but this was dependent on the thickness of the bagasse mates and the consistent pressure that was always provided to them, regardless of the top roller and changes in the feed. The hydraulic pressure for five mills in the case of MSF application were displayed in Table 4.8. However, the actual operating pressure was less than 100 bar, which was below the standard. Ageing and lack of spare components are the main causes of this. It was preferable to do thorough inspection and prompt maintenance in accordance with the preventive maintenance program prior to hydraulic pressure failure.

4.7.5 Causes of mill rollers size redaction

The other factor in juice extraction was mill rollers under size. In one set of mills, there are three main rollers (top, feed, and delivery) and one small roller feeding roller in the case of MSF. During the operation, the mill rollers' diameter gradually became undersized due to the friction between the rollers and bagasse mate. When the mill rollers diameter became under the opening between top to feed (feed opening) and top to delivery (delivery opening) very wide and the bagasse was easily passed without enough pressing by mill rollers hydraulic and cause very high losses of pol. % in bagasse. By using brix carve which show back and front juice brix to correct mill setting better.

Table 4.8 Standard of mills hydraulic pressure in MSF (source: mills manual)

Mills	Hydraulic pressure	
	Drive side	Non drive side
1	130	133
2	133	135
3	146	148
4	160	168
5	170	172

4.7.6 Causes by mill setting

In three rollers mill, rollers are named top roller, feed roller, and discharge roller. They are arranged in triangular pattern. Which removes sucrose 95-97% (Ravindra et. al., 2021). It was necessary to ensure that the mills was set up for optimal performance. The first key issue to appreciate from the theory of milling was that mill setting does not merely encompass the positioning of the feed (front), top, and discharge (back) rollers in the appropriate positions. There were an optimum compaction ratio for the openings at each stage of the passage of bagasse through the process, including whichever of the following are installed: Donnelly chute to underfeed roller; Underfeed to mill feed; Mill feeds to trash plate center height and Mill feed to delivery. Setting up milling tandem for given throughput usually starts with deciding the desired work openings between the final three rollers of each mill, i.e. that between the top and discharge/delivery roller (the discharge opening) and that between the top and feed roller (the feed opening). Many different methods was used around the sugar world, but virtually all effectively calculate settings (openings) between rollers to give an ascribed volume sufficient to pass the required rate of fiber at the desired compaction. This principle were applied using densities and ratios that have been empirically validated (Rein, 2007).

Mill setting was considered as the cause of loss of pol. % in bagasse through different ways. As shown in Figure 4.22, the relation between three rollers were to optimize the operation when the arrangement of the rollers was as per the calculated mill setting. One of the causes of overflow and blockage considered poor mill setting. During the operation season, the relationship between one rollers to another was huge impact on losses. When the opening of the feed to the top (feed opening / T) wide it consumes more and discharges less causing an overflow of bagasse and when the opening less it consumes less bagasse which creates blockage and interrupts the operation due to the operations were interlock with carriers. In the case of top to delivery opening (delivery/ back opening) when it was wide the bagasse came from the feed were directly discharged without enough pressure exerted from hydraulic mills which causes losses of pol.% in bagasse and also when the opening more narrow than required it create blockage and disturb the operation by overflow. Especially, when such thing to happened in the last mill in addition to losses of bagasse high moisture contain bagasse were transported to the boiler which difficult for combustion, so good mill setting plays important role in the reduction of pol.% in bagasse.

4.7.7 Impact of Messchaert grooves

The bottom of the roller groove provides important channel drainage backward from the pinch point between two rollers. These was possible because the cane/bagasse fibers tend to bridge across the sharp v at the bottom of the groove. However, the channel left here was very small cross section and the volumes of juice to be drained can be large, particularly at the first mill and at subsequent mills when high imbibition rates are applied. The available drainage channel can be increased considerably by machining additional deep grooves. The messchaert groove needs messchaert knife or combs to scrap the bagasse fill into the grooves and which assist the juice drainage and reduce re-observation, so poor messchaert knife arrangement was the cause of resistance of juice and re-observation takes place.

4.7.8 Effect of imbibition on losses of sucrose

Imbibition and juice maceration plays important role in achieving better mill extraction. When bagasse were subjected even to high and repeated pressures, it never gives up all the juice that it contains. It approaches minimum moisture, 45% in general, and 40% in the most favorable cases; that was, it retains high proportion of juice, amounting roughly to half its weight. In order to extract as much as possible of the sugar which it retains, it was, therefore, necessary to resort to an artifice: since this moisture content cannot be reduced, the effort will be made to replace by water the juice comprising it (Hugot, 1986). Imbibition water dilutes the juice in bagasse and reduces its viscosity. The characteristics of low viscosity of juice increase the flow of juice through bagasse. The hot water further helps in reducing the viscosity of the juice. However higher temperature of water sometimes leads to slippage of bagasse in the mill. The higher imbibition water was restricted due to the capacity of the boiling house and availability of steam and therefore it restrains to increase crushing grate.

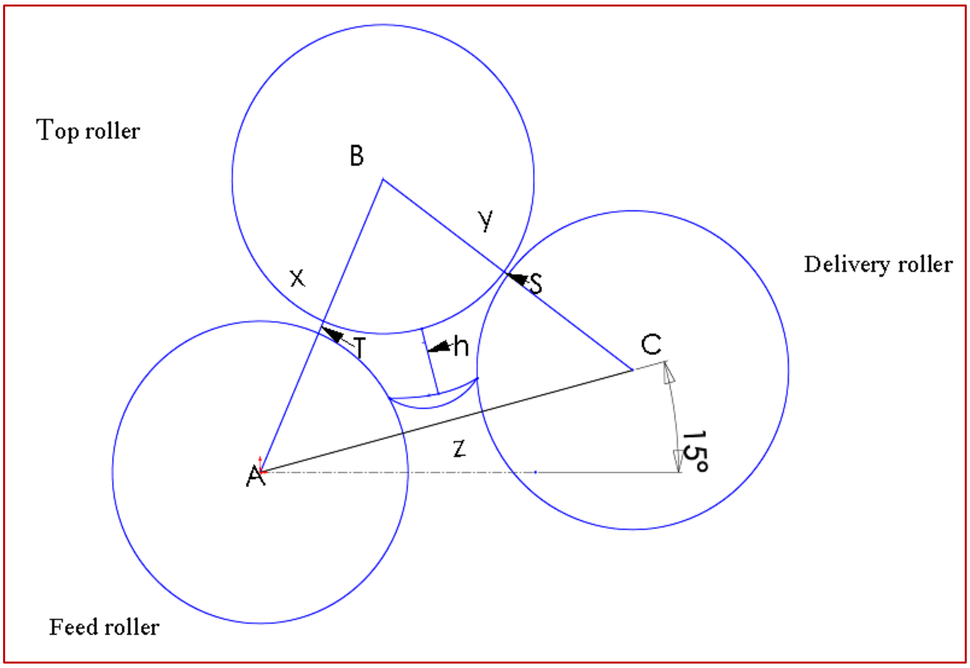

Figure 4.22 Arrangement of mill rollers

It may please be noted that higher imbibition water do not increase the moisture in the bagasse. But inadequate juice drainage, low compression, higher speed, improper cane preparation are the main reasons for increase in moisture of bagasse. Rise in imbibition of 5% cane and 42.7 % fiber, there was an increase of about 4.7 and 0.9 % in mixed juice and pol extraction; respectively, while were 4.7 and 1.0 %. Pol % bagasse decreased by 0.55, 0.48 and 0.35 for every 5 % increased in imbibition rate from 20 to 35 % with the variety (Tawfeuk et al., 2019).

The higher the imbibition temperature the more sugarcane juice that can be produced. Because the higher the temperature the more dilute sugar so that sucrose easily diffuses out and the production juice were high. The imbibition temperature can affect the level of solubility of sucrose in warm conditions. Cell walls have semipermeable power, where sugar can break out of the bagasse cells as long as the cell alive. The purpose of providing high-temperature was to reduce fuel economy usage, accelerate the cell-cell splitting reaction due to high given imbibition temperature. This was also affect the performance of sugarcane milling machine which was represented by Mill Extraction in taking raw juice pol in sugarcane. Giving imbibition were also an attempt to suppress the loss of sugar in the bagasse. Milling performance was so responsive to the proportion of water used in the process that a milling result cannot be properly assessed without an accompanying expression of imbibition (Gunawan et al., 2018).

4.7.9 Mill bypass

During the operational season, machine breakdown were considered to be minimum. When unexpected failures occur which take long time to maintain, it was better to provide bypass to continue crushing with the remaining mills. Those failures are like:-mill turbine failure, mills pinion worn out, tail bar coupling sheared, and reduction gearbox internal component failure. Due to the mill being bypassed probabilities of losses at this time was very high.

4.8 Causes of sucrose loss in filter cake

Mud filtration was carried out to recover juice from mud that has been discharged from the clarifier using a rotary drum filter that employs the principle of vacuum filtration (Sandeep et al., 2014). Over 90% of the mud was actually clear juice that has to be recovered. The purpose of the filter station was to separate as efficiently as possible, the mud solids from the clear juice in clarifier mud. The mud from the clarifier were conditioned before filtration. The coarse material were screened out of bagasse to leave fine bagacillo which mixed with the mud. Some lime and flocculants may be added, especially when mud proves to be difficult to filter. The reason for the filter cake pol. % being above the specification of 3.0% may be explained by poor mud conditioning due to insufficient bagacillo added to the mud to act as the filtering aid, or insufficient water spray to the rotary vacuum filter resulting in poor filtration, hence causing loss of juice to the scum. It is also possible that low vacuum during the filtration operation results in loss of juice in the scum, since low vacuum leads to reduced sucking of the juice from the mud. This occurs during operations in cases when the vacuum pumps develop mechanical problem, creating low vacuum, which may also be caused by low water volume supplied to the vacuum pumps. Another cause may be physical damage of the rotary vacuum filter screen resulting in loss of juice to the scum when the filter operation was inefficient. There are several reason in which pol. % of sucrose losses increase in filter cake at clarification section (Sangura, 2014).

The suspected causes of losses with filter cake were discussed below. Those are mainly: Nash vacuum pump under capacity, vacuum drop due to high and low vacuum line leakage, perforated sieve thorn out, bridge plate roughness, improper mud conditioning and inappropriate use of imbibition and unsuitable speed of rotary drums

4.8.1 Vacuum drop

In the filtration process, vacuum drops exist due to the following reason. First, when Nash vacuum pumps were under capacity due to mechanical failures like failure of the bearing, clearance between impeller and housing were wide and gland leakages of pump was the reason for vacuum drop. Second, leakage at low and high vacuum lines, valves, bridge plates, and through packing. Thirdly, torn out of sieves due to poor arrangement of scrapers and aged. When the bridge plate was worn the unit does not seal to create high and low vacuum to separate sucrose from mud. Figure 4.23, shown below the worn-out bridge plate. Paul (2014) discussed that it is also possible that low vacuum during the filtration operation results in loss of juice in the scum, since low vacuum leads to reduced sucking of the juice from the mud.

