ST. MARY'S UNIVERSITY

SCHOOL OF GRADUATE STUDIES

INSTITUTE OF QUALITY AND PRODUCTIVITY MANAGEMENT

QUALITY IMPROVEMENT USING STATISTICAL PROCESS CONTROL TOOLS IN PROCESS CONTROL IN DAIRY INDUSTRY- THE CASE OF SEBETA AGRO INDUSTRY

BY

AYTENEW ABEJE

JANUARY, 2021

ADDIS ABABA, ETHIOPIA

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THE THESIS SUBMITED TO ST. MARY'S UNIVERSITY, SCHOOL OF GRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN QUALITY AND PRODUCTIVITY MANAGEMENT

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APPROVED BY BOARD OF EXAMINERS

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DECLARATION

I, declare that this work entitled "Quality Improvement Using Statistical Process Control Tools in Process Control in Dairy Industry-The case of Sebeta Agro Industry" is outcome of my own effort and study and that all sources of materials used for the study have been accordingly acknowledged. I have produced it independently except for the guidance and suggestion of my research advisor.

Moreover, this study has not been submitted for any degree in this University or any other University.

Aytenew Abeje

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Date__________________________________

Ameha Mulugeta (PhD)

Research Advisor

Signature ______________________________

Date__________________________________

ENDORSEMENT

This is to certify that this study work, “Quality Improvement Using Statistical Process Control Tools in Process Control in Dairy Industry-The case of Sebeta Agro Industry undertaken by Aytenew Abeje for the partial fulfillment of Master of Science in Quality and Productivity Management in St. Mary’s University, is an original work and not submitted earlier for any degree either at this University or any other University.

Ameha Mulugeta (PhD) ________________________________

Research Advisor

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List of Abbreviations/Acronyms

CEA	Cause and Effect Analysis
CED	Cause and Effect Diagram
CL	Center Line
CSF	Critical Success Factor
Dg	Dornic degree
GAP	Good Agricultural Practice
GHP	Good Hygiene Practice
GSP	Good Storage Practice
JIT	Just In Time
LCL	Lower Control Limit
PDCA	Plan Do Check Act
PH	Per Hydrolyses
PLC	Private Limited Company
QC	Quality Control
QI	Quality Improvement
SAI	Sebeta Agro Industry
TQM	Total Quality Management
UCL	Upper Control Limit
UHT	Ultra Heated Treatment
UV	Ultra Violet

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Abstract

In order to gain a competitive advantage in a competitive market improving quality and productivity of product or process is needed for every business company. This study addresses the ideas of quality improvement using statistical process control tools in the process control in the production line of pasteurized milk. Statistical process control tools are significant to evaluate/monitor process variability, to detect changes in the production process and reduce milk quality defects by identifying the vital few defects that the trivial many causes and to give suggestion for quality improvement. In this study the approach used is direct observation, focus group discussion, bar chart, flow chart, control chart (X bar R chart and X bar S chart), Pareto and cause and effect diagram, have been applied to improve quality and productivity of products and reduction of quality problems and quality defects. There are various quality parameters in the process such as weight/volume, temperature, titrable acidity and milk fat which have influence on the quality of the final products of pasteurized milk. It has been found that Sebeta Agro Industry has many quality problems and quality defects in the process of pasteurized milk production line. The vital few problems in the process of pasteurized milk were increased temperature, underweight and overweight of pasteurized milk and defects were clotting/souring, return, breakage and damage. Specifically clotting/souring and returns were high in the process of pasteurized milk production line. The main aim of this study is to analyze the impacts of SPC tools on quality improvement and provide guidance how to use SPC tools in process control and problem analysis to improve quality and productivity performance. The major and root causes of pasteurized milk quality problems and defects were stated and possible remedy suggestions were proposed. Even though SAI has many limitations to apply all suggestions for quality improvement within short period of time, the company documented that suggestions will bring significant improvement for quality and productivity through time.

Key words: quality improvement, statistical process control tools, process variability, quality defects, quality problems.

CHAPTER ONE

INTRODUCTION

This chapter has presented background of the study, background of the organization/study area, statement of the problem, basic research questions, objective of study including general and specific objectives, significance of the study, and scope of the study, limitation of the study, operational definitions of some terminologies and organization of the research report.

1.1. Background of the Study

To bring changes in dairy product distribution patterns, product formulations, the export market, and consumer expectations have all resulted in a greater demand for dairy products that meet high quality standards at first and over a longer shelf-life. To manufacture high-quality dairy products, processors are demanding higher-quality raw milk, which means compositionally standardized within the norm, free from off-flavors and odors, free from detectable drug residues, adulterants (added water) and having low total bacteria counts. To ensure that using quality raw milk, processors routinely monitor their suppliers at the source by the help of quality measuring instruments and doing laboratory quality tests according to the standards. The quality and shelf life of dairy products influenced by the quality of raw materials, the manufacturing processes, the way the end product packaged, storage conditions and whether it has been opened. Temperature control during all storage stages is particularly important for dairy production. Quality is a concept whose definition has changed overtime. In the earlier, quality meant "conformance to valid customer requirements". That is considered conforming good or acceptable product or service (Deming, 1950).

Quality is one of the most important decision factors in the selection of products and services (Montgomery, 2005). Hence, quality leads to business success, growth, increases competitiveness and involves the employee achieving the business goals, brings a significant return of investment and improves the work environment. The study and the analysis of quality must be aimed at understanding, meeting, exceed and outstanding customer needs and expectations (Kolarik, 1995).

Food manufacturing companies are seriously confronted by consumer-oriented markets that require continuous improvement to enhance product quality (Pable *et al*., 2010). There are quality initiatives or methods of quality improvement such as total quality management (TQM), Six Sigma, Zero Defects, Lean and Kaizen and just in time (JIT). By applying these quality initiatives can improve product quality, avoid penetrating food legislation and gain consumers' trust. Total Quality Management (TQM) is a comprehensive philosophy of living and working in organizations that emphasizes the persistent pursuit of continuous improvement (Chase and Aquilano, 1995).Continuous improvement is a basic principle of a total quality management system. Plan-do-check-act (PDCA) cycle is a tool to achieve continuous improvement, often called the Deming Wheel.

Statistical process control (SPC) is a technique developed based on Shewhart's outset of process variability, which can be applied both in manufacturing processes and service operations for quality sustainability purposes. According to Montgomery (2009), SPC defined as a powerful collection of problem-solving or quality improvement tools valuable in achieving process stability and improving capability through the reduction of product variability. The main purpose SPC application is to detect and reduce special cause variations for process stability and allow measurement and evaluation of the performance in a process to improve its quality. According to Montgomery (2005), statistical process control tools can be supportive in developing activities previous to manufacturing, in measuring process variability, in analyzing variability relative to product requirements or specifications, and in eliminating variability in the process. Generally, the Seven quality control (QC) tools are check sheet, Pareto chart, flowchart, cause and effect diagram, histogram, scatter diagram and control chart . These tools are also known as Total Quality Management (TQM) tools.

The benefit of SPC application could improve process performance by reducing product variability and improves production efficiency by reducing quality problems and defects.

According to Benton (1991) and Talbot (2003), the benefits of SPC application could be groups into the following categories, viz., maintain a desired degree of conformance to quality design, increase product quality, eliminate unnecessary quality checks, reduce the percentage of defective parts, reduce returns from customers, reduce scrap and rework rates, provide evidence of quality, ability to reduce costs of quality and lead times. In general, SPC can be used in dairy industry to monitor the natural variation of a process and minimize the deviation from a target value and thus play a major role in process improvement in production line of pasteurized milk.

1.2. Background of the Organization

Sebeta Agro industry dairy manufacturing PLC was chosen to use SPC tools and concepts in order to improve quality and reduce process problems and product defects. Sebeta Agroindustry is, established in 1991 E.C. The Company is located in Sebeta Town, Oromia Regional state, Ethiopia, Africa. The company produces different dairy products like pasteurized milk, Yoghurt, cream, Butter, Cheeses, UHT and fruit Juices, fulfill the needs of different local dairy farms in Ethiopia. By using sophisticated technological set up, a company is producing different dairy products and Fruit in a nonstop manufacturing environment. A company utilizes raw materials that are available locally in different areas of the country especially Oromia region from local farmers. The main components used to manufacture dairy products and fruit juices are raw milk and various fruit juices mainly they used to flavor yoghurts.

1.3. Statement of the Problems

There are many ways to deal with quality problems in manufacturing company. Quality principles in dairy production are to prevent unnecessary breakage, damages, clotting, returns, and overweight, underweight, improve process visibility and understanding and control quality problems like above or below the standards of temperature, milk titration of acidity, milk fat in dairy industry. According to the recorded data (December, 2019), the total production volume of milk was 1328741 liters per a month. From this actual production of milk, 100255 liters of defects were occurred. From 100255 liters of defects , 7390 liters breakages, 62781 liters returns, 12137 liters damages and 17947 liters were clotting or souring. Depend on these visible recorded defects indicates that; there were many process variations observed in the production line of pasteurized milk in case of SAI. This study was looked at variations and their causes, and how to improve and control a process using Statistical Process Control (SPC), and identify the impacts of SPC application on quality improvement and analyze it.

This study was fond out the effective way of Improving the Quality and Productivity of milk production in dairy industry. This study was applied quality improvement and methods of SPC and strong commitment to solve quality problems, to reduce defects, improve the yield of acceptable products, increase customer satisfaction, continuous cost reductions and deliver best in-class organizational performance. This study was used a multiple measure design where the mean quality rate of dairy products and processes under normal operating conditions compared to the mean quality rate of the same dairy products under the application of statistical process control.

1.4. Basic Research Questions

Succeeding the research objectives, the research has followed specific research questions to be answered.

1. What are the impacts of SPC tools application on quality improvement in dairy industry in case of SAI?
2. How SPC tools are applicable to reduce quality problems and defects in dairy industry?

1.5. Objective of the Study

1.5.1. General Objective of the Study

The general objective of the study is:

❖ To analyze the impacts of SPC tools application on quality improvement and provide guidance to the use of SPC tools in dairy industries to improve quality and productivity performance.

1.5.2. Specific Objective of Study

Specific objectives of the study are: -

➢ To name possible SPC tools used to improve the milk quality and productivity performance in the Sebeta Agro-Industry milk manufacturing processes of the plant.

- To identify the main causes and effects of quality problems and defects in dairy industry in case of SAI.
- To identify and analyze the impact of SPC application on quality improvement performance in case of SAI.
- To generate a guidelines for effective application of SPC practices in dairy industry in case of SAI.

1.6. Significance of the Study

The company has achieved good quality by minimizing quality problems and defective products which in turn reduce quality costs and increase productivity.

The benefits of quality improvement with SPC tools were improved process performance by reducing product variability and improved production efficiency by reducing quality problems and defects. By taken random samples of output, variability in a process was evaluated objectively by managers, as opposed to using subjective techniques to identify activity inefficiencies. The purpose of this study has analyzed the impacts SPC application on quality improvement in case of SAI and fond an objective way to spot inefficiency and repair the quality problems and defects via the combined expertise of the personnel involved.

1.7. Scope of the Study

In spite of the fact that, SAI have different milk collection sites including Sululta, Holeta, Kara kore and Sebeta and chilling centers as well as Debre Zeit,Chancho and Debre Tsige. This study has conducted only Sebeta milk processing or pasteurizing plant found. Dairy products in case of SAI, include Cheese, Yoghurt ,cream, Butter, Fruit juice, Pasteurized milk or plastic milk and whey as a byproduct. This study has involved pasteurized milk process and products because the study only proceeds in Sebeta main production plant founds. Pasteurized milk processes were taken volume or weight, fat contents, titration of milk acidity, temperature, nutrient contents labeling and expire date of plastic milk. Of the basic seven types of SPC tools available, but only some individual charts were used according to quality characteristics. The data was used to identify quality problems and defects in pasteurized milk products from batch manufacturing process for the pasteurized milk products activity. SPC tools were identified to visualize the process and compared actual quality to estimated quality under normal operating condition and application of statistical process control in the process.

1.8. Limitation of the Study

The limitation of this research was the exclusion of other dairy industries which have a negative impact in inferring conclusion on the level of quality improvement using SPC tools application throughout the dairy industries in the country. To be Rational behind the selection of participants due to constraints of time as well as convenience and limited budget of the research. There were also resource constraints, in terms of time and logistics as well as the difficulties in accessing data. In addition to these, there was limitation to which types of methodology used that could briefly help in analyzing data.

1.9. Operational Definition of Terms

CAUSE AND EFFECT DIAGRAM: is a tool that helps to identify, sort, and display possible causes of a specific problem or quality characteristic (Hubbard, 2013).

CHEECK SHEET: simply charts used to collect data about an activity in way that is easy to use and analyze as well as to determine the relative frequency of data in different categories (Bidder, 1990).

CONTROL CHART: is a graphical method for displaying control results and evaluating whether a measurement procedure is in control or out-of-control (Limam, 2010).

HISTOGRAM: is a bar chart showing a distribution of variables and helps to identify the cause of problems in a process by shape of the distribution as well as the width of the distribution (Mataragas et al., 2012).

KAIZEN: means every day, everyone, everywhere improvement in the organization (Imai, 2007, p. 18).

LEAN: means increasing the speed of production by eliminating process steps which do not add value. It is efficiency system (Slack et al., 2007, pp. 466–469).

PARETO CHART: is a bar graph used to isolate critical few causes of problems and priorities for process improvement can be established (Fotopoulos et al., 2011).

PROCESS VARIATION: variability of process over time (Montgomery, 2005).

QUALITY DEFECTS: nonconforming quality characteristics of products.

QUALITY IMPROVEMENT: systematic and continuous process of value adds activity that leads to measurable improvement in products or services (Gidey *et al.*, 2014).

QUALITY PROBLEMS: problems that faces to process and products.

QUALITY: is product or service which fulfills an aggregate requirement of customers, in all aspects, at present and in the future and which customers can buy it(Feigenbaum, 1961).

SIXSIGMA: means a metric that demonstrates quality levels at 99.9997% performance for products and process (Pyzdek 2003, p. 59).

STASTICAL PROCESS CONTROL: is an analytical decision making tool which allows you to see when a process is working correctly and when it is not (Montgomery, 2007).

TOTAL QUALITY MANAGEMENT: is the art of managing the whole to achieve excellence (Chase & Aquilano, 1995).