4.8.2 Cause due to unsuitable mud conditioning

Mud conditioning were the process of optimizing the thickness of mud as required. When the mud was poorly conditioned either thick more or very thin below the specification. The scarcity and improper use of bagacillo affect the process of mud conditioning. The reason for the filter cake pol % being above the specification of 3.0% were explained by poor mud conditioning due to insufficient bagacillo added to the mud to act as the filtering aid, or insufficient water spray to the rotary vacuum filter resulting in poor filtration, hence causing loss of juice to the scum (Paul, 2014).

4.8.3 Improper usage of imbibition

The purpose of sweetening were to facilitate the process of sucrose extraction easily from the mud, so poor usage of imbibition affects the operation process and raises losses of sucrose.

4.8.4 Using of inappropriate speed of rotary drum

The speed of this motor is constant: 1,450 r.p.m. generally, It drives the filter drum by means of belt and double-worm reduction gear. Speed-regulation device controlled by hand-wheel permits the speed reduction ratio of the v-belt to be varied; accordingly, the final speed of rotation of the drum may be regulated between maximum of 1 rotation in 3min and minimum of 1 in about 10 min. Thus scale of speed regulation provided allowing the speed to be varied between extreme values in the ratio of approximately 1 to 3, so running the drum out of range cause losses (Hugot, 2007).

4.8.5 Perforated Sieve Blockage

Perforated sieves equipment were used to separate sucrose from mud. The exterior surface of the drum consists of sheet of copper, brass, or stainless steel perforated with many holes. They were more flexible and less fragile. During operation, the perforated sieve hole blocked by poor mud conditioning and wrongly mud scraper arrangement, failure of scraper which causes losses of sucrose at filter cake.

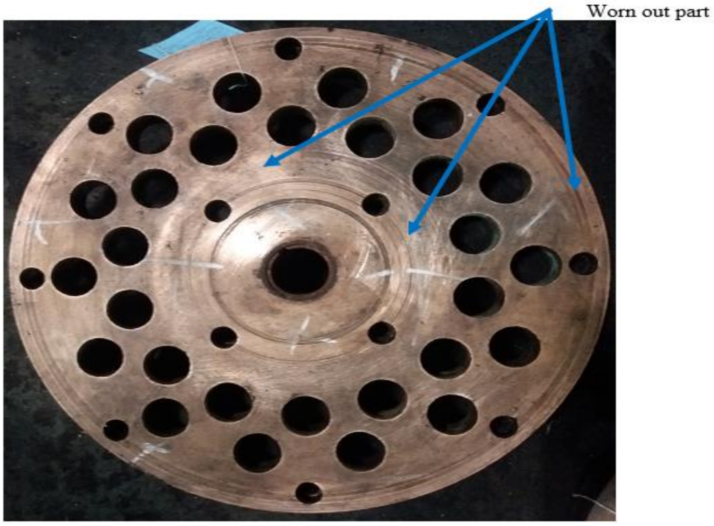

Figure 4.23 Bridge plate

Process parameter of O.C. filter

Temperature 80C^0-85C^0

Range of alkalinity 8PH-8.6PH

Speed of rotary drum 1in 3 min. to 1in 10 min.

Low vacuum 15mm Hg -25mm Hg

High vacuum 25mm Hg -45mm Hg

Mud thickness 2mm

4.9 Factors of undetermined losses

4.9.1 Introduction

Sugar losses of large proportions occur in and around the mills, particularly if proper attention was not paid to cleanliness and sanitation. These losses undetermined, in fact unrecorded, because the control of the sugar entering the factory begins at the weighing tanks after the juice has left the mills. The secondary losses include factory losses due to inversion, dextran, alcohol and acid formation in the extracted juice incident to inefficient and unhygienic processing. The major factors that affect lead to post-harvest deterioration in sugarcane include cane variety, environment, crop ripening, biotic and abiotic stresses besides several management issue like harvesting mode, transport and storage systems in mills.

4.9.2 Mill sanitation

Undetermined sucrose loss during the processing of sugarcane to sugar estimated between 1-2%, being large financial loss to the industry. Microbial infection of sugarcane juice were from the microorganisms that enter the mill with the cane supply, and those from the floor washing and filtrate. Microbial degradation contributes 93% of the sucrose loss in mixed juice. Effective cleaning and sanitation procedures were needed to reduce microbial degradation in the factory (Fernando et al., 2022). Eggleston (2002) reported that 93% of the sucrose loss in mixed juice was caused by microorganisms. Microbial infection of sugarcane juice results from the microorganisms that enter the mill with the cane supply, and those from the factory recovery stream and the filtrate. The growth and accumulation of these microorganisms lead not only to sucrose loss, but the formation of increasing proportions of non-sucrose impurities which affect crystallisation rates and sucrose yield. Effective cleaning and sanitation procedures were needed to reduce microbial degradation in factory (Fernando, et al., 2022).

A sugar mill converts sugarcane to sugar crystals by various continuous processes like crushing, evaporating, filtering & Distillation. Starting from the primary juice, these microorganisms have been found to be present at all stages of sugar manufacturing up to sugar and final molasses. Sugarcane juice processed an excellent medium for the growth of many types of microorganisms. These include bacteria and fungi capable of degrading of sucrose in production process.

4.9.3 Inversion

Many species of bacteria and yeasts produce enzyme invertase that splits sucrose into glucose and fructose. This results in sucrose loss with high reducing sugars levels due to inversion. These microorganisms, especially Leuconostoc mesenteroides also produce copious amount of extracellur polymeric substance, notably dextran. These slimy polymers interfere in the process of sugar crystal formation and result in elongated crystals & fermentation. This adversely affects the sugar quality & gives out a bad odor. It was therefore extremely important that the microbial activity in the cane juice were kept at the minimum. To maximize the sugar recovery from each of the processes, different sugar process chemicals are used for individual production processes. Our comprehensive ranges of high performance chemicals have been formulated scientifically to deliver significant operational benefits with economizing the production process. Microbial activity in a sugar mill can be controlled by the application of a properly selected mill sanitation chemical (Manerkar, 2018).

Casey, (1999), discussed that invention relates to the sanitation of sugar factories and more particularly to the reduction of the degradation and loss of sucrose in sugar juices in the sugar factory resulting from bio-chemical reactions. It has been known that in the production of sugar from sugar cane and sugar beets there has been major loss of sugar due to inversion of the sucrose in the raw sugar juices and other types of degradation of the juices caused by bacterial action, enzymes, and perhaps other biological factors.

Under normal milling conditions sugar loss is estimated to be around 1.0 to 2.5 kg of sucrose per ton of cane ground between crusher juice and mixed juice depending on the factory conditions. About 13 per cent of this loss (crushing of stale cane) is due to chemical inversion, 25 per cent is due to the activity of cell free enzymes and about 62 per cent is eaten up by the microorganism present in juice and mills. Therefore, proper mill sanitation use of effective biocide is important to enhance processing efficiency and sucrose recovery. The extent of loss in Indian sugar mills is reported about 5 to 10 kilogram sugar per ton of cane ground, may be even more when crushing is extended in summer months (MM Roy, 2020).

4.9.4 Machinery component failure

In the process of sugar production, machinery component failure was one of the most series issues regarding losses, especially at milling stations. When one machinery component fails, it takes time to maintain and put the unit in line at this time inside screened, and unscreened tank exposed to reaction and degradation of the juices caused by bacterial action, enzymes, and perhaps other biological factors happen. The other causes of undetermined loss are leakages of lines, valves, pumps, tanks, at flanges, and poor collection of dust sugar. Line leakages are caused by stress and aging. When the pump start and the discharge valves do not open it searches for weak zone and was torn also when the line were aged enough and does not change timely it exposes it to leakage. Valve and pump leakage was through body worn out and through their glands. Especially when it comes to vacuum and centrifugal stations there was gland leakage which difficult to recover. Close inspection and timely maintenance for their gland leakage through proper packing, otherwise look for the shaft straightens for repair.

4.10 Analysis of data from questionnaires

The data collected from questionaries' were analyzed through SPSS and the result and effect were discussed in the listed table below.

4.10.1 Educational back ground of respondent

The data in Table 4.9 below shows that the organization has educated manpower, with 75% of respondent's holders a first degree and 25% of them are diploma that implies there was no scarcity of educated man power.

Table 4.9 Educational back ground of respondent

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Diploma	10	25.0	25.0	25.0
	Degree	30	75.0	75.0	100.0
	Total	40	100.0	100.0	

4.10.2 Experience of respondent

The study was examined the year of experience respondent and present the finding in Figure 4.24 below, 30% of them was serve in between 1-5, 6-10, and >16 years.

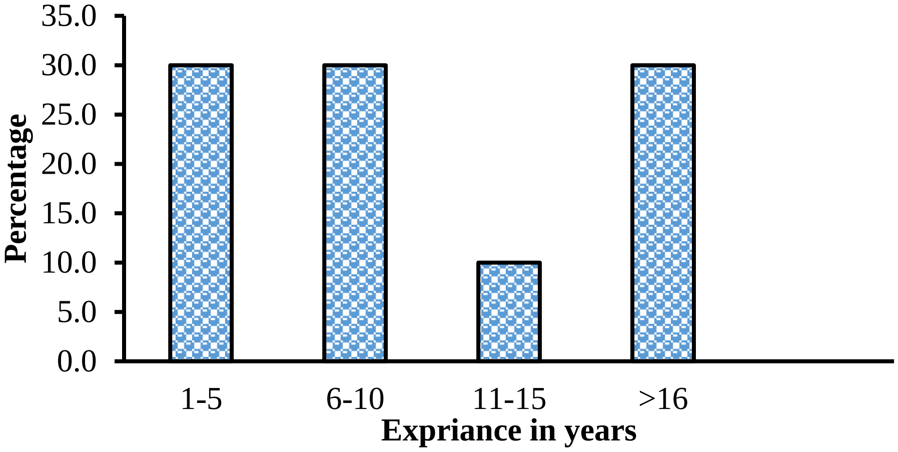

Figure 4.24 Respondent experience years

4.10.3 Losses sugar with bagasse due to poor operation

As mentioned in the Table 4.10 below 35 % of respondent response on losses of sugar with bagasse due to poor operational parameter was high.

Table 4.10 Response on losses of bagasse due poor operational parameter

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	3	7.5	7.5	7.5
	Low	4	10.0	10.0	17.5
	Medium	12	30.0	30.0	47.5
	High	14	35.0	35.0	82.5

	Very high	7	17.5	17.5	100.0
	Total	40	100.0	100.0	

The sucrose losses with bagasse due to poor operational parameter was analyzed with five elements and 35 % of the respondent response was high and 30% of them was medium, 17% of them was very high and 10 % were suggests that it has low impact. Generally losses of sucrose with bagasse due to poor operational parameter was high.

4.10.4 Losses with bagasse due to low pressure exerted on the top roller by mill hydraulics

As indicated in Table 4.11 shown below of losses with bagasse due to low pressure exerted on top roller by mill hydraulic was 52.5% with very high.

Table 4.11 Cause of low pressure exerted on the top roller by mill hydraulics

		Frequency	Percent	Valid Percent	
Valid	Low	3	7.5	7.5	7.5
	Medium	5	12.5	12.5	20.0
	High	11	27.5	27.5	47.5
	Very high	21	52.5	52.5	100.0
	Total	40	100.0	100.0	

As described in the above Table 4.11 the respondent response on Losses with bagasse due to low pressure exerted on the top roller by mill hydraulics 52.5% very high, 27.5% high, and 12.5% medium. The data was shows that the effect of mills hydraulic on the losses of sucrose with bagasse was very high.

4.10.5 Losses happen due to the negligence of operators

The effect of losses of sucrose due to the negligence of operators was indicated in the Table 4.12 shown below.

Table 4.12 Response on Losses happen due to the negligence of operators

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	3	7.5	7.7	7.7
	Low	7	17.5	17.9	25.6
	Medium	21	52.5	53.8	79.5
	High	8	20.0	20.5	100.0
	Total	39	97.5	100.0	
Missing	8	1	2.5		
Total		40	100.0		

The table 4.12 shows that out of 40 respondent 39 was response on Losses happen due to the negligence of operators. The effect of operator's negligence on losses of sucrose was 52% medium, 20% high, and 17% of respondent responses low. Based on these analysis there is no excaudate on impact on operates negligence at mill section.

4.10.6 Losses happen due to inadequate use of imbibition

The impact of inadequate use of imbibition was analyzed in the Table 4.13 shown below.

Table 4.13 Response on Losses happen due to inadequate use of imbibition

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very low	1	2.5	2.6	2.6
	Low	5	12.5	12.8	15.4
	Medium	12	30.0	30.8	46.2
	High	15	37.5	38.5	84.6
	Very high	6	15.0	15.4	100.0
	Total	39	97.5	100.0	

Missing	8	1	2.5
Total		40	100.0

As discussed in the Table 4.13 the effect of inappropriate uses of imbibition was 37.5% high, 30% medium, 15% very high, 12.5% low, and 2.5% very low. Based on this the impact of inappropriate uses of imbibition was high that need attention.

4.10.7 Losses related to mill roller size reduction

The effect of gradual mill roller size reduction during cane extraction on the losses of sucrose with bagasse was discuss in the Table 4.14 shown below.

Table 4.14 Response on Losses related to mill roller size reduction.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	6	15.0	15.0	15.0
	Medium	9	22.5	22.5	37.5
	High	16	40.0	40.0	77.5
	Very high	9	22.5	22.5	100.0
	Total	40	100.0	100.0	

The losses of sucrose related with mill roller size reduction was analyzed in the above Table 4.14 that was 40% high, 22.5 % very high, 22.5 medium, and 15% low this was implies that the effect of mill rollers size reduction takes the high 40% percentage.

4.10.8 Bagasse pol. % losses due to improper mill setting

The effect of improper uses of improper mill setting was discussed in the Table 4.15 shown below.

Table 4.15 Response on Bagasse pol% losses due to improper mill setting

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very low	5	12.5	12.5	12.5

	Low	5	12.5	12.5	25.0
	Medium	6	15.0	15.0	40.0
	High	19	47.5	47.5	87.5
	Very high	5	12.5	12.5	100.0
	Total	40	100.0	100.0	

As discussed in the Table 4.15 the effect of improper mill setting was 47.5% high, 15.5% medium, 12% very high, 12.5% low, and 12.5% very low. Based on this the impact of improper mill setting was high that need attention.

4.10.9 Losses of pol. % in bagasse due to improper usage of mill speed

The Losses of pol. % in bagasse due to improper usage of mill speed was discussed in the Table 4.16 shown below.

Table 4.16 Response on Losses of pol% in bagasse due to improper usage of mill speed

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low	4	10.0	10.0	10.0
	low	7	17.5	17.5	27.5
	medium	9	22.5	22.5	50.0
	high	16	40.0	40.0	90.0
	Very high	4	10.0	10.0	100.0
	Total	40	100.0	100.0	

The effect of use improper mill speed was analyzed in the Table 4.16 shown above. Based on this 40% high, 25% medium, 17% low, and 10% very high. Regarding to these analysis the impact of improper use of mill speed was high.

4.10.10 Losses of sucrose due to poor mill sanitation

The effect of poor mill sanitation was discussed that 47.5% medium, 30% high, 12.5% low, and 2.5% very high in the Table 4.17. Based on this analysis 47.5% of respondent was responses there is no significant effect seen due to poor mill sanitation.

Table 4.17 Responses on Losses of sucrose due to poor mill sanitation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very low	2	5.0	5.1	5.1
	Low	5	12.5	12.8	17.9
	Medium	19	47.5	48.7	66.7
	High	12	30.0	30.8	97.4
	Very high	1	2.5	2.6	100.0
	Total	39	97.5	100.0	
Missing	8	1	2.5		
Total		40	100.0		

The effect of poor mill sanitation was discussed that 47.5% medium, 30% high, 12.5% low, and 2.5% very high in the Table 4.17. Based on this analysis 47.5% of respondent was responses there is no significant effect seen due to poor mill sanitation.

4.10.11 Losses due to inversion

The Table 4.18 shown below discussed the effect of inversion in sucrose losses. The impact of inversion in sucrose losses was analyzed and the result shows 37% medium, 25% high, 22% low, and 12.5% very high. Regarding on this data 37% of respondent's effect of losses with inversion was seen medium.

Table 4.18 Response on losses due to inversion

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very low	1	2.5	2.5	2.5

	Low	9	22.5	22.5	25.0
	Medium	15	37.5	37.5	62.5
	High	10	25.0	25.0	87.5
	Very high	5	12.5	12.5	100.0
	Total	40	100.0	100.0	

4.10.12 Loss of sucrose with final molasses due to crystallizer disc leakage

The effect of crystallizer's disc leakage were analyzed in the Table 4.19 shown below. The impact of crystallizer's disc water leakage were analyzed and high 40%, medium 25%, very high 20%, and low 10%. Based on this analysis the crystallizers disc water leakage were highly affect the sugar production.

Table 4.19 Loss of sucrose with final molasses due to crystallizer disc leakage.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	2	5.0	5.0	5.0
	Low	4	10.0	10.0	15.0
	Medium	10	25.0	25.0	40.0
	High	16	40.0	40.0	80.0
	Very high	8	20.0	20.0	100.0
	Total	40	100.0	100.0	

4.10.13 Loss of sucrose with final molasses due to crystallizer battery (reheating) tube and body leakage

As indicated in the Table 4.20 the analysis of losses of sucrose due to crystallizer battery leakage 55% of respondent responses the effect were high.

Table 4.20 Impact of crystallizer battery (reheating) tube and body water leakage.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	1	2.5	2.5	2.5
	Low	2	5.0	5.0	7.5
	Medium	10	25.0	25.0	32.5
	High	22	55.0	55.0	87.5
	Very high	5	12.5	12.5	100.0
	Total	40	100.0	100.0	

Based on the above Table 4.20 the effect of crystallizer battery leakage were discussed and 55% high, 25% medium, and 5% very high, so the result shows the effect was high.

4.10.14 **Losses caused by the perforated stainless steel sieve**

The Table 4.21 shown below discussed effect by the perforated stainless steel sieve hole being too large and torn out was 42%.

Table 4.21 Losses caused by the perforated stainless steel sieve hole being too large

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	1	2.5	2.5	2.5
	Low	3	7.5	7.5	10.0
	Medium	7	17.5	17.5	27.5
	High	12	30.0	30.0	57.5
	Very high	17	42.5	42.5	100.0
	Total	40	100.0	100.0	

As mentioned in the Table 4.21 the effect of centrifugal screen on the sugar losses was discussed and 42.5% very high, 30% high, 17.5% medium, and 7.5% low, so the impact of perorated screen were very high (42.5%).

4.10.15 Inappropriate use of hot water at a continuous centrifugal machine

The Table 4.22 shown below indicate that the inappropriate uses of hot water was rectify the losses by 40%.

Table 4.22 Inappropriate use of hot water at a continuous centrifugal machine

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	2	5.0	5.0	5.0
	Low	6	15.0	15.0	20.0
	Medium	11	27.5	27.5	47.5
	High	16	40.0	40.0	87.5
	Very High	5	12.5	12.5	100.0
	Total	40	100.0	100.0	

The respondent response on the effect of inappropriate use of hot water at continuous centrifugal machine were considered high 40%, medium 27.5%, low 12% and 10% very high. Regarding to this the impact on sugar losses were high as shown in Table 4.22 above.

4.10.16 Losses of sucrose due to operators' fear, negligence, and poor communication

The effect of operators were analyzed the Table 4.23 shown below and the result were 35% high.

Table 4.23 Losses of sucrose due to operators' fear, negligence, and poor communication

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	6	15.0	15.0	15.0
	Low	9	22.5	22.5	37.5
	Medium	10	25.0	25.0	62.5
	High	14	35.0	35.0	97.5

	Very high	1	2.5	2.5	100.0
	Total	40	100.0	100.0	

At centrifugal machine the effect of operators were discussed with five element and the respondents response were analyzed that 35% high, 25% medium, 22% low and 2.5% were response very high. In generally the effect of operators' fear, negligence, and poor communication on the losses of sucrose was high as indicated in Table 4.23 above.

4.10.17 Loss due to Nash vacuum pump under capacity caused by vacuum drop

In Table 4.24 shown below the effect of Nash vacuum pump under capacity were discussed 37.5% respondent were responses high.