1.10. Organization of the Study

This study has divided into five chapters. The first chapter has provided background of the study, organization of the study, statement of the problem, research question, objective of the research, and significant of the study including scope and limitation of the study. The second chapter has discussed in relevant literatures to gain understanding related to quality improvement using statistical process control tools in process control has narrated in depth from perspective of theoretical and practical implications. Chapter three has given an account of the research methodology description and justification of the design and researcher procedures followed in this study. Chapter four has presented and analyzed data find out results which could answer the research questions. Chapter five has focused on drawn conclusion based on findings, and making appropriate recommendation.

CHAPTER TWO

REVIEW OF THE RELATED LITERATURE

This chapter has covered an overview of literature that is related to the research problem presented in the previous chapter. Defining the concept of quality, concept of quality improvement, statistical process control(SPC) tools, effective use of statistical process control, success factors in the application of the statistical process control, common and special cause of variation, prevention and detection of process variation and conceptual framework of the study.

2.1. Defining the Concept of Quality

According to the Proximity/Merriam- Webster U.S. English Thesaurus, and other similar on-line Thesaurus, quality may be viewed from several perspectives. Quality is meritoriously near the standard or model and eminently good of its kind and of the very top quality. Quality is the highest stratum of a society, usually high level of merit or superiority, a level of excellence or distinction, a degree of excellence, Something that gives especial worth or value, inherent and distinctive, rating or positioning in relation to others (as in a social order, community, class, or profession) and a peculiar and essential character, nature, or feature. Quality is perceived differently by different people. In a manufactured product, the customer as a user recognizes the quality of fit, finish, appearance, function, and performance. The quality of service may be rated based on the degree of satisfaction by the customer receiving the service.

William Edwards Deming (1900 – 1993) was one of the first to think about quality in modern times, especially quality in management. Demming was an American statistician, professor, author, lecturer and consultant. From 1950 Onwards, he taught top managements in Japan how to improve product and service quality through various approaches to design and testing, including the application of statistical methods. His focus was on "the efficient production of the quality that the market expects" and is perhaps best known for his "Plan-Do-Check-Act" cycle (Aguayo Rafael, 1991).

Joseph M. Juran (1904 – 2008) also wrote extensively on the subject of quality, and was invited to Japan in 1954, where his particular ideas flourished. He is principally remembered as an evangelist for quality and quality management. His focus was on "Fitness for purpose" as defined by the customer (Phillips-Donaldson Debbie, 2004).

Philip B. Crosby (1926 – 2001) started out in quality as a test technician. Subsequently, as a businessman and author, he contributed to management theory and quality management practices by focusing on "Zero defects" through "doing it right the first time". In fact he believed that an organization that established a quality program would see savings returns that would more than pay off the cost of the quality program and hence promoted the idea that "quality is free"(Harwood William B.,1993).

According to Deming (1950), quality is a concept whose definition has altered overtime. In the previous, quality meant “conformance to valid customer requirements”. That is considered conforming good or acceptable product or service. Quality refers to the combination of characteristics of a product or service and process that determines the product's ability to satisfy specific needs of the customer. In summary and some common definitions are given below.

- Quality is degree of excellence (The Concise Oxford Dictionary).
- Quality is fitness for purpose or use or customer satisfaction (Juran J. M., 1998).
- Quality is conformance to requirements (Crosby Phillip, 1979).
- Quality is the total composite product and service characteristics of marketing, Engineering, manufacture, and maintenance through which the product and service will meet the expectation of the customer (Feigenbaum, 1961).
- The totality of features and characteristics that bear on the ability of product or service to satisfy a given need - British Standard 4778 (British Standard Institution; 1991).
- Quality is a dynamic state associated with products, services, people, process, and environments that meet or exceeds expectations and help produce superior value (Goetsch and Davis, 2010).

- Quality should be aimed at the needs of the customer, present and future (Deming, 1986, et al., 2008).

According to Montgomery (2005), quality is one of the most important decision factors in the selection of products and services. Hence, quality leads to big business achievement, development, and increases competitiveness. Ryan (1989), defined quality as a decision-making technique that uses statistics to monitor the consistency of a production process and the resulting product as improves the work environment. Quality Control (QC) is an important task in factory as it deals with product inspection before the product was shipped to customers. From this understanding all these definitions of quality seem to be correct in some occasions, it further created a confusion what definition is to be applied to which product or service. So, we need to develop a definition that can answer any situation by combining all these definitions. Hence, a comprehensive and perspective thinking is required to develop such a definition.

2.2. Concepts of Quality Improvement

Quality improvement (QI) is systematic and continuous actions that lead to measurable improvement in products or services. To make improvements, an organization needs to understand its own delivery system and key processes. QI approach recognize that both resources or inputs and activities carried out or processes are addressed together to ensure or improve quality of products or services or outputs/outcomes.

Processes within the organization contain two major components: what is done which means what product or service is provided, and how it is done which means when, where, and by whom product or service is delivered.

To achieve improvement in the global competitiveness market is feeding a continuous technological progress with new generations of technology and products, with higher capability of intensive productions and with a general raising in buyers demand and expectation for quality. Quality cannot be reduced just only to reliability performances, but it is a merging of different factors between technological aspects and clients satisfaction (Sailaja *et al*., 2014).

Companies need to constantly improve quality of their products and offering in order to enhance customer satisfaction by fulfilling their requirements, competitive advantage in terms of customer satisfaction, long retention time and gaining larger market (Gidey *et al.*, 2014).Therefore the cycle of life of designing, developing and manufacturing a new product requires being shorter in time and lower in cost. But at the same time, the quality level or quality dimensions should not to suffer by the reduction of resource. By understanding the importance of quality improvement, every industrial company covering a position of leaders in every specific field of technology, is inexorably pushed toward a high level of technology, only achievable using an integrating approach for quality improvement. It is possible to ensure and improve quality in the production stage via operative quality management which includes all operational methods and activities focusing upon monitoring processes and removing causes of non-conformity and defects in all stages of a product's life cycle. A critical part of operative management focuses upon the process itself, i.e. in the production company upon production. It is no longer possible to improve quality during production as a process of transforming input elements into required outputs or products but when the requirements and conditions stated in the pre-production stages are not met, this can cause a decrease in quality improvement against the required level. If we do not have any means of measuring the performance of manufacturing unit in trouble, how can we improve it? As W. Edwards Deming said "If you cannot measure it, you cannot improve it". Usually variation is the only main reason for varying or low quality of their product/service, increasing dissatisfaction among customers and decreasing business credibility as a result. Therefore for effective business approach, one has to watch over quality product or service and control variation, by quality control with control charts and statistical process improvement.

There are many different conceptions, methods and tools that may be used to maintain the good quality level or quality improvement and help in continuous development in the company (Zu, et al., 2008; Bendoly, 2016; Gołaś, et al., 2016). From methodologies that are available for quality of process improvement include Six Sigma, Lean Management, Lean Six Sigma, Agile Management, Re-engineering, Total Quality Management, Just-In-Time, Kaizen, Hoshin Planning, Poka-Yoka, Design of Experiments, and Process Excellence. According to Pyzdek (2003), defines Six Sigma as a rigorous, focused and highly effective implementation of proven quality principles and techniques. Six Sigma organizations work assiduously to achieve an overall Six Sigma level of performance for each key process that equals to 3.4 defects per million opportunities for each core process. The reason Six Sigma organizations focus on achieving the Six Sigma level is to improve the quality of products and services for their customers. The largest problem that impedes the highest level of quality is due to process variation. To improve quality, the variations must be identified, analyzed, measured, improved and controlled in a very systematic and holistic way to ensure that process inputs are converted to the highest quality level of output that meets customer requirements Pyzdek (2003). Six Sigma is, essential for process quality improvement, where sigma is a statistical measure of variability in a process (Pyzdek 2003, p. 59).

Kaizen is a combination of two Japanese words: kai – "change" and zen – "good". In this translation Kaizen means a change for a good.

Kaizen is away of quality improvement step-by-step, ordered and continuous improvement, improvement of value (Pieczonka, Tabor, 2003, p. 86).

Kaizen means improvement, which means continuous improvement in personal life, on social and work platform. In a company context, kaizen is permanent improvement of all – managers and employees (Imai, 2007, p. 18). Fundamental goals of kaizen concern improvement of quality, cost and time of delivery. It means continuous improvement of products' quality, processes, lower costs and shorter time of order realization (Skrzypek, 2014, pp. 90–91).

Lean is way of organization improvement approach and its key part of kaizen concept. The key principle of lean operations is elimination of all wastes in order to improve an operation by operating faster, more dependable, produces higher-quality products and services and operates at low cost (Slack et al., 2007, pp. 466–469).

Total Quality Management (TQM) is a comprehensive and structured approach to organizational management that seeks to improve the quality of products and services through ongoing refinements in response to continuous feedback (Chase & Aquilano, 1995). The main focus of total quality management is to achieve a comprehensive integration among organizational staff and their functions in order to gain better enhancement, progress and preservation of products and services quality to achieve customer satisfaction (Talib, 2013). This shows that TQM is directly focuses on improving business quality and satisfaction of managers through enhancing the employee's involvement in decision making processes by utilizing teams of quality improvements and quality circle strategies (Yusuf et al., 2007).

Therefore, total quality management is a managerial strategy that aims to enhance organizational performance and efficiency through enhancing the quality of services and products in the organizations (Arumugam et al., 2008). Additionally, TQM is considered as a comprehensive integration between several models, procedures, individuals and communication processes to cover all customer demands (Van Ho, 2011).

According to Talib and Rahman(2010a), TQM practices include commitment of top-management, focus on customers, training and education, continuous improvement, supplier management, involvement and encouragement of employees, benchmarking, and quality information and performance. The outputs are the enhanced productivity and quality, the achievement of high level customer satisfaction, the improved customer loyalty and on-time delivery.

Generally, quality improvement is continuous process of value add activities in the process of produce products or provide services by the help of different conceptions, methods and tools. The success of quality improvement in the company in the field of continuous improvement is dependent on employees, because they create a quality culture and makes simple to improve everything in the process of the production line.

2.3. Statistical Process Control (Spc) Tools

Statistical process control (SPC) is a framework of ideas (Wheeler and Chambers ,1992) and a collection of problem-solving tools useful in achieving process stability through the reduction of variability (Quesenberry, 1997; Mitra, 1998; Montgomery, 2009). To reduce variability tools Statistical Process Control (SPC) to demonstrate efficient stabilization of production processes (Khediri; Weihs; Limam, 2010; Milan; Fernandes, 2002).

The Statistical Process Control (SPC) is a set of statistical tools for quality oriented problem solving environment in processes and decision making by managers. According to

Deming (1986), the leading management thinker in the field of quality after 1945, concluded that “The central problem in management and leadership is Failure to understand the information in variation.” According to Montgomery (2012), SPC is defined as a powerful collection of problem-solving tools useful in achieving process stability and improving capability through the reduction of variability. Efforts have been made to expand the concept of SPC beyond the process monitoring technique. SPC is categorized into several types of topics such as:

- ✓ Technological innovation (Bushe, 1988, Roberts et al., 1989)
- ✓ Process management technique (Bissell, 1994)
- ✓ control algorithm (O, H ,1997)
- ✓ A component of total quality management (TQM) (Barker, 1990)
- ✓ One of the quality management systems in the food industry (Caswell et al., 1998).

According to Montgomery (2007), SPC tools are described as follows:

- ✓ The estimation of the process distribution under normal conditions
- ✓ Determine whether the process is stable
- ✓ Continued monitoring and control process
- ✓ Comparison of process performance and specifications
- ✓ Identify how to continuously improve the process

The focus of SPC is understanding the variation in values of quality characteristic (Woodall, 2000). The process stability refers to the stability of the underlying probability distribution of a process over time and these very often can be described as the stability of the distribution parameters overtime (Mahalik and Nambiar, 2010). The process stability extremely crucial as it is one of the pre-requirement condition prior to the process capability indices determination (Brannstrom-Stenberg, 1999, Motorcu and Gullu, 2006, Sharma and Kharub, 2014).

The primary purpose SPC application is to detect and reduce special cause variations for process stability. Statistical Process Control (SPC) can be expanded to the industrial processing industry and has an obvious significant share in quality aspects of manufacturing industry especially the food industry. The quality control in the food industry is scientifically related to technology, sensory attributes, physical, safety, chemical make-up and nutritional value (Grigg and Walls, 2007).According to Rungtusanatham et al., (1997), the term SPC implementation requires a clear understanding of the procedures to be adopted and activities to be performed using a set of tools indicating participating management. Therefore, such argument is seconded with the implications from the dual concepts of SPC - "the operation of statistical control" and "the state of statistical control" suggested by Shewhart, (1939). According to Pena-Rodriguez (2013), Lim et al., (2014), Grigg (1998), there is a crucial need to develop customize guideline for the food industry to apply and integrating all these tools in a systematic manner at the correct problem.

There is no standard set of tools within SPC, however, Gaafar and Keats (1992), Duffuaa and Ben-Daya (1995) and Juran & Gryna (1998) argue that there is a general agreement on the seven tools which includes data gathering, Histogram, Pareto chart, cause and effect analysis (CEA)/fishbone diagram, scatter diagram, check sheets and control charts. However, it is generally agreed that control chart is a primary tool within SPC.

CHECK SHEET

Check sheets are simply charts for gathering data and used to provide a simple means for recording data and enable the analyst to determine the relative frequency of occurrence of the various categories of the data. Brainstorming activities arranged in the process in proper sequence (Bidder, 1990, Hubbard, 2013).

HISTOGRAM

A histogram is a picture of the variation of a product or the results of a process and used to illustrate and identify the distribution of the observations from a set of data. A graphical representation of the frequency of occurrence process that the points or a class that represents a set of data points. (Ooi and McFarlane, 1998, Srikaeo et al., 2005, Mertens et al., 2009, Mataragas et al., 2012, Dalgiç et al., 2011, RábagoRemy et al., 2014).

PARETO CHART

Pareto chart is a vertical bar graph displaying rank in descending order of importance for the categories of problems, defects or opportunities. Emphasize the need to focus first on the 20% of the causes that matter, without totally ignoring the remaining 80% (Cravener, 1993, Varzakas and Arvanitoyannis, 2007, Dalgiç et al., 2011, Fotopoulos et al., 2011).

CAUSE AND EFFECT DIAGRAM (CED)

Cause and Effect Diagram display the relationships between different causes for the effect that is being examined. CED identify all possible relationships among input and output variables, that is, five or six categories of the following skeletons are machines, methods, materials, manpower, measurements, environments (Varzakas and Arvanitoyannis, 2007, Saini et al., 2011, Hubbard, 2013, Desai et al., 2015).