Table4.24 Loss due to Nash vacuum pump under capacity caused by vacuum drop

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	2	5.0	5.0	5.0
	Low	5	12.5	12.5	17.5
	Medium	15	37.5	37.5	55.0
	High	15	37.5	37.5	92.5
	Very high	3	7.5	7.5	100.0
	Total	40	100.0	100.0	

Based on the above table 4.24 the effect of Nash vacuum pump on the losses of sucrose at filtration section were considered to be high with 37.5%, medium 37.5%, low 12.5%, very high 7.5% and very low 5%. This was indicate that the effect was high.

4.10.18 Loss occurs due to leakage of low and high vacuum lines, valves, bridge plates,

The impact of leakage at filtration section were discussed in Table 4.25 shown below and 57.5% of them were respond very high.

Table 4.25 Loss occurs due to leakage of low and high vacuum lines, valves, bridge plates

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	1	2.5	2.5	2.5
	Low	3	7.5	7.5	10.0
	Medium	4	10.0	10.0	20.0
	High	9	22.5	22.5	42.5
	Very high	23	57.5	57.5	100.0
	Total	40	100.0	100.0	

The result of analysis on Table 4.25 were 57.5% very high, 22.5%, 10% medium based on this the effect of high and low vacuum line , valves, bridge plate on the losses of sucrose were very high.

4.10.19 The loss occurs as a result of the sieve being ripped out

The effect of sieve being ripped out, resulting in vacuum drop were analyzed in the Table 4.26 shown below very high with 40% respondent response.

Table 4.26 The loss occurs as a result of the sieve being ripped out

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	1	2.5	2.5	2.5
	Low	4	10.0	10.0	12.5
	Medium	7	17.5	17.5	30.0
	High	12	30.0	30.0	60.0
	Very High	16	40.0	40.0	100.0
	Total	40	100.0	100.0	

As discussed in the table 4.26 the impact of the torn out sieve where very high (45%), high (30%), medium (17.5%). Based on this analysis the effect was very high and need attention.

4.10.20 Usage of inadequate mud conditioning (mud thickness)

As indicated in the Table 4.27 shown below the causes of sucrose losses with filter cake due to inadequate mud conditioning were considered 45% that was high.

Table 4.27 Usage of inadequate mud conditioning (mud thickness)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	1	2.5	2.6	2.6
	Low	3	7.5	7.7	10.3
	Medium	13	32.5	33.3	43.6
	High	18	45.0	46.2	89.7
	Very High	4	10.0	10.3	100.0
	Total	39	97.5	100.0	
Missing	8	1	2.5		
Total		40	100.0		

The effect of inadequate uses of mud conditioning were analyzed on the Table 4.28 shown above. The discussion result were 45% high, 32.5% medium, 10% very high, and 7.5% responses low effect. In general the impact of poor mud conditioning were high on losses of sucrose with filter cake

4.11 Improvement

Process improvements are often achieved through specific opportunities, commonly called problems, being identified or recognized. A focus on improvement opportunities should lead to the creation of teams whose membership is determined by their work on and detailed knowledge of the process, and their ability to take improvement action. The teams must then be provided with good leadership and the right tools to tackle the job (Oakland, 2008).

By using reliable methods, creating a favorable environment for team based problem solving, and continuing to improve using systematic techniques, the never-ending improvement cycle of plan, do, check, act will been gaged. This approach demands the real time management of data, and actions on processes – inputs, controls and resources, not outputs. It will require a change in the language of many organizations from percentage defects, percentage ‘prime’ product and number of errors, to process capability (Oakland, 2008).

Those organizations which have made most progress in implementing a company-wide approach to improvement have recognized at an early stage that SPC is for the whole organization. Restricting it to traditional manufacturing or operations activities means that a window of opportunity has been closed. Applying the methods and techniques outside manufacturing will make it easier, not harder, to gain maximum benefit from an SPC program (Oakland, 2008).

There are five way of problem solving and improvement that shortly described below:

1. **Pareto analysis**

   The technique of arranging data according to priority or importance and typing it to a problem-solving framework is called Pareto analysis. This is a formal procedure which was readily teachable, easily understood and very effective. Pareto diagrams or charts are used extensively by improvement teams all over the world; indeed the technique has become fundamental to their operation for identifying the really important problems and establishing priorities for action. The stepwise procedure to perform Pareto analyses was as follow.

   a. Step 1: List all the elements
   b. Step 2: Measure the elements
   c. Step 4: Create cumulative distributions
   d. Step 5: Draw the Pareto curve
   e. Step 6: Interpret the Pareto curves

2. **Cause and effect analysis**

   In any study of a problem, the effect– such as a particular defect or a certain process failure – is usually known. Cause and effect analysis may be used to elicit all possible contributing factors, or causes of the effect. This technique comprises usage of cause and effect diagrams and brainstorming. The cause and effect diagram often mentioned in passing as, ‘one of the techniques used by quality circles’. Whilst this statement were true, it is also needlessly limiting in its scope of the application of this most useful and versatile tool. The cause and effect diagram, also known as the Ishikawa diagram (after its inventor), or the fishbone diagram (after its appearance), shows the effect at the head of central ‘spine’ with the causes at the ends of the ‘ribs’ which branch from it.

   The problem was handed to a newly appointed management trainee who used the following stepwise approach.

   a. Step 1: Identify the effect

b. Step 2: Establish goals
c. Step 3: Construct the diagram framework
d. Step 4: Record the causes
e. Step 5: Incubate and analysis the diagram

This type of analysis is yet another step in the systematic approach to process improvement. It should be noted, however, that the relationship between certain factors was not simple one and it may be affected by other factors. In these circumstances more sophisticated analysis of variance may be required (Oakland, 2008). Cause and effect analysis was used to elicit all possible contributing factors, or causes of the effect. This technique comprises usage of cause and effect diagrams and brainstorming. The cause and effect diagram was often mentioned in passing as, one of the techniques used by quality circles. Whilst this statement was true, also needlessly limiting in its scope of the application of this most useful and versatile tool. The cause and effect diagram, also known as the Ishikawa diagram (after its inventor), or the fishbone diagram (after its appearance), shows the effect at the head of a central 'spine' with the causes at the ends of the 'ribs' which branch from it. The principal factors or causes are listed first and then reduced to their sub-causes, and sub-sub-causes if necessary. This process is continued until all the conceivable causes have been included. The factors are then critically analyzed in light of their probable contribution to the effect. The factors selected as most likely causes of the effect are then subjected to analysis to determine the validity of their selection. This analytical process is repeated until the true causes are identified (Oakland, 2008).

Constructing the cause and effect diagram

An essential feature of the cause and effect technique is brainstorming, which is used to bring ideas on causes out into the open. A group of people freely exchanging ideas bring originality and enthusiasm to problem solving. Wild ideas are welcomed and safe to offer, as criticism or ridicule is not permitted during a brainstorming session. To obtain the greatest results from the session, all members of the group should participate equally and all ideas offered are recorded for subsequent analysis. The problem was handed though the used the following stepwise approach.

Step 1: Identify the effect

This sounds simple enough but, in fact, is often so poorly done that much time is wasted in the later steps of the process. It is vital that the effect or problem is stated in clear, concise terminology. This will help Process problem solving and improvement to avoid the situation where the 'causes' are identified and eliminated, only to find that the 'problem' still exists

Step 2: Establish goals

The importance of establishing realistic, meaningful goals at the outset of any problem-solving activity cannot be over-emphasized. Problem solving was not a self-perpetuating endeavor. Most people need to know that their efforts are achieving some good in order for them to continue to participate. A goal should, therefore, be stated in some terms of measurement related to the problem and this must include a time limit.

Step 3: Construct the diagram framework

The framework on which the causes are to be listed can be very helpful to the creative thinking process. The author has found the use of the five 'Ps' of production management very useful in the construction of cause and effect diagrams. The five components of any operational task are the:

- Product, including services, materials and any intermediates.
- Processes or methods of transformation.
- Plant, i.e. the building and equipment.
- Programs or timetables for operations.
- People, operators, staff and managers.

Step 4: Record the causes

It is often difficult to know just where to begin listing causes. In a brainstorming session, the group leader may ask each member, in turn, to suggest a cause. It is essential that the leader should allow only 'causes' to be suggested for it is very easy to slip into an analysis of the possible solutions before all the probable causes have been listed. As suggestions are made, they are written onto the appropriate branch of the diagram. Again, no criticism of any cause is allowed at this stage of the activity. All suggestions are welcomed because even those which eventually prove to be 'false' may serve to provide ideas that lead to the 'true' causes.

Step 5: Incubate and analyses the diagram

It is usually worthwhile to allow a delay at this stage in the process and to let the diagram remain on display for a few days so that everyone involved in the problem may add suggestions. After all the causes have been listed and the cause and effect diagram has 'incubated' for a short period, the group critically analyses it to find the most likely 'true causes'. It should be noted that after the incubation period the members of the group are less likely to remember who made each suggestion. It is, therefore, much easier to criticize the ideas and not the people who suggested them.

4.12 Six Sigma Approach

Six Sigma is a disciplined, systematic, data-driven approach to process improvement. Organizations world over has implemented Six Sigma successfully for more than 20 years with the aim of continuously improving the process (Gijo, 2010). The application of the Six Sigma problem solving methodology, DMAIC, reduced the rejection and rework and thereby improved productivity and on time delivery to customer. Six Sigma is a calculation to classify companies to a certain level to improve the productivity of sugar production.

4.12.1 The use DMAIC process to solve problems

The DMAIC process to problem-solving consists of five phases in which you need to take specific actions and use specific tools. The DMAIC process includes a DMAIC template which includes the following steps:

Step one is the define phase

The goal of sugar factory was to enhance productivity through minimization of factory down time and sucrose losses. Down time (machine break down) were the root cause of low production. The performance of the milling section directly impacts on the overall efficiency of the factory. If there were no crushing, there was no sugar production. The loss sections like milling, clarification, and centrifugal also have great impact on the volume of sugar produced. To understand the process and its challenges, using suppliers, input, process, and customer (SIOPC) and flow charts are used as shown in Figure 4.25.