FLOW CHART

Flow chart breaks the process down into many sub-processes. Analysing each of these separately minimizes the number of factors that contribute to the variation in the process. Brainstorming activities arranged in the process in proper sequence (Dalgic et al., 2011, Mertens et al., 2009, Cinar and Schlesser, 2005, Srikaeo and Hourigan, 2002).

SCATTER DIAGRAM

Scatter plot is used to show how a pair of variables is related and the strength of that relationship. Demonstrate the results of a series of experiments applied to document the relationship between the variables (Knowels et al., 2004, Grigg, 1998, Pluta, 2014).

CONTROL CHART

Control chart is composed of three parallel lines, one central represents the average value (CL), the lower representing the lower control limit (LCL) and upper one representing the upper control limit (UCL).Are presented on points representing the samples taken at various times of the process (Diniz, 2001, Vieira, 1999). The control process is performed by measuring the variables in separate points in control charts. During the measurements, the results are checked against the control limits which are expected according to the desired pattern. The results obtained from the measurements indicate that the process has random or specific causes of variability (Khediri; Weihs; Limam, 2010, Paese; Caten;

Ribeiro, 2001).The graft of process characteristics plotted in sequence, it includes the calculated process mean of statistical control limits (Grigg, 1999, Grigg and Walls, 2007a, Ittzes, 2001, Hayes et al., 1997).

Quality improvement by Statistical Process Control (SPC) in Food Processing Systems:

Table 2.1: The control diagrams for variable data and control chart factors

UCL & LCL Mean			n	A2	D3	D4
			2	1.88	0	3.27
X-Chart	R-chart		3	1.02	0	2.57
			4	0.73	0	2.28
$UCL_{\bar{x}} = \bar{\bar{X}} + A_2 \bar{R}$	$UCL^{R} = D4\ \bar{R}$		5	0.58	0	2.11
			6	0.48	0	2
$LCL_{\bar{x}} = \bar{\bar{X}} - A_2 \bar{R}$	$LCL = D3\ \bar{R}$		7	0.42	0.08	1.92
			8	0.37	0.14	1.86
	$\bar{R} = \frac{\sum_{i=1}^{n} Ri}{n}$		9	0.34	0.18	1.82
$\bar{\bar{X}} = \frac{\sum_{i=1}^{n} xbari}{n}$			10	0.31	0.22	1.78

Source: The control diagrams for variable data and control chart factors (Juran & Gryna, 1998)

Note: Number of observations in each sample (n), UCL: upper control limit, LCL: lower control limit, A2, D3, and D4 are constants.

In above table 2.1 examples of control charts, sample sizes varied significantly. For p-charts and c-charts are used sample sizes in the hundreds and as small as one item for a c-chart, whereas for X and R-charts are used samples of four or five. In general, larger sample sizes are needed for attribute charts because more observations are required to develop a usable quality measure. Standard deviation S- charts are an alternative to the R-chart and used as the sample size increases because they provide a better estimate of the variability of a set of data than the R- chart. R- charts are commonly used because the calculations are simpler than those for s charts. X-double bar-R chart is applicable when the sample size (n) is between 2 to 10 and X-double bar-S chart is applicable when the sample size (n) is more than 10.

2.4. Effective Use of Statistical Process Control (SPC)

According to Hitoshi (2006), statistical methods are effective tools to improve production process and reduce defects. Statistical tools require fairness and accuracy to observation. The maxims of statistical mode of thinking are:

- ✓ Give more importance to facts than theoretical concepts.
- ✓ Do not interpret facts in terms of sense or idea. Use figures resulted from precise observational result.
- ✓ Observational results, along with their errors and variation, are part of a hidden whole. Discovering the hidden whole is the ultimate goal of observation.
- ✓ Accept consistent tendency which appears in a large number of observational outcomes as reliable information.

According to Attaran (2000), in their attempts to stay competitive, US business had embarked on Total Quality management (TQM) techniques such as SPC that leads to higher quality product by reducing-variability and defects. Ved Parkash et al., (2013),described about the SPC, its advantages, limitation, applications and information regarding the control charts. They also introduced the primary groups of input for man, machine, material, method and environment. They explained the application of SPC into three main sets of activities, the first understands the process and is achieved by business process mapping, the second is measuring the sources of variation assisted by the use of control charts and the third is eliminating assignable (special) sources of variation. They suggested SPC, can be used in various industries for improving the quality of the product and helps in lowering the product costs as it provides a better product and/or service.

According to Benton (1991) and Talbot (2003), SPC application are the following advantages: maintain a desired degree of conformance to design, increase product quality, eliminate unnecessary quality checks, reduce the percentage of defective parts purchased from vendors, reduce returns from customers, reduce scrap and rework rates, provide evidence of quality, enable trends to be spotted, ability to reduce costs and lead times. And also SPC application helps to accomplish and achieve a consistency of products that meet customer's specifications and fulfill their expectations.

Generally, effective application or use of SPC tools can be used to monitor the natural variation of a process and minimize the deviation from a target value and play a major role in process improvement. In other words effective use of SPC tools have a positive impact for quality improvement through improving process performance of pasteurized milk in the production line.

2.5. Success Factors in the Application of SPC

The critical success factors (CSF) transfer to failure may lead to issues associated with the implementation, maintenance and continuity of the program (Antony et al., 2000; Lim et al., 2014; Rohani et al., 2010; Woodall & Montgomery, 1999). If there is a better control over these factors, the chance of success in the implementation of SPC is higher (Gordon et al., 1994; Elg et al., 2008; Rohani et al., 2010).

The managerial or organizational aspect and the technical or operational aspects are the two important aspects associated with SPC implementation (Does et al., 1997; Mason & Antony, 2000; Elg et al., 2008; Putri & Yusof, 2008; Rohani et al., 2009; Rohani et al., 2010; Xie & Goh, 1999).

According to Xie & Goh (1999), emphasize an holistic approach to the implementation of SPC, based on three basis: the first, related to the SPC Management, which involves issues such as the role of senior management, focus on Continuous Improvement, training and teamwork; the second, related to the human factor, which presents resistance to change issues, difficulties with the use of computer technologies and the need for incentives; the third, focuses on the implementation of the SPC, including the use of appropriate tools for monitoring the process. The main reasons for failures in implementing are related to: organizational and social factors (Does et al., 1997); lack of senior management commitment (Antony et al., 2000); lack of training and understanding of SPC (Does et al., 1997; Antony et al., 2000); decreased attention after the introduction (Does et al., 1997) and the lack of understanding of the potential benefits of the SPC (Mason & Antony, 2000).

In general SPC tools application face problems related to critical success factors (CSF).These factors are the following:

- ✓ It needs to invest time, money and training in the application of the SPC (Does et al., 1997).
- ✓ It needs constant attention and senior management support (Antony & Taner, 2003; Does et al., 1997).
- ✓ It is important the effective use and correct interpretation of control charts.
- ✓ It must overcome the difficulties in the use of statistics to build the chart, understanding and identification of corrective actions.
- ✓ It is important to plan for the application of SPC and the management after application (Antony & Taner, 2003).

The identification of CSF for the application of SPC is crucial, but only the consideration of factors is not enough, they must be connected in an intelligible plan (Lim & Antony, 2014).

2.6. Common and Special Causes of Variation

Variation is part of our everyday lives and in our private lives we make allowances for its effects from the process of getting to work in the morning to the output of a complex manufacturing system. There are two basic elements that help to quantify variations which are the central tendency and the spread. We need to have a handle on both these since they are vital to successful process. According Shewhart (1931 & 1980), control is simply a state where all variation is predictable variation but not the complete absence of variation. A controlled process isn‘t necessarily a sign of good management, nor is an out-of-control process necessarily producing non-conforming product (Pyzdek, 2003). In any production process a certain amount of inherent or natural variability is the cumulative effect of many small, essentially unavoidable causes. According to Montgomery (2005), natural variability in the framework of statistical quality control, is often called a "stable system of chance causes" and an inherent part of the process. Variation is caused by a source of variation that is not part of the constant system were called assignable causes by Shewhart, special causes of variation by Deming (Pyzdek, 2003).The main sources of assignable causes are improperly adjusted or controlled machines, operator errors and defective raw material. Such variability is generally large when compared to the background noise, and it usually represents an unacceptable level of process performance (Montgomery, 2005).

The basic rule of statistical process control is: Variation from common-cause systems should be left to chance, but special causes of variation should be identified and eliminated.

Shewhart described process variability in terms of assignable- cause and chance-cause variation (Montgomery, 2009). Chance causes, or common causes, are the many small, essentially unavoidable causes that are inherent to the production process. Assignable causes, or special causes, are identifiable causes and result in extra variation or a shift in the production process output. A process that is operating with only chance causes is said to be in statistical control. A process that is operating in the presence of assignable causes is said to be out of control. The control limits are not simply pulled out of the air. They must be calculated from actual process data using valid statistical methods. Without statistical guidance there could be endless debate over whether special or common causes were to blame for variability (Pyzdek, 2003).

2.7. Prevention and Detection of Process Variation

A process control system is essentially a feedback system that links process outcomes with process inputs. There are four main elements involved, the process itself, information about the process, action taken on the process, and action taken on the output from the process. By the process, we mean the whole combination of people, equipment, input materials, methods, and environment that work together to produce output. The performance information is obtained from evaluation of the process output. The output of a process includes more than product, it also includes information about the operating state of the process such as temperature, cycle times, etc. Action taken on a process is future-oriented in the sense that it will affect output yet to come. Action on the output is past-oriented because it involves detecting out-of-specification output that has already been produced. There has been a tendency in the past to concentrate attention on the detection-oriented strategy of product inspection. With this approach, we wait until an output has been produced, then the output is inspected and either accepted or rejected. SPC takes you in a completely different direction: improvement in the future. A key concept is the smaller the variation around the target, the better. Thus, under this school of thought, it is not enough to merely meet the requirements; continuous improvement is called for even if the requirements are already being met. The concept of never-ending, continuous improvement is at the heart of SPC (Pyzdek, 2003).In general identifying sources or causes of variation is important to control process variation through prevention and detection with the help of SPC tools in the process of pasteurized milk production line.

2.8. Conceptual Framework of the Study

In dairy industry consumers expect fluid milk (pasteurized or packed milk) and other dairy products to be nutritious, fresh-tasting, and wholesome. To consumers, “quality” means that the product tastes good and that it keeps well in their home refrigerators. Consistent high quality dairy and fluid milk products are essential to allow dairy products to successfully compete with other food and beverage products.

Consumer satisfaction with dairy products is also high importance for retailers due to the direct and indirect costs associated with consumer complaints. To maintain and/or increase market share, processors need to meet and exceed consumer and customer quality expectations. To that end, milk quality improvement is needed in order to assist dairy plants in improving the quality of dairy products and to monitor, make recommendations, and provide data that can help to improve the quality of pasteurized milk produced in dairy industry.

QI approach recognize that both resources or inputs and activities carried out or processes are addressed together to ensure or improve quality of products or services or outputs/outcomes. Therefore to improve the quality of pasteurized milk, it is better to use many different conceptions, methods and tools that may be used to maintain the good quality level or quality improvement and help in continuous development in the company.

Quality tools (SPC tools) primarily purpose is to control process variation by reducing causes to variation and product defects during the process of pasteurized milk in the production line. Depending on the quality characteristics of dairy industry (temperature, acidity/milk titration, fat and milk volume/weight) are critical in the process of the production line. To control variations of these quality characteristics in the process requires control chart, to identify the root causes of variation requires cause and effect diagram, to analyze product defects requires Pareto chart and other SPC tools are required for different quality improvement purposes. This shows that effective use of SPC tools have a positive impact for dairy industries by maintain a desired degree of conformance to design, increase product quality, eliminate unnecessary quality checks, reduce the percentage of defective parts, reduce returns, reduce scrap and rework rates, provide evidence of quality, enable trends to be spotted, ability to reduce costs and lead times.

The main critical success factors of SPC application are lack of senior management commitment, lack of training and understanding of SPC, decreased attention after the introduction and the lack of understanding of the potential benefits of the SPC. Identification of CSF for the application of SPC is crucial, but only the consideration of factors is not enough, they must be connected in an intelligible plan. So, quality improvement using statistical process control (SPC) tools application in dairy industries have been identified, a general framework to serve as a conceptual model for initiating and application of SPC in dairy industries is needed. Based on the findings from the theoretical review in this study, the conceptual framework is developed to improve quality by effective application of SPC tools in the dairy industries. The framework is developed in consideration of effective application of SPC, key success factors of SPC application, SPC principles and tools that have been identified to analyze the impacts in dairy industries

CHAPTER THREE

RESEARCH METHODOLOGY

This chapter has covered the activities and processes that were undertaken to gather data for the research work. It has given full details of how data are collected and processed for this research work. The discussion was research designs, research approach, data collection tools, primary data, direct observation, focus group discussion, secondary data, literature review, document review, data analysis, and ethical consideration of the research.

3.1. Research Design

Research design is a choice of an investigator about the component his project and development of certain component of the design (Yogesh Kumare; 2006). The essential difference between the various study in the descriptive and explanatory research designs is that the descriptive research measure the type of occurrence with learning what and how a variable occurs and explanatory research design tries to explain relationship among variables for instance why the problem rate is higher; (Donald R. Cooper Sschindler, 2014). Hence, this study has used descriptive research design. It has tried to identify what quality problems was cause of variation, describe the way how to identify and visualize quality problems in the process of the production line, identify and measure quality defects, analyze and describe the impacts of SPC tools application on quality improvement and guide application of SPC tools for quality improvement in SAI. This shows the study has used descriptive research design that identify, measure and describe the type of occurrence related to quality in the process of pasteurized milk production line.

3.2. Research Approach

There are two types of research approaches; deductive and inductive research approaches. A deductive approach is aimed and testing theory that the emphasis of from general theory and more commonly associated with quantitative research. Inductive approach is usually use research question to narrow the scope of the study and associated with qualitative research; Gabriel (2013).

This study has used to a large extent on a deductive reasoning in sense it aims to analyze impacts of SPC tools application on quality improvement within the production line and comparing the analysis with the theory then trying to make conformity with the help of experimental data that have done by SAI quality control laboratory. This research was entail/involve a qualitative and quantitative measurement of study variables.

3.3. Data Collection Tools

The researcher has attempted to gather adequate and relevant information with the concerned topic by using primary and secondary data collection tools. The data was used quantitative and qualitative data. Quantitative assume the meaning and refers to measure of it the how much and qualitative refers to the meaning the definitions analogy or model characterizing something Cooper Sschindler (2014).

3.3.1. Primary Data

Primary data is data which the researcher collects to answer the specific research questions. In carrying out this study, multiple data collection methods were used to address the research questions.

3.3.1.1. Direct Observation

Direct observation has used to gather relevant information through suspicious observation of process flow, operator activity and performance. It was used to observe quality of raw material, supervisors commitment to quality, quality control activities through the process, methods of work, working equipment handling and working environment. And also direct observation was used to gather relevant and accurate information related to main causes of quality problem, quality improvement technique, methods of quality problem solving activities and methods to identify defective product. It has used to understand impacts of SPC application on quality improvement and SPC application guide line in the process of pasteurized milk production line. To search this kind of information it was better to know the number of shifts in SAI. There were three shifts with eight working hours for each shift, from the three shifts, the study has used two hour per day for three days which means for one day one shift for two hours observation and totally six hours observation were conducted to address the specific objectives of the research.

3.3.1.2. Focus Group Discussion

Focus group discussion has used depend on different literature studies to identify quality problems, cause of variation, cause of product defects, factors affect quality and productivity performance, possible statistical process control tools used and impacts of SPC application. It was conducted focus group discussion with two teams. The team members were selected purposely in the company. The first team has contained nine members and the second team has contained eleven members.

3.3.2. Secondary Data

Secondary data has collected to enrich this research and supplement what was collected from observation and group discussion. Secondary data drawn to augment the primary data and help triangulate findings based on other data.

3.3.2.1. Literature Review

The research topic have supported by different recently published Reference books, E-Books, E-journals and Articles were surveyed in order to understand the concept, principle, guide line and impacts of SPC application on quality improvement in dairy industry. Literature review survey has used to identify quality improvement tools, cause of quality problems, product defects, physical and working environment factors, working equipment, work method and procedure that affect process in the production line of pasteurized milk.

3.3.2.2. Document Review

Document review has used; to collect general information about profiles of the industry and demographic characteristics of the employees. To identify and visualize the existing quality problems and impacts of SPC application on quality improvement were reviewed quality control daily recorded documents related to pasteurized milk temperature, acidity of milk titration, volume or weight and fat content. To show product defects and impacts of SPC were reviewed production daily recorded documents related to damage, return, breakage, clotting or souring, and other related reports in the company from internal sources. Internal sources were the quality manager report on cause of quality problems and production manager daily report on production input and output and audit reports related to production.

3.4. Data Analysis

The data analysis conducted were those related to the research problems and objectives through extracting the needed information from a document having the company specifications and were taken by different analysis devices. The analysis has covered profile of the organization, demographic characteristics of employees, document review data collection using control charts, application of control charts using milk temperature, weight, acidity and fat contents to show variations in the process of pasteurized milk production. Application of Pareto and cause and effect diagram by using product defects of damage, returns, breakage and clotting or souring in order to show product defects and identify root causes for this defects. Gap analysis has used for defective products to estimate the impacts of SPC application on quality improvement. Furthermore, to summarize results of the document review data collection were described, analyzed and synthesized in tables, control charts, figure, percentage and charts with the help of Minitab 18 for the purpose of significance study. To know the basic needed facts that the technique used to reduce large numbers of error data gathering from primary and secondary sources. It has analyzed and interpreted by using statistical methods that were percentage, Mean, standard deviation, range, control charts compare and contrast of data and theoretical aspects.

3.5. Ethical Consideration

This research considers ethical issues by having a signed nondisclosure agreement with the senior management of the company, which guarantees the confidentiality of data related to the company's intelligent properties. The respondents were clearly guaranteed secrecy protection, and this was mentioned in the invitation letter. The research proposal were discussed and agreed by both sides, the researcher and the company's senior management to clarify a clear research objective and to avoid dishonesty about the nature or aims of the research. This study also has received ethics approval from University of St. Mary’s University. The reports of the research output were clarified and discussed in a final review meeting with the company’s senior management to avoid misleading or false reporting of research findings. Moreover, there was no personal interest and the researcher has acted professionally.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND DISCUSSION

This chapter has covered an overview of data analysis and discussion that related to the research problems and objectives. The analysis covered profile of the organization, demographic characteristics of employees, flow charts for describing various process and process improvement using variable control charts. It has also covered application of control charts using pasteurized milk quality performance measures, application of Pareto diagram using pasteurized milk quality defects, application of cause and effect diagram using causes of pasteurized milk quality defects and gap analysis of defective pasteurized milk products.

4.1. Data Presentation and Analysis

4.1.1. Profile of the Organization

Sebeta Agro- Industry is the most recognized private dairy processing company in Ethiopia. It processed different dairy products such as liquid milk, butter, cheeses, yoghurt, UHT, cream and fruit juices. The company currently has about 250 employees. Those employees found under different departments such as quality control, production, maintenance, finance, auditor, personnel, marketing, sales, agriculture, purchaser and logistics.

4.1.2. Demographic Characteristics of the Employees

Demographic characteristic is statistical data about the characteristics of the population age, gender, and educational level of a population. But our concern is that current educational background in Sebeta Agro industry employees using frequencies and percentage.

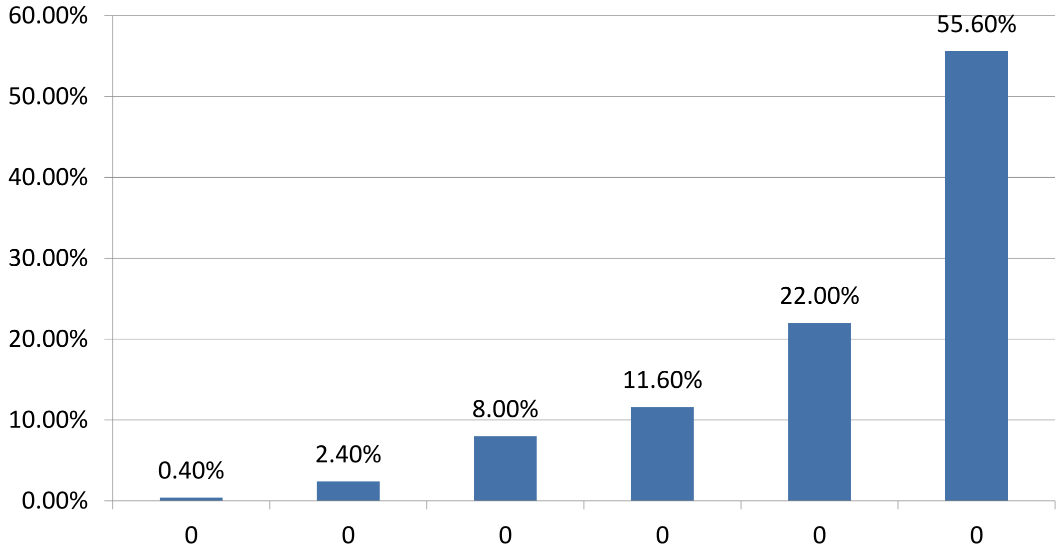

Figure 4.1 Bar charts for educational level of employees

Source: own computation based on data collected word excel (2020)

The educational background of the employees in the company were 55.60% below certificate, 22% certificate, 11.60% diploma, 8% degree holders, 2.4% master's degree holders and 0.40% philosophy doctor (PhD) holders. As we have seen the above graph, most of the employees, 55.60% were below certificate educational level. For sure the educational level of employees positively affects quality and productivity improvement and defects analysis using SPC tools in dairy industry, since most of SAI employees are below the average of educational level.

4.2. Flow Charts for Milk Processing in Dairy Industry

Flow chart is a generic tool that can be adapted for a wide variety of purposes, and can be used to describe various processes, such as a manufacturing process, an administrative or service process, or a project plan. Flow chart is a picture of separate steps of a process in sequential order. They build a step by step picture of the process for analysis, discussion, or communication purposes (Dalgic *et al*., 2011). Basically flow chart used to understand the process, identify possible improvements, help employees to know where they fit into the process and generate support through participation. The flow diagram indicated in (Fig 4.2) schematic picture for pasteurized and standardized milk production. The flow diagrams provide clear and simple description of the steps in the processing of pasteurized milk production from reception of raw milk to final distribution and its associated quality control tests/inspection provided from receipt to distribution of end products. Moreover all the possible process steps, which might have an influence on the quality of the product, are included.

4.2.1. Application of Flow Charts in Milk Processing in Dairy Industry

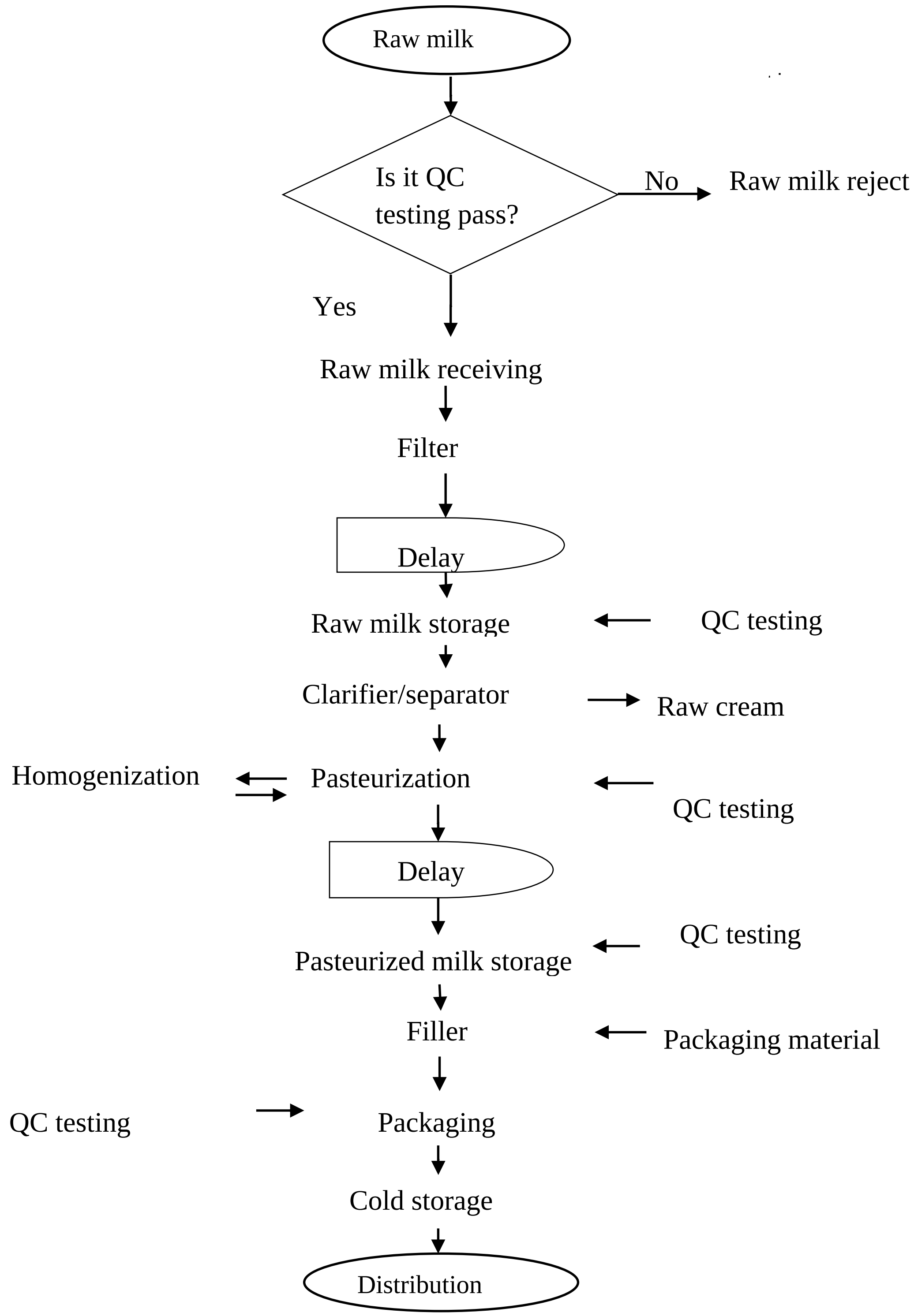

Figure 4.2 Flow charts for milk processing

Sources: Own computation based on observation, (2020) From the above flow chart (Fig 4.2) shows that quality inspection by laboratories (QC) is an effective and necessary means in realizing quality control. The accuracy and effectiveness of laboratory has a direct impact on the normal operation of the quality control procedures. Inspection/tests results by laboratories provide also important and irreplaceable information to the quality assurance system. In addition, in the course of troubleshooting procedures, inspection results of laboratories will serve as an important source of evidence in determining the cause of defects.

Laboratory (QC) tests used for quality control may, in line with the flow of process, be classified in to three types- raw material inspection, intermediate and finished product inspection.

Raw material inspection/test refers to quality analysis being carried out when raw materials are transported into the factory. The goal is to ensure that only good quality raw materials and additives that conform to their respective specification are used in the formulation and for the manufacture of products. For instance, when milk as raw material is received by the factory it will undergo several tests such as the fat content, density determination (lacto meter test), acidity (lactic acid test), alcohol stability (coagulation test), temperature, PH and others.

Intermediate product inspection refers to the tests conducted on the various intermediate products and operation results in the course of production. The goal is to identify and if necessary eliminate substandard products, reduce the waste and prevent rejects from moving onto the next processing section.

Finished products test refers to inspection conducted on the end products. The goal is to prevent the release of substandard products in to the market. To ensure marketability, a series of the tests are done on physical-chemical characteristics and to assess the microbiological quality and incubation testing. Special attention is paid to compositional attributes that are included in the labeling.

Currently SAI has three production lines. Those are pasteurized milk production line, cream or butter and cheese production line. From those production lines our study area focuses on pasteurized milk production line. Because pasteurized milk production line is the main production line in the company of SAI, there were different quality defects that were stated in statement of the problems of the study compared to other production lines. From the above (Fig 4.2) shows that pasteurized milk processing has sequential steps. This sequential step of pasteurized milk process contains major issues. Among those issues temperature change, fat content and volume or weight fluctuation, souring or clotting, and some of pasteurized milk quality defects like breakages, damage, returns and others are occurred in the process of pasteurized milk production line. Those major issues are analyzed by using variable control charts, Pareto analysis and using cause and effect diagram to identify, sort and display possible causes of specific problem or quality characteristics.

4.3. Process Improvement Using Control Chart in Dairy Industry

Production processes will often operate in the in control state, producing acceptable product for relatively long periods of time. Rarely, assignable causes will occur, apparently at random, resulting in a shift to an out of control state where a large proportion of the process output does not conform to requirements. A major purpose of SPC is quickly detect the occurrence of special causes/process shifts therefore investigation of the process and corrective action may be under taken before many nonconforming products are manufactured.