Supplier	Input	Process	Output	Customer
Harvesting	Cane and different chemicals		Sugar	Stoke holders

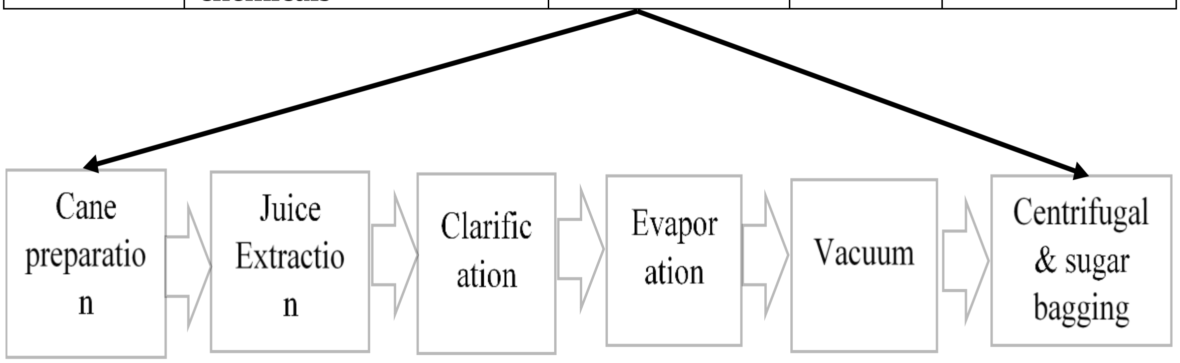

Figure 4.25 Supplier, Input, Process, Output, and Customer (SIPOC) charts

Step two is the measure phase

Collection of data from maintenance log sheet and laboratory data for machine break down and sucrose losses respectively. Measure the collected data, by statistical process control

(SPC) tools to know the losses control or there is special causes variation which well described in data analysis section and by using cause and effect diagram identify the root causes of the failures.

Step three is the analysis phase

This phase is to identify the root-cause that was causing the problem. For this step, it need to visualize the data collected, use Pareto charts to represent numerical data, use a fishbone diagram to capture the knowledge of the process participants during the session, and use the 5 whys diagram to narrow down the findings to the last few causes of the problem.

Step four is the improvement phase:

Solve the problem in the process through root cause analysis for major problem in each section related with losses. The following Table 4.28, 4.29, and 4.30 shows the root cause and their remedy in juice extraction, filtration and centrifugal section respectively.

Table 4.28 Root cause analysis of major problem of milling station

Root cause analysis of major problem of milling station		
Problem	Root causes	Remedy
Failure of turbine	Lack of inspection and close follow up	Do timely and close inspection
	Poor maintenance	Doing timely inspection and proper preventive maintenance.
	Shortage spare part	Provide new spare part as per required
	Shortages of steam	Communicate with boiler crew to gate enough steam
Failure of pinion	Wrongly assembled	Check mill setting as per the campaign tch
	Lack of lubrication oil	Use proper lubrication oil and check if there is leakage
	Edged	Change with the new spare
	Foreign material insert	Provide protection gourd
Failure of tail bar coupling	Lack of spare part	Change by new spare part
	Improper mill setting	Check mill setting as per the campaign tch

Failure of mill hydraulic	Lack of oil kit/seal	Change the oil seal by new
	Piston shaft under size (leakage)	Weld and recondition as per the given dimension
	Foreign material insert	Inspection and follow up
	Aging(old enough)	Change by new spare part
Poor messchaert knife arrangement	Improper setting of messchaert knife	Mount it in proper way (inside the groove) closely follow up and substitute when it is missed.
	Poor inspection	Closely follow-up and timely inspection

Table 4.29 Root cause analysis of major problem of filtration station

Root cause analysis of major problem of filtration station		
Problem	Root causes	Remedy
Sieve thorn out	Poor arrangement of scraper	Arrange in correct manner and inspect closely
		Conduct proper preventive maintenance
	Old enough	Change by new spare part
Nash vacuum pump problem	Pump housing worn out	Recondition as per the standard or change the housing
	Impeller worn out	Recondition as per the standard or change the impeller
	Gland leakage	Provide proper packing
vacuum line and valves leakage	Line worn out	Maintain damage portion and change if necessary
Bridge plate problem	Rough surface	Repair and renew
	due to wear age	Change by new spare
	Lack of spare part	Provide new spare part as per required
Operators problem	Skill gap	Train the operator motivate the their achievement
	Negligence	Advise and help to understand the responsibility

Table 4.30 Root cause analysis of major problem of filtration station

Root cause analysis of major problem of filtration station		
Problems	Root cause	Remedy
Calandria tube and steam chest steam leakage	Worn-out of Calandria tubes and its tube plate	Close inspection and replacement
Crystallizer cooling disc and battery water leakage.	Worn-out of disc at joint and on the surface due to friction between massecuite and disc.	Check and repair regularly Close follow up and timely inspection Doing test again and again before put inline the unit Change the disc with spare part.
Low performance of perforated sieve at centrifugal	Worn out due to aged and damaged by foreign material	Check and replace by new spare Check the separation sieve in the massecuite tank is in good position before run the machine. Check the condition of massecuite viscosity. Check the cooling water around continues machine neck is free from blockage.
Hot water spray blockage	Over feeding	Check the water spry hole is free from blockage. If not remove and clean it.
Wide perforated hole of basket	Worn out due to aged	Measure and change with spare.

Basket and sieve hole blockage	Massecuite dry	Check and clean per shift regularly.
Man error	Skill gap, negligence, fear, lack of motivation	Give periodical training. Motivate by incentive.

Step five is the control phase: In this phase, it's better to sustain the improvements gained already implemented in the improvement phase. Create a monitoring plan for the improvements and a response plan in case there is a drop in the process performance.

Prevention of failure is the primary objective of process improvement and is caused by a management team that is focused on customers. The system which help them achieve ongoing improvement is the so called Deming cycle Figure 4.26. This will provide the strategy in which the SPC tools will be most useful and identify the steps for improvement.

Plan

- The factory may have to plan maximum sugar production volume and low sucrose losses.
- Plan to have minimum machine break down in all section, especially at cane preparation and juice extraction.
- Plan to provide high brix quality with low suspended matter for clarification section.
- Plan to have high field yield cane form cane harvesting section.
- The main objective of extraction section is to satisfy clarification section through providing enough volume of juice.
- Reduce cost of unnecessarily failures of cane handling and milling section through periodic preventive maintenance and quality inspection.

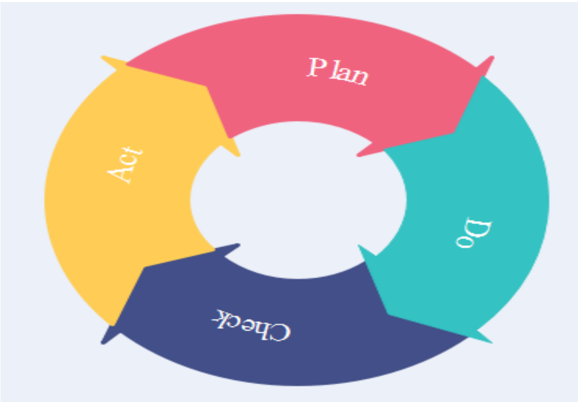

Figure 4.26 PADC diagram

Do

- Collect necessarily information about tandem A mill No.3, mill turbine No.2 tandem A and Cane handling A to identify the problem.
- Use SPC tools to determine does the process is in control or there is special causes of variation.
- The following charts in Figure 4.27, 4.28, and 4.29 was identified the key sub process that need continual improvement.

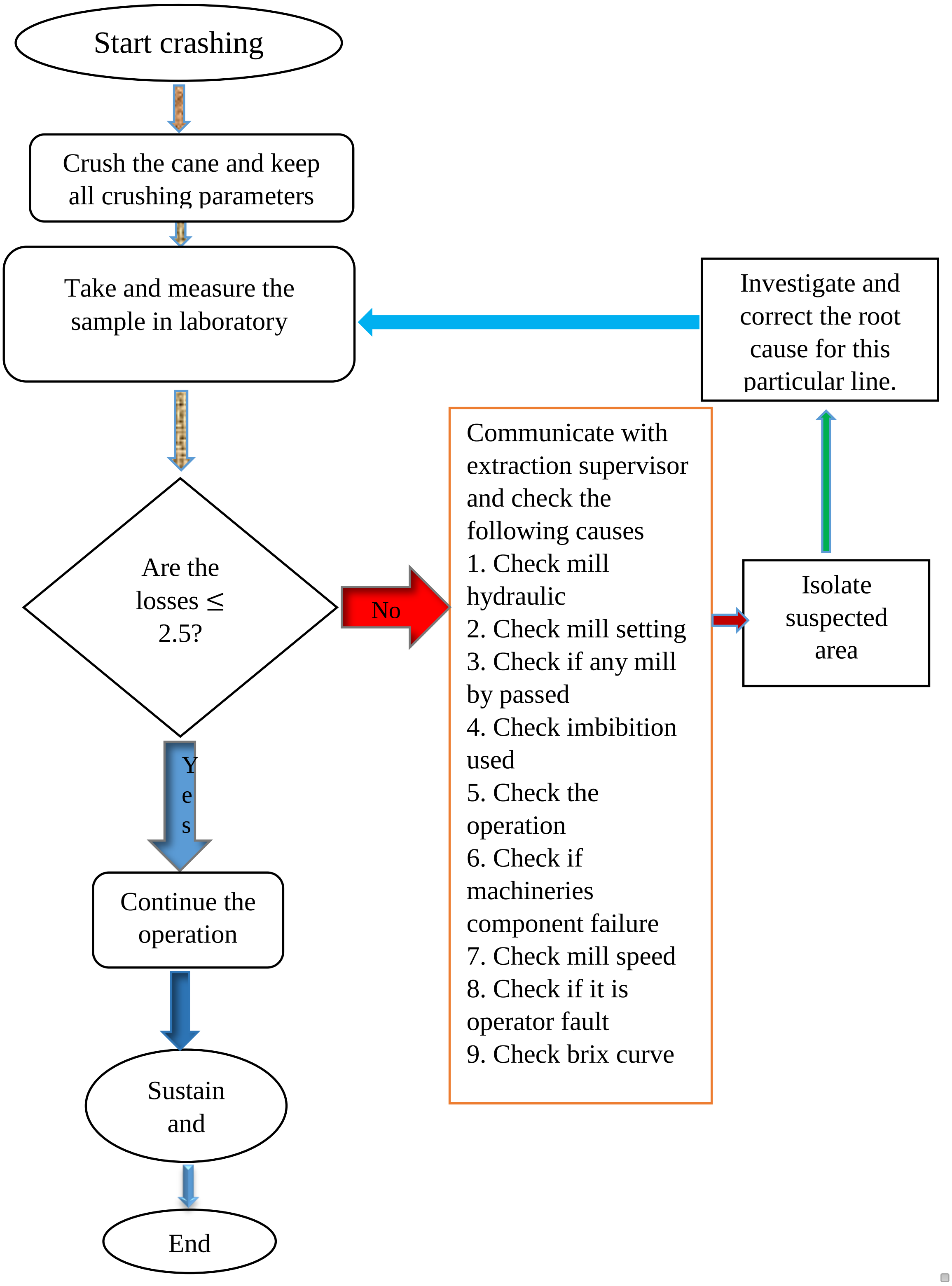

Figure 4.27 Flow chart diagram at milling station.