Control chart is a statistical processes control tool which shows us the graphical records, the quality of particular characteristics in the processes (Diniz, 2001, and Vieira, 1999). Control chart graphically shows the processes which is being controlled, under control and out of control in the control limit. The processes is out or under control in the control limit shows there is special cause of variation which is avoidable cause of variation and the processes is in the control limit the processes shows random cause of variation which is unavoidable causes inherent to the production processes (Montgomery, 2009).

The main objectives of the control chart application in this study is to detect assignable cause, identify root cause of problem, implement corrective action and verify and follow up the process improvement of pasteurized milk production line by using real value/variable data of quality characteristics whereas pasteurized milk temperature, fat, acidity and volume/weight.

The quality of a product can be evaluated using either an attribute of the product or a variable measure. Depending on the quality characteristic there are two types of control charts. Those are control charts for attributes, which is summarize the output of a process or operation over time and have only two values such as good or bad, conforming or none conforming, acceptable or not acceptable. Control charts for variables, which is a product characteristic that is measured real value on continuous scale such as weight/volume, temperature, fat, acidity of milk and others. In the present study the data has been collected in variables, in February, 2020 from the process of pasteurized milk production line of SAI. To determine when to use which variable control charts depends on subgroup size and summarize as follows.

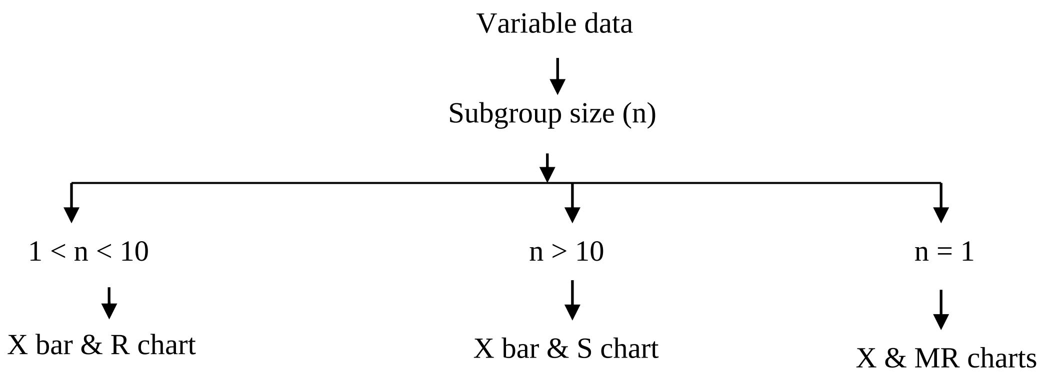

Figure 4.3 Determination of control charts for variables based on the subgroup size

Source: The control diagram for variable data control chart factors (Juran & Gryna, 1998)

In this study the variable data of pasteurized milk has been collected and organized in subgroup size (n) = 4 for pasteurized milk temperature, acidity of milk and milk fat and subgroup size (n) = 12 for pasteurized (plastic milk) volume or weight. Therefore as the above (fig 4.3) shows that quality characteristics of variable data organized in subgroup size (n) = 4 analyzed by variable control charts of X bar R- charts and subgroup size (n) = 12 analyzed by variable control charts of X bar S- charts.

4.3.1. Application of Control Charts Using Pasteurized Milk Temperature

In dairy processing company in case of SAI pasteurized milk cooling temperature is monitored in degree centigrade. According to the base period, 29 samples were observed in sample size (n = 4).

Table 4.1 Data for X bar R-chart of pasteurized milk cooling temperature in degree centigrade with mean and range

Sample 1	Sample 2	Sample 3	Sample 4	Range	X bar
7	9	6	9	3	7.75
6	9	10	6	4	7.75
7	8	8	8	1	7.75
8	8	9	7	2	8
8	7	6	6	2	6.75
5	7	7	8	3	6.75
8	7	8	8	1	7.75
7	6	7	7	1	6.75
8	8	8	6	2	7.5
6	11	8	8	5	8.25
8	8	7	6	2	7.25
6	7	8	7	2	7
8	8	8	7	1	7.75
9	8	7	8	2	8
8	9	8	10	2	8.75
8	4	8	8	4	7
8	8	9	9	1	8.5
8	7	6	7	2	7
8	9	6	10	4	8.25
8	6	6	6	2	6.5
9	8	8	7	2	8
8	8	8	8	0	8
7	7	8	8	1	7.5
6	8	8	6	2	7.5
7	7	8	6	2	7
8	7	10	8	3	7
8	9	10	8	2	8.75
8	9	8	7	2	8
8	6	6	6	2	6.5

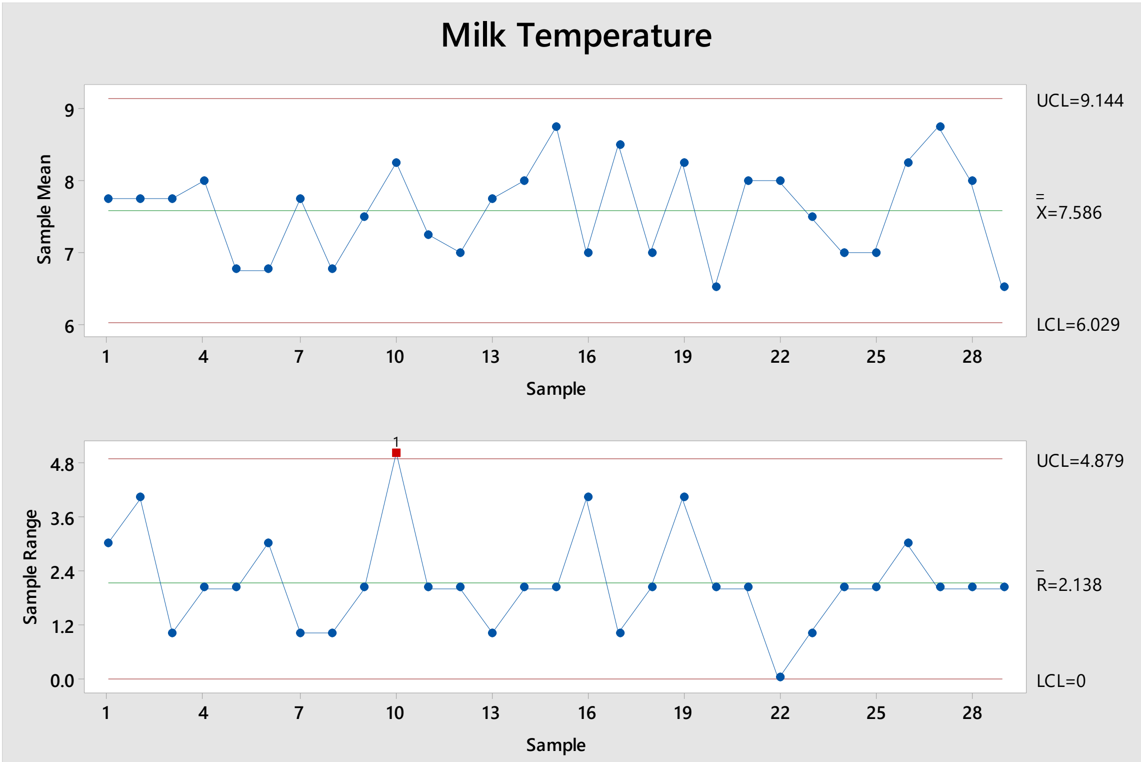

Figure 4.4 Control charts for pasteurized milk Temperature

Sources: Own computation based on data collected (Minitab 18), (2020)

Control limits for X bar – charts	**Control limits for R- chart**
Upper control limit (UCL)= 9.144	Upper control limit (UCL) = 4.879
Center line (CL) = 7.586	Center line (CL) = 2.138
Lower control limit (LCL) = 6.029	Lower control limit (LCL) = 0

In dairy industry pasteurized/plastic milk temperature analysis is the main quality parameter. From this analysis the pasteurized milk temperature should be 7.586 degree centigrade. In the above X-bar R-chart of the graph shown, all the samples were taken closest to the average of the samples and processes are takes place at normal conditions, since the processes was in the control limit between in the UCL and LCL. This was indicates that the processes has been random or chance causes were present. All sample mean points plotted within CL, then no action is necessary. In the plastic milk temperature R-chart graph shown the general variability of the processes but affected by the processes changes. From the above R- chart almost all samples were taken around the range of the mean but one sample point fall beyond the control limit that indicates special causes were present in the process of pasteurized milk and corrective actions are required to find and eliminate causes responsible for pasteurized milk temperature increased by tracing back to the process. Assignable causes and corrective measures have been identified as follows to improve the process performance of pasteurized milk temperature.

Table 4.2 Causes and corrective measures for pasteurized milk temperature variation

Assignable/special causes for pasteurized milk temperature variation	**Corrective measures or suggested action plans for increased pasteurized milk temperature**
Power reduction or insufficient power	Change production time of UHT milk machine and pasteurized milk packing machine or does not operated the two machines at the same time.
Increase atmospheric temperature	Use mechanical ventilator to reduce atmospheric temperature and maintain process stability of pasteurized temperature.

After assignable cause identified and corrective measures/action plans have been suggested, the process performance of pasteurized milk temperature improvement is observed in the month of April 2020, presented below as follows (Fig 4.5).

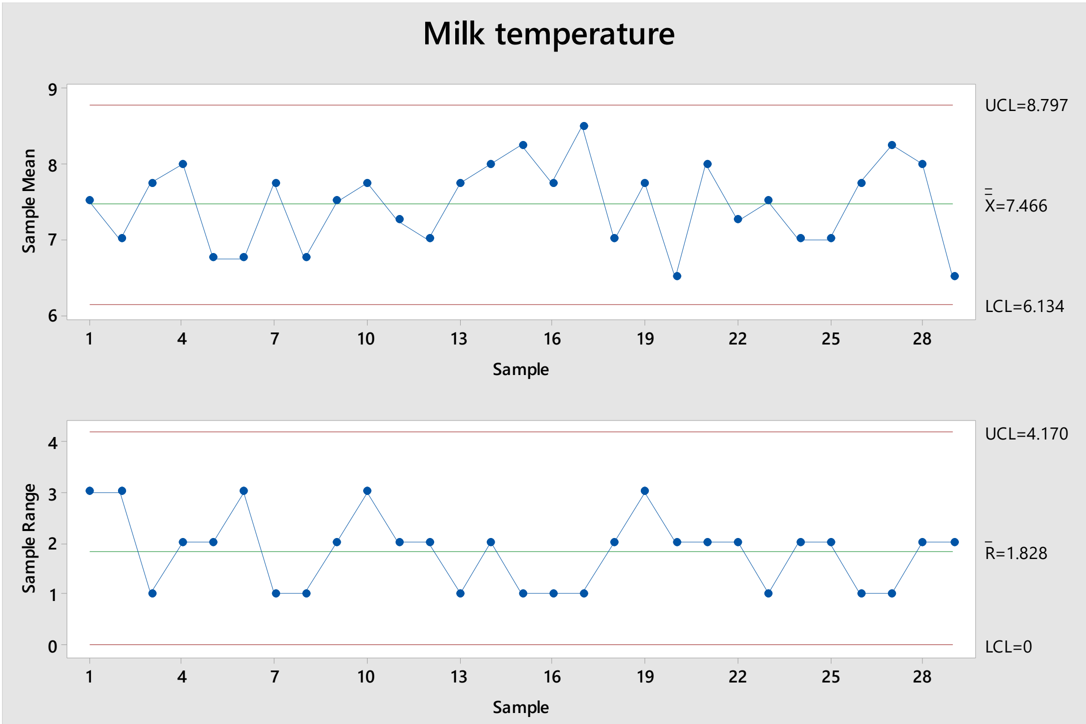

Figure 4.5 Control charts for improved pasteurized milk Temperature

4.3.2. Application of Control Charts Using Pasteurized Milk Volume

In dairy processing company pasteurized/plastic milk volume/weight is monitored in milliliter (ml) or gram (g). According to the base period, 29 samples were observed in sample size (n = 12).

Table 4.3 Data for pasteurized milk volume of weight in milliliter or gram with means and standard deviation (n=12**)**

Sam 1	**Sam 2**	**Sam 3**	**Sam 4**	**Sam 5**	**Sam 6**	**Sam 7**	**Sam 8**	**Sam 9**	**Sam 10**	**Sam 11**	**Sam 12**	**X bar**	**Std**
500	501	500	498	499	501	502	502	503	505	505	500	501.3333	2.19
500	500	500	501	500	500	500	500	498	503	501	500	500.25	1.14
0	0	505	495	495	500	501	500	500	500	500	501	416.4167	194.53
0	0	0	0	505	495	500	500	501	500	500	500	333.4167	246.25
500	500	501	500	505	505	515	500	500	500	495	500	501.75	4.90
498	501	504	504	503	500	508	500	509	505	505	505	503.5	3.29
500	500	501	500	500	499	500	500	495	490	500	500	498.75	3.14
505	509	505	505	506	505	500	510	510	505	0	0	421.6667	196.98
500	501	500	501	505	505	500	500	505	498	506	506	502.25	2.90
500	501	500	500	500	500	505	500	501	503	501	501	501	1.54
500	501	500	501	503	502	500	501	505	502	500	501	501.3333	1.50
500	501	506	503	504	502	501	500	500	0	0	0	376.4167	226.99
0	0	505	510	505	505	503	502	500	505	505	505	420.4167	196.39
505	505	505	509	511	500	505	505	500	500	501	500	503.8333	3.71
508	516	503	505	500	498	496	496	498	510	504	506	503.3333	6.12
495	513	504	500	500	501	500	501	500	0	0	0	376.1667	226.88
505	495	501	503	502	490	500	500	505	495	500	500	499.6667	4.40
501	504	496	499	501	502	500	500	500	500	501	500	500.3333	1.87
495	510	500	500	505	500	500	500	500	500	500	500	500.8333	3.59
498	498	500	500	495	503	502	503	500	498	500	501	499.8333	2.33
503	501	503	500	505	505	495	501	501	501	501	501	501.4167	2.61
495	501	505	510	500	495	505	505	510	0	0	0	377.1667	227.49
500	495	500	500	500	501	500	500	505	510	495	501	500.5833	3.96
501	501	502	503	505	501	510	505	506	500	501	500	502.9167	3.03
500	500	501	499	500	505	505	505	0	0	0	501	376.3333	226.95
502	501	501	503	498	505	505	505	495	500	500	505	501.6667	3.17
500	500	500	501	495	0	505	510	495	510	490	495	458.4167	144.49
500	505	495	0	0	495	497	507	510	0	0	495	333.6667	246.48
505	504	505	498	496	500	500	505	490	515	505	505	502.333	6.18

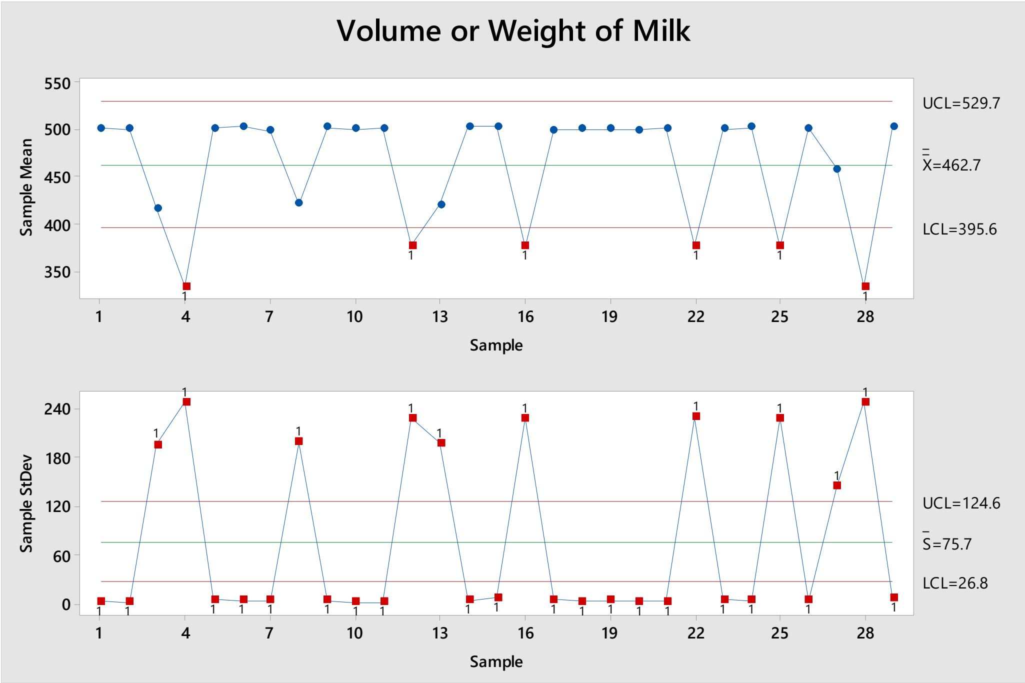

Figure 4.6 Control chart for pasteurized milk volume or Weight
Source: Own computation based on data collected (Minitab 18), (2020)

Another quality parameter of pasteurized milk production in dairy industry is volume or weight. The average weight/volume of plastic milk should be around 462.7 gm. /ml. The X-bar and S-chart graphics in table 4.3 are created from the weight/volume of 29 samples were observed in sample size (n = 12).

Control limits for x- bar charts

Upper control limit (UCL) = 529.7

Central line (CL) =462.7

Lower control limit (LCL) = 395.6

Control limits for s-charts

Upper control limit (UCL) =124.6

Central line (CL) = 75.7

Lower control limit (LCL) = 26.8

From the above X bar control charts out of twenty nine (29) samples, six (6) samples plots out sides of control limits or under the control limit, which indicates that the process is out of control limits and there were special cause of variation. As a result corrective actions are required to find and eliminate causes responsible for underweight of pasteurized milk. However, a point that plots outside of the control limits is interpreted as evidence that the process is out of control. Corrective actions were required to find and eliminate the assignable causes. It is usual to connect the sample points on the control chart with straight-line segments, so that it is easier to visualize how the sequence of points has evolved over time. Most the samples were closest to the mean of central value of samples. Among the 29 total samples none of them were above the UCL.

From the above Standard deviation control chart out of twenty nine (29) samples of volume contents of pasteurized milk, nineteen (19) samples were distributed below the LCL of standard deviation. The remaining ten (10) samples were distributed out of the UCL of the standard deviation. Which indicates the process performance is out of the control limits. Hence to improve the process performance of pasteurized milk weight corrective measures were required through identified assignable causes by tracing back to the process of pasteurized milk weight as follows.

Table 4.4 Causes and corrective measures for pasteurized milk weight variation

Assignable/special causes for pasteurized milk weight variation	**Corrective measures or action plans for pasteurized milk over/ under weight**
Lack of frequently follow up of packing machine (operator)	Check the correct adjustment of packing machine, filler and plastic milk volume by ten minutes interval.
Lack of frequently follow up quality of milk weight/volume (quality control)	Monitor and sampling the quality of milk volume by twenty minutes interval.

After assignable cause identified and corrective measures/action plans have been suggested, the process performance of pasteurized milk volume or weight improvement is observed in the month of April 2020, presented below as follows (Fig. 4.7).

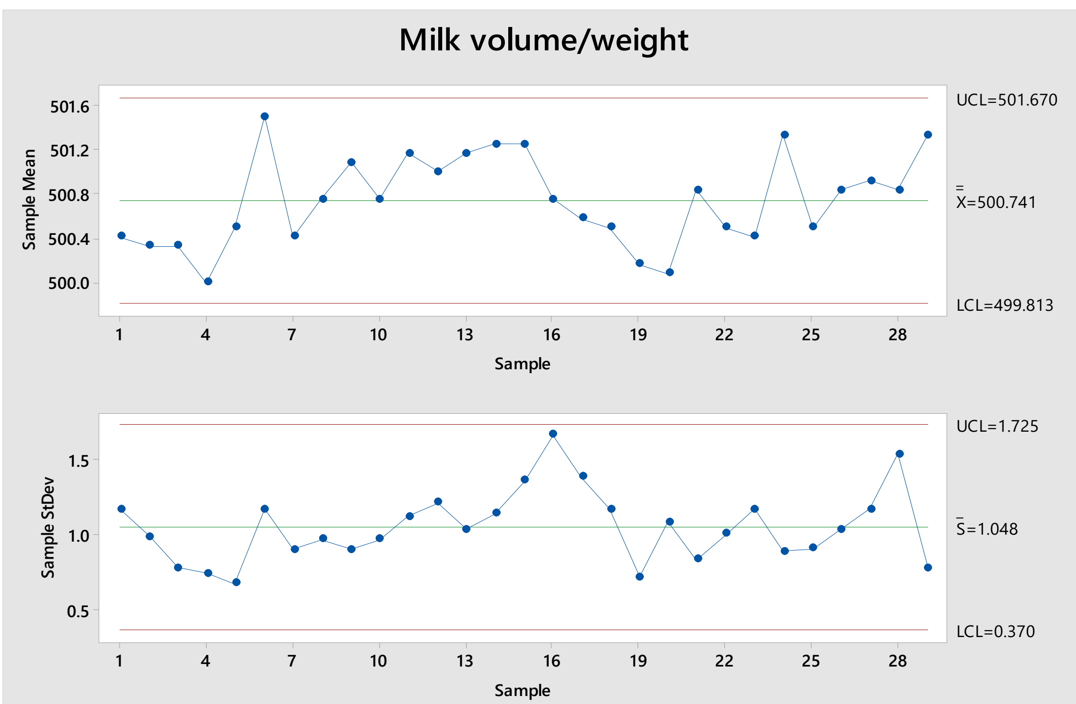

Figure 4.7. Control charts for improved pasteurized milk volume/weight

4.3.3. Application of Control Charts Using Acidity of Pasteurized Milk

Table 4.5 Data for X-bar R-charts of pasteurized milk titrable acidity in Dornic degree (dg) or ml (n=4)

Sample 1	Sample 2	Sample 3	Sample 4	X bar	Range
1.3	1.6	1.4	1.0	1.325	0.6
1.3	1.7	1.2	1.2	1.35	0.5
1.4	1.4	1.3	1.7	1.45	0.4
1.2	1.6	1.2	1.8	1.45	0.6
1.7	1.6	1.4	1.7	1.6	0.3
1.4	1.6	1.2	1.1	1.325	0.5
1.2	1.6	1.3	1.3	1.35	0.4
1.6	1.7	1.0	1.8	1.525	0.8
1.7	1.1	1.2	1.7	1.425	0.6
1.6	1.4	1.1	1.6	1.425	0.5
1.6	1.1	1.1	1.8	1.4	0.7
1.4	1.5	1.3	1.9	1.525	0.6
1.7	1.5	1.2	1.6	1.5	0.5
1.8	1.3	1.1	1.5	1.425	0.7
1.5	1.5	1.0	1.2	1.3	0.5
1.1	1.6	1.1	1.8	1.4	0.7
1.4	1.7	1.5	1.0	1.4	0.7
1.1	1.6	1.0	1.6	1.325	0.6
1.5	1.6	1.3	1.4	1.45	0.3
1.9	1.4	1.4	1.2	1.475	0.7
1.1	1.6	1.0	1.7	1.35	0.7
0.9	1.8	1.2	1.8	1.425	0.1
1.1	1.8	1.6	1.5	1.5	0.7
1.5	1.4	1.2	1.3	1.35	0.3
1.7	1.5	1.3	1.6	1.525	0.4
1.7	1.7	1.6	1.6	1.65	0.1
1.2	1.9	1.7	1.1	1.475	0.8
1.1	1.8	1.3	1.2	1.35	0.7
1.8	1.7	1.8	1.8	1.325	0.1

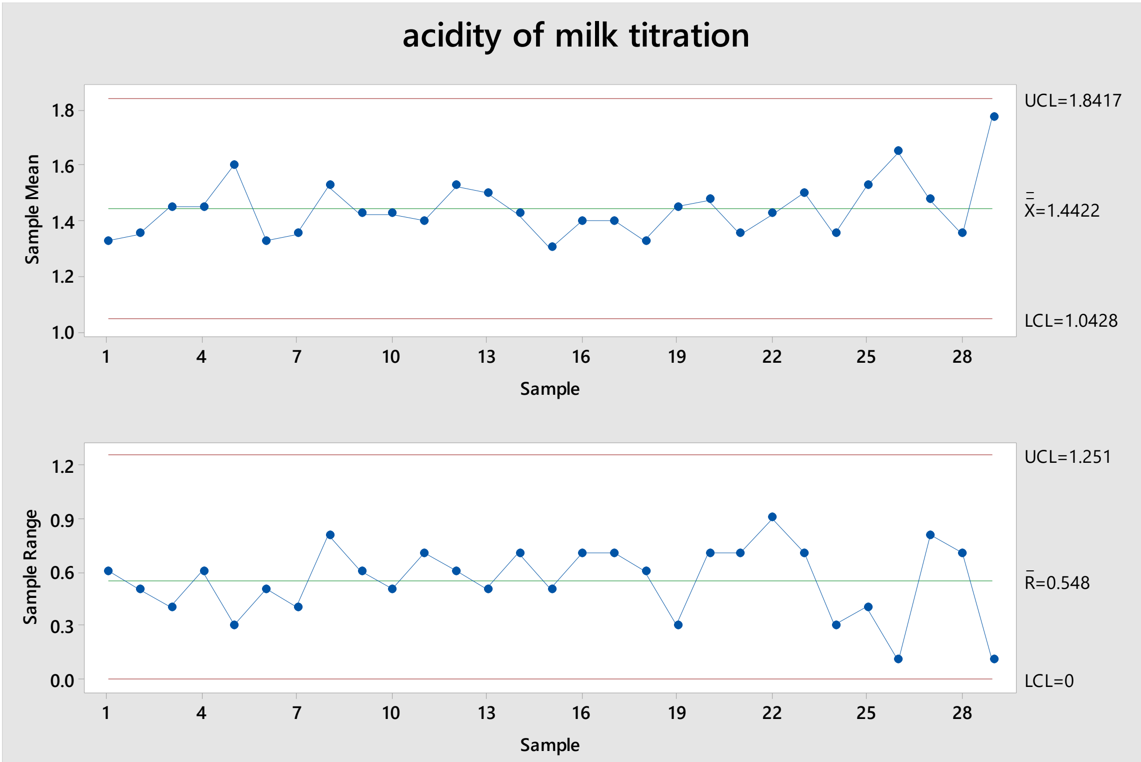

Figure 4.8 Control chart for acidity of pasteurized milk

Source: Own computation based on data collected (Minitab 18), (2020)

Control limits for x- bar charts	**Control limits for s-charts**
Upper control limit (UCL) = 1.8417	Upper control limit (UCL) =1.251
Central line (CL) =1.4422	Central line (CL) = 0.548
Lower control limit (LCL) = 1.0428	Lower control limit (LCL) = 0

Acidity analysis in the production of pasteurized milk is the basic quality parameter in dairy industry. The measurement unit of pasteurized milk acidity or titration is Dornic degree (dg) or ml. The average acidity of pasteurized milk should be around 1.44dg or ml.

The x-bar R- chart graphics are created in table 4.5 from the acidity analysis of 29 samples of in sample size (n=4). The control limits drawn in both plots were obtained by using equations given in (table 2.1) from literature review of study. These control limits were chosen in order to determine the process performance in control or out of control. From the above X- bar and R-charts all of the sample points would fall between the control limits. With the understanding that the points plot within the control limits, the process is expected to be in control, and no action is necessary.