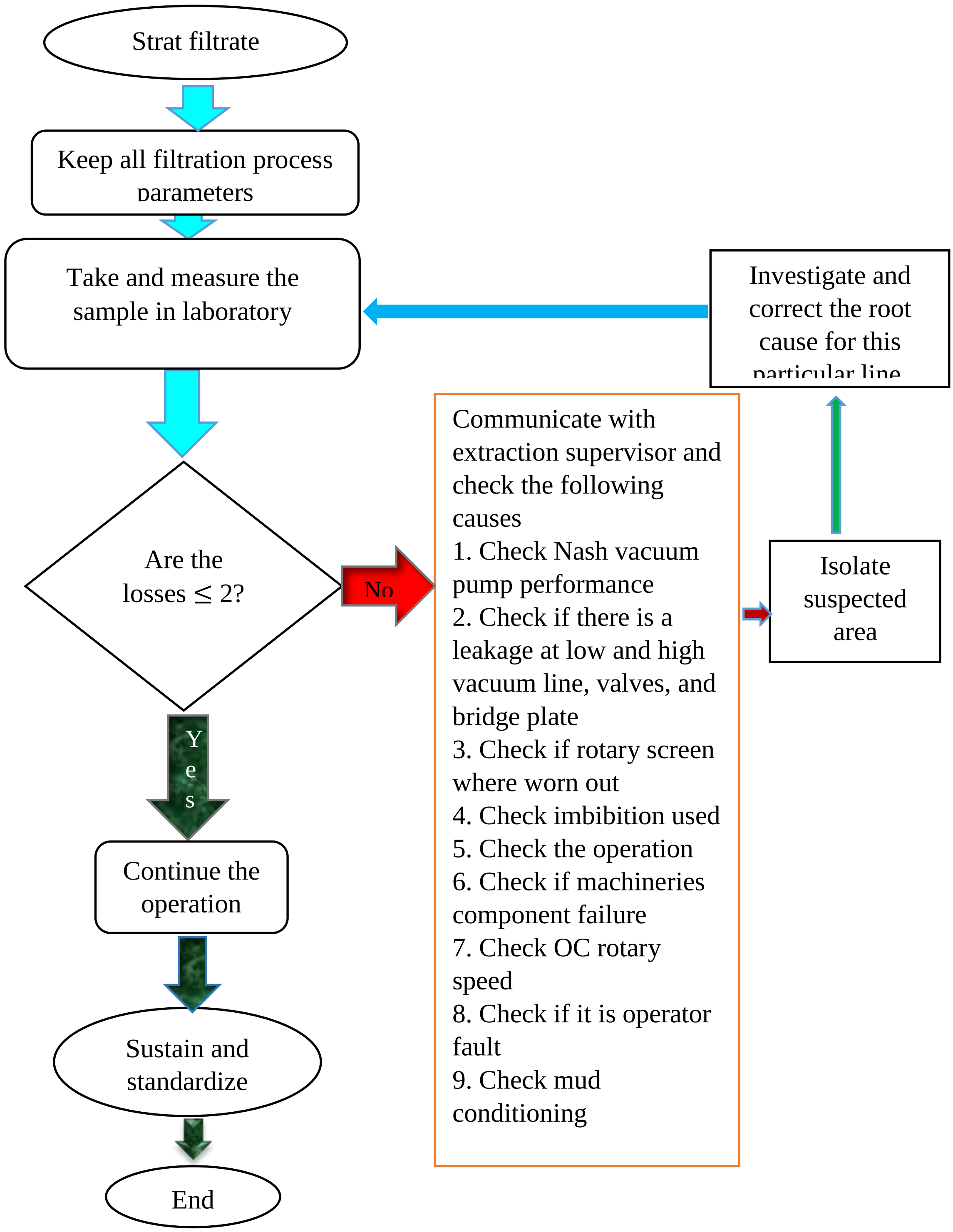

Figure 4.28 Follow chart diagram for filter cake

The follow chart diagram indicate that the process follow and the causes of the specific problem to identify by quick fix method and then continues the operation.

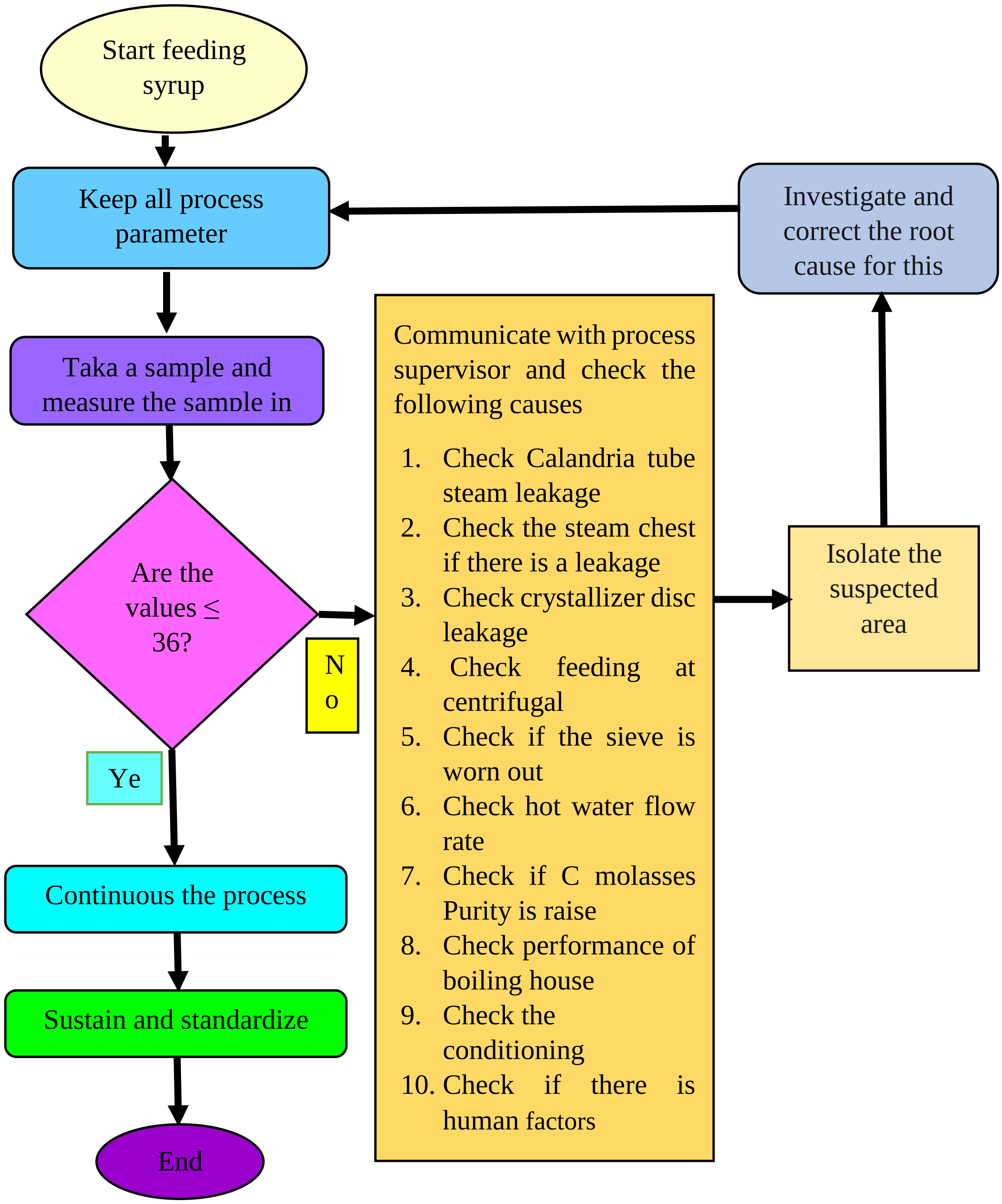

Figure 4.29 Follow chart diagram for controlling losses with molasses

Check

- The collected data from mechanical maintenance log sheet and production record book in Figure 4.1, 4.2, and 4.3 and Appendix B, C, D, and E respectively was analyzed by Statistical process control (SPC) to determine the process stability.

Pareto chat and cause and effect diagram are also used to analysis the effect of special cause variation.

Act

- The main purpose of these phase is analysis the finding during data check phase to improve the process.
- Step by step process improvement is based on their priority.
- Repeat the step to improve the process and eliminate the waste.

Generally sugar in Ethiopia serves for direct household consumption and as an intermediate input for other industries like pastries, bottling companies and breweries. As the requirement of sugar increase the productivity of sugar decrease. The main goal of sugar cane factory was to have an efficient and profitable operation with the required sugar quality and maximum sugar recovery with high productivity. The problems in sugar industries is the loss of sucrose in operational process. The monetary value of the losses of sucrose is of extreme importance because of the direct impact on productivity and profitability. Productivity were affected by the presence of mechanical machineries component break down and losses of sugar in various section as discussed earlier. The reduction of down time were through follow up, close inspection, proceed timely preventive maintenance and continues training for workers to top up with resent technology to increase the volume of production and productivity of the company. The maximum recovery of sugar losses were needed in sugar factory that was through investigation, identification and elimination production process bottle neck through the use of statistical process control tools and six sigma.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As a result of this research shown the existence of mechanical equipment breakdown and sucrose losses in various sections, such as losses of sugar with bagasse at milling, losses of sugar with mud at clarification, losses of sugar with molasses at centrifugal, and undetermined losses of sugar, production and productivity gradually declined. In order to reduce the impact and increase productivity, study was done on the effects of machinery failures and sugar byproduct losses. The research covered the investigation of productivity bottlenecks, controlling mechanisms for machinery breakdown and sugar losses, and suggestions for improvement. The major causes for low crushing were machine breakdown in milling section like mill #3 shaft journal seat worn out and mill turbine #2 failure and the root causes of sugar losses were due to failures of cooling crystallizer disc, re-heater hot water leakage, centrifugal machine sieve worn out, hydraulic failure, poor mill setting. As the sugar losses were increase the productivity were decrease as a result since form 2018/19-2020/2021 GC the losses percentage were at the pick that was 1.74%, 3.54%, and 3.37% respectively. This in turn indicated lack of maintenance schedule to improve maintenance technique.

Therefore, from the study identifying and eliminating production bottleneck were necessary to improve production performance and productivity of any manufacturing industry. Also using SPC approach enables continuous improvement of the company productivity. It can also be concluded that the proposed suggestion were beneficial to the company and by continuously practicing SPC tools, to improve their performance and productivity of the company.