4.3.4. Application of Control Charts Using Pasteurized Milk Fat

Table 4.6 Data for X-bar R-charts of pasteurized milk fat in percent with mean and range (n=4)

Sample 1	Sample 2	Sample 3	Sample 4	X bar	Range
2.9	2.6	1.7	2.5	2.425	1.2
2.7	2.5	2.2	2.6	2.5	0.5
2.0	2.7	2.1	2.9	2.425	0.9
1.9	2.6	2.0	1.9	2.1	0.7
2.6	2.8	2.8	2.0	2.55	0.8
2.1	2.7	2.1	1.9	2.2	0.8
2.0	2.7	1.8	2.1	2.15	0.9
2.6	2.8	1.9	2.3	2.4	0.9
2.6	1.9	2.0	2.3	2.2	0.6
2.7	2.4	2.1	2.0	2.3	0.7
2.2	2.7	1.9	1.9	2.175	0.8
2.5	2.7	2.3	2.5	2.5	0.4
2.7	2.0	1.7	2.6	2.25	0.7
2.7	2.8	2.3	2.1	2.475	0.7
2.5	2.7	1.8	2.5	2.375	0.9
2.0	2.7	2.1	2.3	2.275	0.7
1.8	2.8	2.8	2.7	2.525	1
2.5	2.3	2.0	1.9	2.175	0.6
2.6	2.6	1.9	2.6	2.425	0.7
3.0	2.7	2.0	2.6	2.575	1
1.9	2.6	2.0	1.8	2.075	0.8
3.0	2.0	2.0	2.1	2.275	1
2.9	2.9	2.2	2.2	2.55	0.7
2.8	2.7	1.8	2.4	2.425	1
2.4	2.7	2.3	2.0	2.35	0.7
2.6	2.8	2.1	1.9	2.35	0.9
2.9	2.9	2.0	2.0	2.45	0.9
1.7	3.0	2.3	2.4	2.35	1.3
2.6	2.9	2.7	2.5	2.675	0.4

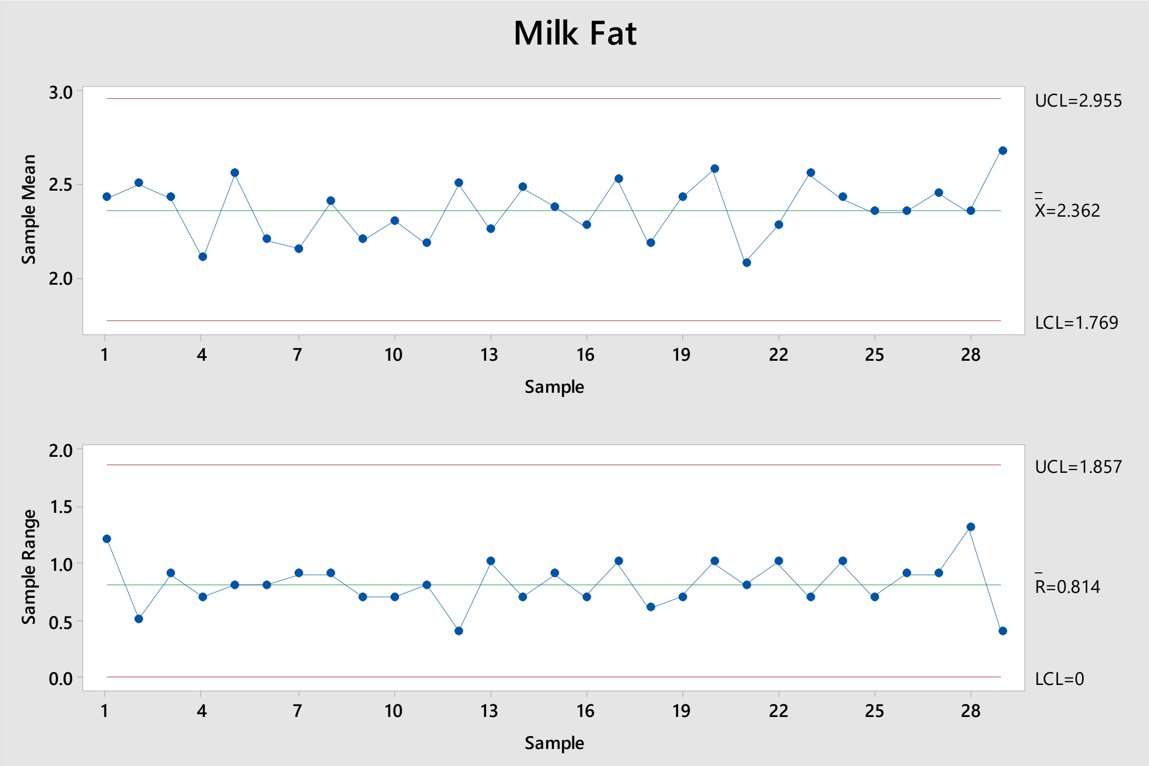

Figure 4.9 Control charts for pasteurized milk fat

Source: Own computation based on data collected (Minitab 18), (2020)

Control limits for x- bar charts	**Control limits for R-charts**
Upper control limit (UCL) = 2.955	Upper control limit (UCL) =1.857
Central line (CL) =2.362	Central line (CL) = 0.814
Lower control limit (LCL) = 1.769	Lower control limit (LCL) = 0

In the dairy industry fat content analysis of pasteurized milk is one of quality parameters. The average fat content should be around 2.4%. The x-bar R- chart graphics are created in table 4.5 from the fat analysis of 29 samples in sample size (n=4). The control limits drawn in both plots were obtained by using equations given in (table-2.1) from the literature review. From the above X-bar R- chart shows that all sample points plot within the control limit, which indicates that the process of pasteurized milk production takes place in controlled. Therefore the process is in controlled and no need of inquiry and corrective action is necessary.

4.4. Application of Pareto Diagram Using Milk Quality Defects

Despite the fact that control chart is a very powerful tool for investigating the causes of variation in a Process, it is most effective when used with other SPC problem-solving tools such as Pareto chart and cause- effect diagram.

In the present study have used only variable control charts for process improvement by using variable data of pasteurized milk quality characteristics. However, Pareto chart was used for solving problems of milk quality by using attribute data of milk quality defects. Therefore both are used individually for the purpose quality improvement in different quality problems in the process of pasteurized milk production line.

Pareto chart is a vertical bar graph displaying rank in descending order, of importance for the categories of problems, defects or opportunities. It is simply a frequency distribution of attribute data arranged by category.

A Pareto chart is used to isolate critical causes of defective products and achieving process stability and improving capability through reduction of variability. Pareto has its own Principle helps to realize that the majority of results come from minority of inputs; this principle is 20/80, which states that the performance measure can be improved 80% by eliminating only 20% of the causes of unacceptable performance (Fotopoulos et al., 2011). According to this principle to identify the main defects which occurred frequently in pasteurized milk production line in SAI, through two months combined defect data had been collected (February and March, 2020). Depend on the Pareto principle possible performance measures are; breakages, returns, damages, clotting/ souring, overweight, underweight, unwritten expired date, cooling temperature out of standard, PH out of standard and microbial load out of the standard to separate the vital few causes resulting in unacceptable performance from the trivial many causes.

Table 4.7 Data collected for number of visual defects over the past two months (February, and March 2020)

S no.	Types of Defects Per liter (L)	Number of Defective		Total number of defective
		February	March	
1	Breakage	3220	4725	7,945
2	Return	4963	27119.5	32,082.5
3	Damage	2781.5	3224.5	6,006
4	Clotting / souring	19060	27098	46,158
5	Over weight	1114	1330	2,444
6	Unwritten expired date	430	610	1,040
7	Under weight	1598	1175	2,773
8	Cooling temperature out of standard	506.5	313	819.5
9	Microbial load out of standard	291	411	702
10	PH out of standard	675	289	964
Total				100,934

Source: Own computation based on data collected (2020)

From the (table 4.8) mentioned defects except clotting or souring occurred in the processes of pasteurized or plastic milk production up to the delivery of the end customers but the one which clotting /souring is occurred before the processes started. From this quality defects, clotting/souring was the main quality problem. Whereas real applications have many defect types and many parts as a result, all of those types of defects are controlled over time.

Table 4.8 Pareto analysis worksheet for visual defects over the past two months

Types of Defect	No. of defective	Percentage of defective	Total percentage of cumulative defective
Clotting / souring	46,158	45.7	45.7
Return	32,082.5	31.8	77.5
Breakage	7,945	7.9	85.4
Damage	6,006	6.0	91.3
Under weight	2,773	2.7	94.1
Over weight	2,444	2.4	96.5
Unwritten expired date	1,040	1.0	97.5
PH out of standard	964	1.0	98.5
Cooling temperature out of standard	819.5	0.8	99.3
Microbial load out of standard	702	0.7	100.0

Source: Own computation based on data collected (Minitab 18), (2020)

From the (table 4.8) contains ten types of defects in descending order, number of defects, percentage of defects and total percentage of cumulative defects in two consecutive months, February and March. This was useful to represent these data graphically as in (Figure4.10). This graph has been prepared using the work sheet in (Table4.8). In (Figure4.10) all defects are shown graphically to find out and prioritize the most effective defect for improvement over these defects.

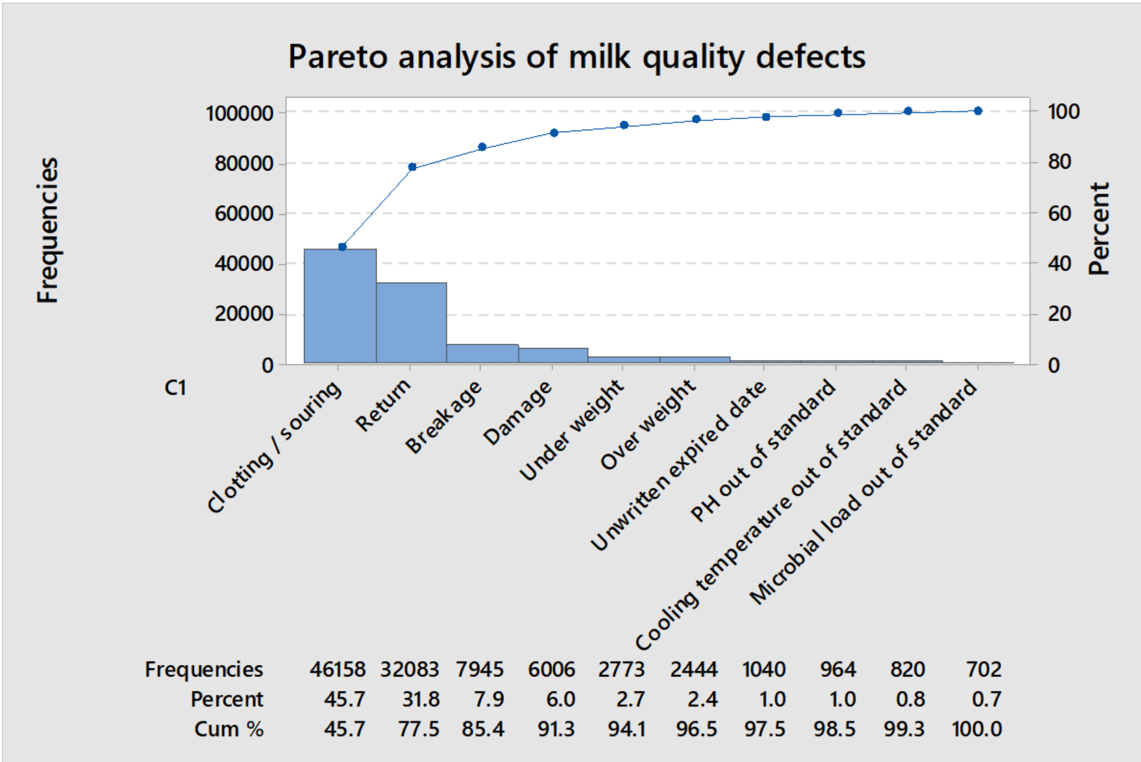

Figure 4.10 Pareto chart for types of visual defects observed over the past two months

Source: Own computation based on data collected (Minitab 18), (2020)

The Pareto chart was constructed based upon data collected (Tables 4.7 and 4.8) and shown that ten types of defects such as clotting/souring 45.7% returns 31.8%, breakage 7.9%, damages 6.0%, underweight 2.7%, overweight 2.4%, unwritten expired date 1.0%, PH out of standard 1.0% cooling temperature out of standard 0.8% and microbial load out of standard 0.7%. From these defects, clotting/souring, return, breakage and damage were taken as critical defects to the company.

The two major physically tested and identified defects are clotting/souring 45.7% and return 31.8% (Figures 4.10). These two major defects are vital few where 77.5% of the overall rejection. These major quality defects identified during the systematic observation. It is nearly impossible to achieve zero defects. Then by taking effective measure it is possible to reach near zero defects. Therefore, it is clear most of all defects will decrease, if the causes for these major defects are reduced.

4.5. Application of Cause and Effect Diagram Using Root Causes of Milk Quality Defects

Pareto chart helps us to prioritize our efforts and focus attention on the most pressing problem or symptom; it is the cause-and-effect diagram that helps to lead us to the root cause of the problem (Devor *et al.*, 2007). From Pareto Analysis (figure 4.6) have identified ten types of defects. From those defect types clotting or souring, return, breakage and damage were identified as major defects. Then we have to analyze major defects by cause and effect diagram to identify the root causes and sub- causes.

Cause and Effect diagram is a tool used for analyzing and illustrating main and root-causes of quality defects. It is sometimes referred to as fishbone diagram since the complete diagram look like a fish skeleton.

The data analyzed by the cause-and-effect diagram usually comes from a brainstorming and direct observation. Brainstorming is a technique used to elicit a large number of ideas from a team using its collective power. It normally takes place in a structured session involving between three to twelve people with five to six people. The team leader keeps the team member focused, prevents distractions, keeps ideas flowing, and records the outputs (Gitlow and Levin, 2009). In the present study have been invited two teams in different time for group discussion/brainstorming to identify the root causes of milk quality defects. These team members were selected purposely. The first team contains one quality manager; three quality control laboratory technicians, two production supervisors; one quality expert/assurance and two raw milk purchaser supervisors have been participated to identify the root causes of souring/clotting milk quality defect. The second team contains one production manager, two production supervisors, two production operators, two sale supervisors, one salesman, one auditor and two quality control laboratory technicians have been participated to identify the root causes of return, breakage and damage pasteurized milk quality defects. The root causes of these top four types of visual quality defects which are clotting/souring, return, breakage and damage can be grouped into measurement, machine, people, work method, material, and environment.