5.2 Recommendation

For Cane Preparation and Juice Extraction Section

- The factory should pay attention to maximize the preparation index since poor preparation index for cane has a substantial impact on both the efficiency of primary juice extraction and losses of sucrose.
- The factory provides the necessary mill hydraulic spares, which have an impact on how well mills work in relation to losses of sugar in bagasse, the utmost attention should be given for maintenance, renewal, and replacement.
- The factory should be uses the right imbibition volume in accordance with the crushing rate since the effects of improper imbibition usage in the milling section were major.
- According to the information provided by the brix curve, the factory must reposition the roller since the reduction of mill roller size in operation results in significant percentages of sugar losses in the milling section.
- The factory should pay close attention to position the roller in accordance with the provided mill setting data as the loss results from incorrectly positioned mill rollers were very high.
- The factory should uses the proper mill speed in accordance with the specified mill speed in the mill setting because the consequences of using improper mill speed were high in terms of sugar losses.
- To reduce the impact of sucrose inversion, the plant should pay close attention to mill sanitation and steam clean it frequently.

Centrifugal Section

- The factory pay great attention to inspect, repair, renew, and change by spare as necessary since the impact of crystallizers' disc water leakage in the centrifugal section was significant.
- Since the consequences of crystallizers re heater hot water leakage being considerable, it is important to replace or upgrade the current re heater due to its large size and challenging operation.
- Due to the significant sugar losses caused by low-grade centrifugal separation screens, the factory should focus on careful inspection, prompt cleaning, and routine maintenance.

- Due to the D-station was the last step in recovering sugar, great care should be taken to ensure that as little sugar as possible is lost in the final molasses.

Mud Filtration Section

- The factory should provide training to machine operators to reduce the impact of sugar losses due to human error at filtration section.
- The company should pay attention to timely repair and replacement since the filtration section's impact of the Nash vacuum pump's poor performance was high.
- The company should focus on providing a bagacillo duct collect fan and its line since it has been bypassed for long time since poor mud conditioning was major contributor to sugar losses with mud.
- The company should ensure that the rotating vacuum screen was regularly repaired and replaced in order to reduce sugar loss due to scum.
- To prevent a lack of machine knowledge, the operator and other workers who are directly involved in the production process need skill training

Future work

- Since sugar processing was broad and diversified sector, more research must be done to determine the crucial stages of sugar loss.

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APPENDIX A

Data of Cane Crushed and Sugar Bagged

Year	Plan of cane crushed	Actual of cane crushed	Plan of sugar produced	Actual of sugar produced	Cane crushed in %	Sugar produced in %
2016/17	10,324,430.00	8,743,852.00	1,052,340.00	808,557.00	84.69	76.83
2017/18	9,195,178.00	7,410,484.00	971,751.00	681,374.00	80.59	70.12
2018/19	9,563,940.00	7,516,490.00	950,000.00	633,112.00	78.59	66.64
2019/20	9,888,170.00	8,971,912.00	1,002,962.00	755,951.00	90.73	75.37
2020/21	10,087,433.00	8,895,106.00	971,630.00	762,666.00	88.18	78.49
Total	49,059,151.00	41,537,844.00	4,948,683.00	3,641,660.00	84.56	73.49

APPENDIX B

Losses of pol% in bagasse

Losses of pol % Bagasse						
2016/17	**2017/18**	**2018/19**	**2019/20**	**2010/21**	**Mean**	**Range**
3.04	2.88	3.65	2.9	3.26	3.15	0.8
2.89	2.82	3.42	3.04	3.04	3.04	0.6
2.76	2.94	3.46	2.95	3.33	3.09	0.7
2.82	3.08	3.49	3.21	2.87	3.09	0.7
2.63	2.81	3.15	3.08	3.41	3.02	0.8
2.39	2.81	3.33	2.72	3.04	2.86	0.9
2.28	2.78	3.18	3	2.97	2.84	0.9
2.39	2.85	3.37	3.08	3.11	2.96	1.0
2.38	2.77	3.11	2.88	3.21	2.87	0.8
2.18	2.79	3.41	2.84	3.09	2.86	1.2
2.18	2.48	3.64	2.77	3.15	2.84	1.5
2.14	3.04	3.42	2.66	2.9	2.83	1.3
2.27	2.72	3.44	2.69	3.13	2.85	1.2
2.26	2.75	3.74	2.99	3.08	2.96	1.5
2.25	2.76	3.66	3.01	2.72	2.88	1.4
2.27	3.09	3.4	2.81	2.69	2.85	1.1
2.22	3.42	3.44	3.1	2.72	2.98	1.2
2.19	3.29	3.58	2.9	3.26	3.04	1.4
2.19	3.47	3.74	2.7	2.97	3.01	1.6
2.21	3.2	3.6	2.8	2.87	2.94	1.4
2.45	2.86	3.21	2.66	2.95	2.83	0.8
2.57	2.89	3.59	2.44	3.04	2.91	1.2
2.24	2.85	3.86	3.12	3.15	3.04	1.6
2.25	3.03	3.99	2.99	3.01	3.05	1.7
2.21	3.03	3.54	3.23	2.81	2.96	1.3
2.3	3.22	3.89	3.19	3.07	3.13	1.6
2.26	3.29	4.01	2.96	3.39	3.18	1.8
2.48	3.16	3.78	2.79	3.04	3.05	1.3
2.21	2.84	3.91	2.85	3.08	2.98	1.7
2.17	2.84	3.26	2.48	3.34	2.82	1.2
2.14	2.82	3.6	2.56	3.76	2.98	1.6
2.24	2.85	3.67	2.72	3.34	2.96	1.4
2.24	2.77	3.56	2.52	3.23	2.86	1.3
2.13	3.09	3.88	2.94	3.14	3.04	1.8
1.98	2.85	3.29	2.76	3.17	2.81	1.3
2	2.87	3.25	2.7	4.37	3.04	2.4

APPENDIX C

Losses of pol% filter cake

Day	2016/17	2017/18	2018/19	2019/20	2020/21	Mean	Range
1	2.97	4.1	3.7	5.6	3.3	3.93	2.63
2	2.87	3.5	5.6	3	3.8	3.75	2.73
3	2.17	3	2.7	3.3	3.1	2.85	1.13
4	4.32	2.2	2.9	3	3.7	3.22	2.12
5	2.65	2.6	5.3	2.18	3.5	3.25	3.12
6	3.4	3.4	3.7	2.05	2.7	3.05	1.65
7	1.95	2.5	4.2	1.82	3.4	2.77	2.38
8	1.89	2.5	3.6	2.15	4.1	2.85	2.21
9	2.48	2.3	2.6	1.92	2.4	2.34	0.68
10	2.15	1.8	2.4	1.71	1.7	1.95	0.70
11	1.92	2.3	2.6	1.8	2.6	2.24	0.8
12	2.07	2.8	3.5	1.89	2.3	2.51	1.61
13	1.95	2.1	2.8	2.08	2	2.19	0.85
14	1.88	3.3	3.8	1.83	2	2.56	1.97
15	1.72	1.8	2.7	1.48	4.8	2.50	3.32
16	2.52	1.6	3.4	1.54	2.3	2.27	1.86
17	3.74	2.5	4.2	2.25	1.4	2.82	2.8
18	3.07	2.7	3	2.09	1.6	2.49	1.47
19	2.7	2.3	2.3	1.53	1.9	2.15	1.17
20	2.9	1.7	2.3	1.9	2.1	2.18	1.2
21	3.23	1.9	2.6	1.67	3.9	2.66	2.23
22	2.57	1.7	2.1	1.63	3.1	2.22	1.47
23	1.86	2.2	1.97	1.5	2.6	2.03	1.1
24	3.4	1.6	2.5	1.56	2.8	2.37	1.84
25	4.5	1.7	2.2	2.35	9.5	4.05	7.8
26	4.04	1.7	1.9	2.03	1.9	2.31	2.34
27	5.77	1.9	2.2	2.14	1.9	2.78	3.87
28	5.49	2.9	2.3	2.32	1.7	2.94	3.79
29	5.4	2.3	2.9	2.38	3.4	3.28	3.1
30	2.44	2.1	2.9	1.98	2	2.28	0.92
31	2.07	1.8	3	1.75	2.9	2.30	1.25
32	2.73	2.2	2.2	1.73	2.3	2.23	1.00
33	2.84	2.3	3.9	2.37	3.6	3.00	1.6
34	2.73	1.9	2.7	1.79	3.9	2.60	2.11
35	2.72	1.9	2.4	1.75	7.1	3.17	5.35
36	2.76	1.9	1.9	4.2	3.8	2.91	2.3
37	2.52	1.8	1.9	2.32	1.9	2.09	0.72

APPENDIX D

Losses in final molasses							
Day	2016/17	2017/18	2018/19	2019/20	2020/21	Mean	Range
1	33.38	39.68	39.91	40.2	38.17	38.27	6.82
2	34.31	38.52	35.19	39.97	39.32	37.46	5.66
3	35.87	38.24	39.29	42.15	37.4	38.59	6.28
4	34.95	40.46	38.88	32.78	37.25	36.86	7.68
5	38.43	40.13	37.46	44.87	35.16	39.21	9.71
6	38.78	33.46	37.86	42.95	37.36	38.08	9.49
7	37.13	39.82	42.05	44.3	37.6	40.18	7.17
8	34.58	34.72	38.81	41.27	38.3	37.54	6.69
9	34.91	41.29	40.53	40.27	38.9	39.18	6.38
10	35.88	37.59	35.87	40.43	37.81	37.52	4.56
11	34.73	39.24	39.4	40.76	38.43	38.51	6.03
12	35.77	37.11	39.45	41.89	37.56	38.36	6.12
13	34.73	36.13	39.05	40.73	39.22	37.97	6.00
14	34.83	36.02	38.15	40.68	36.93	37.32	5.85
15	38.33	36.91	38.59	37.4	37.18	37.68	1.68
16	36.19	38.37	37.28	37.12	36.79	37.15	2.18
17	38.72	39.8	36.76	39.13	37.34	38.35	3.04
18	37.91	38.53	37.29	38.95	37.84	38.10	1.66
19	39.22	37.15	36.99	37.86	35.78	37.40	3.44
20	37.24	35.75	34.97	38.79	36.2	36.59	3.82
21	38	37.73	37.12	34.48	36.64	36.79	3.52
22	37.23	35.98	37.8	38.1	35.28	36.88	2.82
23	39.46	36.58	37.29	34.71	35.67	36.74	4.75
24	38.41	36.38	37.94	37.74	36.97	37.49	2.03
25	38.51	37.06	37.41	36.85	36.17	37.20	2.34
26	37.56	37.41	36.34	38.66	36.38	37.27	2.32
27	39.38	38.29	35.46	38.6	36.87	37.72	3.92
28	37.09	37.48	35.9	36.78	38.12	37.07	2.22
29	38.12	40.09	36.9	36.98	38.12	38.04	3.19
30	37.48	39.14	36.9	41.55	37.18	38.45	4.65
31	37.27	39.98	35.9	42.15	35.44	38.15	6.71
32	37.49	41.32	38	40.78	36.63	38.84	4.69
33	40.36	40.22	37.9	39.74	35.83	38.81	4.53
34	38.2	39.14	36	40.1	36.12	37.91	4.10
35	36.75	40.67	37.9	41.87	36.41	38.72	5.46
36	36.62	40.44	37.4	38.21	37.74	38.08	3.82
37	39.45	40.72	37.46	36.11	34.2	37.59	6.52

APPENDIX E

Field yield					
2016/17	2017/18	2018/19	2019/20	2020/21	Mean
10.99	11.53	11.36	10.92	11.81	11.322
10.14	11.78	11.61	10.89	11.63	11.21
10.28	11.88	11.65	11.13	11.85	11.358
10.28	11.9	11.83	10.87	11.63	11.302
10.8	11.99	11.17	10.85	11.39	11.24
10.28	11.62	11.43	10.75	12.06	11.228
9.95	10.87	11.16	10.65	11.96	10.918
10.1	11.14	10.93	11.25	12.12	11.108
10.76	11.34	11.33	11.03	11.95	11.282
11.07	11.28	11.36	11.04	11.64	11.278
10.16	11.47	11.59	10.42	11.15	10.958
10.85	11.39	11.41	10.44	11.4	11.098
10.54	11.09	11.38	10.84	11.03	10.976
9.74	11.65	11.44	11.11	11.03	10.994
9.9	11.6	10.48	11.06	11.43	10.894
10.09	11.99	11.31	11.05	11.68	11.224
9.73	11.35	12.04	10.48	111.06	30.932
9.97	12.12	11.7	10.19	11.2	11.036
10.68	11.68	11.72	10.89	11.52	11.298
10.84	11.68	11.42	10.73	11.75	11.284
10.34	11.27	11.72	10.67	11.73	11.146
10.09	11.24	11.56	10.17	11.75	10.962
10.84	11.51	11.18	9.59	11.18	10.86
10.55	12.06	10.91	10.36	11.3	11.036
11.1	11.56	11.3	10.19	11.42	11.114
11.02	11.39	11.05	10.73	11.78	11.194
10.98	11.6	11.86	10.6	11.64	11.336
11.07	11.11	10.91	10.22	11.14	10.89
10.82	11.22	10.92	10.58	11.72	11.052
10.66	11.46	11.28	10.44	10.62	10.892
10.61	11.39	11.47	10.33	11.55	11.07
11.26	11.8	11.64	10.06	11.83	11.318
10.37	11.36	11.28	10.26	11.31	10.916
10.31	11.67	11.79	9.88	11.98	11.126
10.43	11.22	11.48	10.33	11.75	11.042
9.97	11.47	11.44	10.82	11.36	11.012
10.03	11.89	11.34	9.91	11.44	10.922
10.41	11.92	11.34	9.12	10.48	10.654
10.76	11.66	11.3	10.1	12.35	11.234
10.89	11.35	11.08	10.79	12.14	11.25
10.69	11.63	11.08	10.73	11.84	11.194
10.98	11.02	11.84	10.65	11.73	11.244

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

MASTER OF SCIENCE (MSc)

Part I: Questionnaire to be filled by respondents

Dear participant:

I am currently studying for a Master's degree in mechanical design and manufacturing (MSc) at Adama Science and Technology University I am undertaking a research project entitled - Sugar Productivity Enhancement through Process analysis on the context of Matahara Sugar Factory.

This questionnaire is designed to solicit information for purely academic purpose. This is to enable the researcher complete the thesis in partial fulfillment of the requirement for the degree of master of in mechanical design and manufacturing (MSc).

Your response is truly important to the success of this study. I would like to assure you that your response will be processed as 'Strictly Confidential'. So please try to answer all questions included. I would like to thank you very much in anticipation for your kind cooperation.

I look forward to receive your reply

Sincerely yours,

Note:

- ✓ No need to write your name in this questionnaire.
- ✓ Respond to the statement/question in this questionnaire based on your current level of knowledge and expertise.
- ✓ As you read each statement tick a box that corresponds to your level of agreement.

Thank you

Section A: Basic demographic data (please tick where appropriate)

1. Sex Male ☐ Female ☐

2. Age

A) 18-30 ☐ B) 31 - 40 ☐ C) 41-50 ☐ D) 51-60 ☐ E) Above 61 ☐

3. Educational Back ground

A. High School ☐ B. Diploma ☐ C. First Degree ☐ D. Master Degree & above ☐

4. How much is your monthly basic salary?

A. Below 1000 ☐ B. 1001 - 2000 ☐ C. 2001 - 3000 ☐ D. 3001 - 4000 ☐

E. Above 4000 ☐

5. How long you have served in the organization? (In Year)

A. 1-5 ☐ B. 6-10 ☐

C. 11-15 ☐ D. Above 16 ☐

6. What is your position or work group in the organization?

A. Management group ☐

B. Non-management group ☐

Section B

Instruction I: please put a tick mark (√) at the appropriate box to show below.

A. QUALITY RELATED

To what extent the following statement are appropriate on top management commitment in you organization?

Please indicted below strongly your agree or dis agree with the following statement in your organization. Tick one: strongly agree =5, Agree =4, neutral =3, disagree =2 and strongly disagree =1

No	**Quality system improvement**	5	4	3	2	1
1	There are frequent meetings with external customers.					
2	The company has a clear quality manual.					
3	The quality system in our company is improved continuously.					
4	The Company has a clear documentation procedure.					
5	The company has a clear set of work instructions.					
6	The company has clear standard operating procedures (SOPs) which are clearly understood by the operating staff.					
7	Employees are encouraged to apply better methods when doing work after learning new skills.					
8	The company conducts frequent self-inspection and quality audits.					
	Statistical process control techniques					
9	Cards and graphs are used to measure and control quality.					
10	Management encourages the use of statistical methods.					
11	Statistical techniques are used intensively in the company.					
12	Employees participate in training programs related to statistical process control techniques for quality.					
13	Statistical process control techniques are effective at improving productivity.					
14	Statistical techniques are used for product release.					
15	Acceptance sampling is applied to determine acceptance or rejection of all materials used for manufacturing.					
16	Control charts are used to determine if variations are abnormal or normal and to determine quality characteristics.					

B. TECHNICAL RELATED

Information related to;

1. **Extraction section respondents**

1. Is there a loss of sucrose in bagasse at the extraction section of the Matahara Sugar Factory?

   A. Yes ☐ B. No ☐

Instruction II: If the answer of question No.1 is yes please put a tick mark (√) at the appropriate box to show your level of agreement (on the response scale: 1 to 5) for every statement given.

Response scale:

1	2	3	4	5
Very low	Low	Medium	High	Very high

No	**Item**	**Response scale**				
		1	2	3	4	5
1	Sucrose loss as a result of the mill bypass					
2	Losses with bagasse due to poor operation					
3	Losses with bagasse as a result of the mill hydraulics' low pressure being applied to the top roller					
4	Losses happen due to the negligence of operators.					
5	Losses happen due to inadequate use of imbibition.					
6	Losses related to mill roller size reduction.					
7	Bagasse pol% losses due to improper mill setting					
8	Losses of pol% in bagasse due to improper usage of mill speed					
9	Losses of sucrose due to poor mill sanitation.					

2. **Clarification section respondents**

Instruction I: please put a tick mark (√) at the appropriate box to show below.

1. In matahara sugar factory is there loss of sucrose in filter cake at clarification section?

   B. Yes ☐ B. No ☐

Instruction II: If the answer of question No.1 is yes please put a tick mark (√) at the appropriate box to show your level of agreement (on the response scale: 1 to 5) for every statement given.

Response scale:

1	2	3	4	5
Very low	Low	Medium	High	Very high

No	Item	Response scale				
		1	2	3	4	5
1	Loss due to Nash vacuum pump under capacity caused by vacuum drop					
2	Loss occurs due to leakage of low and high vacuum lines, valves, bridge plates, which cause vacuum drop.					
3	The loss occurs as a result of the sieve being ripped out, resulting in a vacuum drop.					
4	Usage of inadequate mud conditioning (mud thickness).					
5	Lack of bagacillo					
6	Improper use of chemicals					
7	Improper use of imbibition (condensate water)					
8	Use a rotary drum at an insufficient speed.					
9	Lack of skilled operators					
10	Inappropriate operational parameters					

3. **Centrifugal section respondents**

Instruction I: please put a tick mark (√) at the appropriate box to show below.

4. In matahara sugar factory is there loss of sucrose in final molasses at centrifugal section?

   C. Yes ☐ B. No ☐

Instruction II: If the answer of question No.1 is yes please put a tick mark (√) at the appropriate box to show your level of agreement (on the response scale: 1 to 5) for every statement given.

No	Item	**Response scale**				
		1	2	3	4	5
1	Loss of sucrose with final molasses due to crystallizer disc leakage.					
2	Loss of sucrose with final molasses due to crystallizer battery (reheating) tube and body leakage.					
3	Losses caused by the perforated stainless steel sieve hole being too large and torn out					
4	Inappropriate use of hot water at a continuous centrifugal machine					
5	In an adequate low-grade boiling system					
6	Sucrose losses due to poor performance of C seed preparation.					
7	Losses of sucrose due to the rise of C molasses purity.					
8	Losses of sucrose due to lack of operators' commitment					
9	Losses of sucrose due to lack of skilled manpower					
10	Losses of sucrose due to operators' fear, negligence, and poor communication.					

FOCUS GROUP DISCUSSION

For mechanical maintenance team

1. What are the main reasons why mechanical machine parts fail?
2. How do machine malfunctions affect sugar losses?
3. How can downtime in factories be reduced?

For production team

1. What are the main reasons for sugar losses in different production sections?
2. How can factory losses through byproduct be reduced?

For quality team

1. What role does quality play in reducing sugar losses in different production sections?
2. Are there standard operational procedures (SOP) in the factory?
3. How does quality affect performance and productivity?

Focus group discussion

1. Discuss the basic reasons of mill #3 failures, which account for the majority of plant downtime.
2. Is there an operational problem because the production team led the operation?