Table 4.9.The root causes of milk quality defects

Measurement	Material	People	Machine	Method	Environment
Alcoholmeter calibration	Packaging material quality	Work ethics	Periodic maintenance	Labeling problem	Environmental influence on measurements
	Adulteration	Commitment &involvement	Replacement of spare parts	Lack of Communication	
	Material contamination	Training	Power interruption	Machine setup	
	Hygiene and sanitation of material	Material handling			
		Fasting			

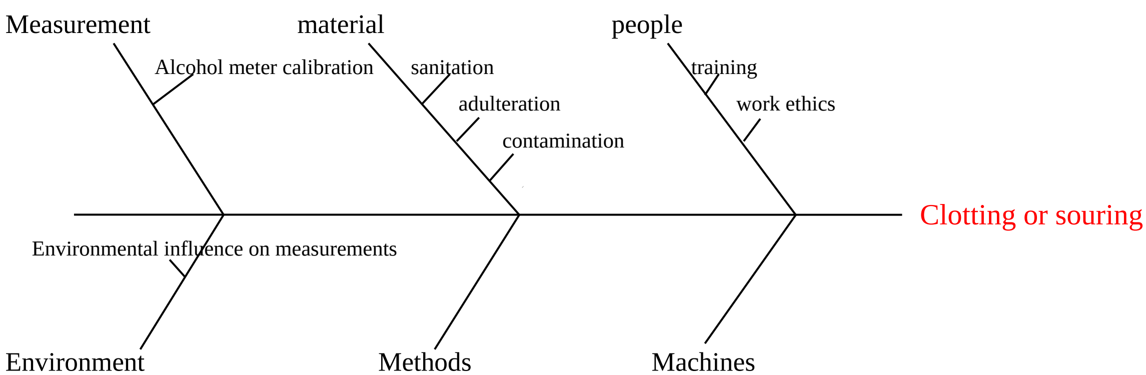

Figure 4.11 causes –effect diagram for clotting or souring

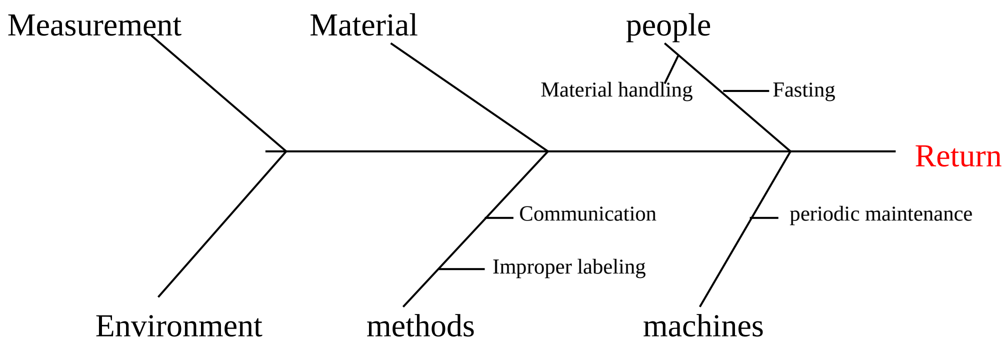

Figure 4.12 cause –effect diagram for return

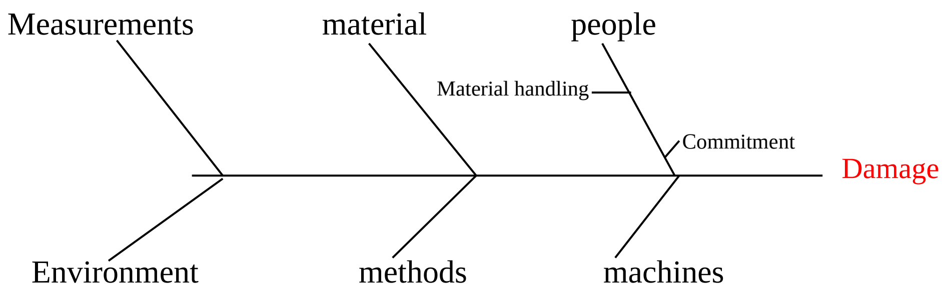

Figure 4.13 cause –effect diagram for damage

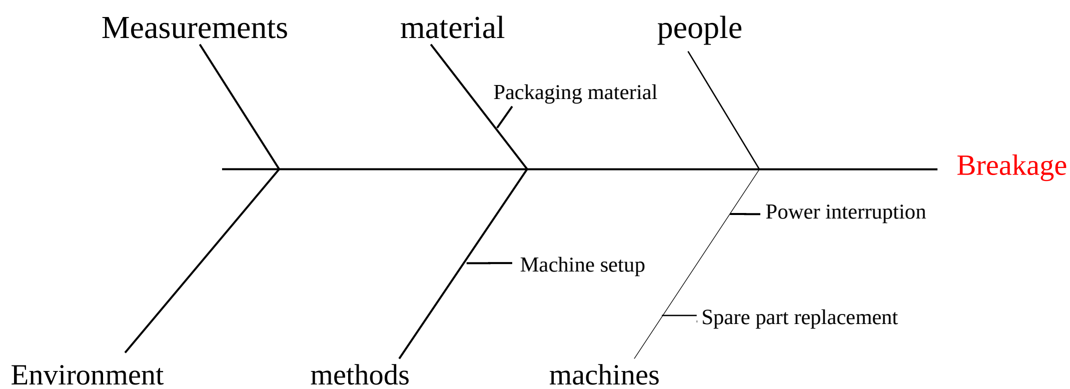

Figure 4.14 cause –effect diagram for breakage

From the Pareto chart, major or vital few problems have been identified such as souring/clotting, return, breakage and damage (figure 4.10). From these quality defects of milk, souring/clotting and returns are major quality defects which contributed 77.5% of the overall due to visual defect rejection. Using fishbone diagram the root causes for the problems or defects were identified. The above (Fig 4.11), (Fig 4.12), (Fig 4.13) and (Fig 4.14) shows that root causes of defects that was produced during brainstorming session. The team was able to quickly identify major potential causes of clotting/souring, returns, breakage and damage.

For clotting/souring quality defect the major causes are lack of work equipment hygiene and sanitation, material contamination, lack of work ethics, lack of training, lack of periodic alcoholmeter calibration, adulteration and environment influences of the measurements (Fig 4.11). For returns quality defect the major causes are lack of material handling, lack of periodic maintenance of machine, lack of communication and labeling problem or improper written expire date of pasteurized milk product and fasting (Fig 4.12).

For breakage quality defect the major causes are lack of follow up machine setup and lack of periodic replacement machine spare parts, power interruption and quality of packaging material (Fig 4.14).

For damage quality defect the major cause is lack of material handling of the pasteurized milk product during transportation and lack of commitment to front workers (Fig 4.13).

Those identified root causes of milk quality defects required corrective measures to bring improvements and needs to observe the improvements after the corrective measures or action plans implemented. The following (Table 4.10) contains suggested corrective measures or actions plans for the root causes of milk quality defects.

Table 4.10.Corrective measures/ action plans for root causes of milk quality defects

Types of milk quality defects	Identified root causes for milk quality defects	Corrective measures for milk quality defects
Clotting or souring	Lack of alcoholometer calibration	Isolate and used only calibrated alcoholometer and provide periodical calibration of measurements.
	Environmental influence on measurements	Replace measurements by free from environmental influence like lactose can and centrifuge Gerber.
	Lack of hygiene and sanitation	Improve hygiene and sanitation program with the standards of detergents concentration (soda ash, caustic soda and nitric acid) and all milk collection equipment, transportation cars, storage tanks, cooling tanks and machines were cleaned.
	Adulteration	Provide payments and incentives to raw milk suppliers depend on good quality of raw milk.
	Contamination	Avoid contamination through created clean

		working environment, proper handling of working equipment and keep personal hygiene of front workers.
	Lack of work ethics	Improve work ethics through provide incentives, improve salary of employees and take discipline measure.
	Lack of training	Prepare training schedule and provided training.
Return	Lack of periodic maintenance	Provide regular maintenance system.
	Fasting	Reduce return in the fasting season through balanced production volume and sales volume or market demand.
	Improper material handling	Set procedures how to properly handle plastic milk started from production up to the end users.
	Lack of communication	Create strong communication between production, marketing and sales department to reduce pasteurized milk return.
	Improper labeling	Use good quality roll and colour to properly label and expired date must be visible.
Breakage	Power interruption	Avoid power interruption by using automatic transfer switch (must be used) to change electric power to generator or mechanical power automatically.
	Lack of spare parts replacement	Properly monitored and provide regular maintenance due to replaced spare parts of pasteurized machines.
	Problem of machine setup	Frequently monitored and adjust machine setup.
	Problems of packaging material quality	Use good quality of packaging material and avoid modified packaging materials.
Damage	Improper material handling	Set procedures how to properly handle and detect defective plastic milk during production time up to the end users.
	Lack of commitment	Provide incentives and accessed preconditions to accomplish day today activities effectively and give responsibility to make decisions and build committed workers.

Corrective measures have been suggested for all identified four milk quality defects to the company. Because of company's own limits or unknown reasons, focus is given only on return, breakage and damage pasteurized milk quality defects, and improvement is observed in these three defects only. As per data collected from the company's daily recorded documents in March 2020, actual pasteurized milk packaged was 999,343 liter and number of defective pasteurized milk from the actual packaged due to return quality defects was 27,119.5 liter of pasteurized milk and in month of May 2020, actual pasteurized milk packaged was 1,499,330 liter and number of defective pasteurized milk from the actual packaged reduced to 12,917 liter. As a result improvement was 14202.5 liters of pasteurized milk per month only owing to return pasteurized milk quality defects. The difference of the two months of defects (27,119.5 – 12,917 = 14,202.5) liters of pasteurized milk was improvement made on a specific return defect regardless of the others defects. That is 14,202.5 liters of pasteurized milk were saved per month only from defective caused by return. As per observation and discussion made on the company the main/critical reason to bring this significant improvement on return defect is strong communication system have been created between sales managers (the ability to sale products), marketing/purchasing manager (the ability to purchase raw materials) and production manager (the ability to produce products) depends on customers requirement. Next to this regular maintenance system and set procedures how to handle plastic milk have been provided to convey this improvement on return defect.

In case of breakage defect in the month of March 2020, the number of defectives pasteurized milk were 4725 and it came reduced to 2614 liters of pasteurized milk. As a result improvement was 2111 liters of pasteurized milk per month due to breakage. After a detailed observation and discussion made on the company to assess the level of contribution from the given corrective measures in the above (Table 4.10) for breakage defect, avoid power interruption and frequently monitored and adjusted machine setup are critical to bring this improvement compared to use good quality of packaging material and provide regular maintenance.

Whereas in case of damage defect in the month of March 2020, the number of defectives pasteurized milk were 3224.5 and it came reduced to 1973.5 liters of pasteurized milk as result an improvement of 1251 liters of pasteurized milk specified. It is also observed that from the given remedies for damage defect, build committed front workers are critical to bring this improvement compared to set procedures how to properly handle and detect defective products during production time up to the end users.

4.6. Results and Discussion

After direct observation and focused group discussion conducted, the identified points are the company has many problems, specifically there were special cause of variation in the process of pasteurized milk temperature and volume/weight and high product defect percentage has been observed in the process of the production line.

From control chart analysis it is understood that, one sample is out of the control limits from pasteurized milk temperature due to the presence of power reduction /insufficient power and increase atmospheric temperature. Corrective measures have been suggested for these special causes for one sample out the control limits from pasteurized milk temperature and improvement is observed in the process of pasteurized milk temperature. Six samples were out of control limits, and similarly 29 samples were distributed out of control limits of standard deviation from pasteurized milk volume or weight due to special cause of variation. These were lack of frequently follow up of packing machine (operator) and lack of frequently follow up quality of milk weight/volume (quality control). Corrective measures have been suggested for these special causes of variation for pasteurized milk volume/weight or samples that was out the control limits and improvement is observed in the process of pasteurized milk volume. This control chart analysis has shown, the impacts of control chart on quality improvement of pasteurized milk through detect special cause of variation, identify root causes of problem, implement corrective action and verify and follow the process improvement of pasteurized milk production line.

From Pareto analysis major or vital few problems have been identified such as clotting/ souring, return, breakage and damage defect (Figure 4.10). It has been observed that the two major visually identified defects are clotting/souring 45.7% and return 31.8% contribute about 77.5%. These two defects contributed 77.5% of the overall due to visual defect rejection.

Using cause and effect diagram analysis the root causes for the problems of pasteurized milk quality defects were identified for each type of defect. Remedies for the root causes were identified and corrective measures have been provided for improvement. After implemented of the corrective measures for the identified defects, improvements have been observed only on return, breakage and damage pasteurized milk quality defects. The return milk quality defect had reduced from 27,119.5 liter in March to 12,917 liter in May, breakage defect had reduced from 4725 liter in March to 2614 liter in May and damage milk quality defect had reduced from 3224.5 liter in March to1973.5 liter in May. Because of unknown reasons of the company, clotting/souring defect had not observed improvement.

According to the observation made the company has used only histogram and check sheet and have basic understanding about the impacts of these tools from the seven quality improvement tools. The company has used check sheet to collect daily recorded data related to quality defects of pasteurized milk like clotting or souring, returns, breakage, damage and others. The company has used histogram to record processing time, evaluating or checking process and measuring the effects of corrective action.

4.7. Summary

As described the previous analysis, the study has addressed the current situation of quality improvement using SPC tools in process control in dairy industry in case of SAI. The target of this study has improved process performance and identified the quality defect of pasteurized milk and given suggestion/corrective measures to improve quality and productivity performance.

In control charts analysis has shown, the processes were statically in control in fat content and titration of acidity of plastic/pasteurized milk in the production line. Acidity of pasteurized milk titration and fat content of pasteurized milk, all sample points were within the control limits, variations in the value may be due to a common causes and process was in control.

Control charts in pasteurized milk volume or weight and temperature were shown statistically out of control conditions in this study, then it needs investigation and corrective actions are required. Weight/volume of pasteurized milk, all sample points fall outside the control limits, there was a variation due to lack of frequently follow up of packing machine by operator and lack of frequently follow up quality of milk volume/weight by quality control and the process is out of control. In pasteurized milk temperature, one sample point fall outside the control limits, there was a variation due to power reduction and increase atmospheric temperature and the process is out of control. Corrective measures are required for pasteurized milk temperature and volume/weight to improve the process of pasteurized milk production line.

Pareto chart were used to prioritizing big problems from different defect types and isolate the vital few and the trivial many causes of milk quality defects. From this quality defects souring and returns were major/vital few quality defects .

Cause and effect diagrams were used to identify major causes for milk quality defects which were identified by Pareto chart and corrective measures are required for identified four major milk quality defects to the company. However the company has used only histogram and check sheet and have basic understanding about impacts of these tools from the seven quality improvement tools.

The present study has resulted in analyze the impact of SPC tools on quality improvement in process control through bar chart, flowchart, control chart (X bar R chart and X bar S chart), Pareto chart, brain storming and cause and effect diagram. The resulting analysis leads to working measures that improve process variation and significantly reducing defects and rework due to defective pasteurized milk products. In general SPC tools have a positive impact on quality improvement in the process of pasteurized milk production by reducing product variability and milk quality defects.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

This chapter has covered conclusion and recommendation of the study.

5.1. Conclusion

It was observed from the result of the analysis and discussion part of the study, a statistical process control (SPC) tools has positive impact to improve process performance by reducing process variability of products and improves quality and productivity performance by reducing quality defects and rework significantly. In addition to this SPC tools help the company to observe the process activities, managing process, determining and monitoring the quality of products, identify possible improvements, help employees to know where they fit in to the process and generate support through participation.

The present study was emphasis on direct observation, focus group discussion, bar chart, flow chart, control chart, Pareto chart, brain storming and cause and effect diagrams or fish bone diagrams analysis have provided useful information. These quality improvement tools have used for analyzing process performance of pasteurized milk production line was in control or out of the control limits, prioritizing milk quality problems and identifying causes for quality defects, and in proposing quality improvement tools to be applied for quality and productivity improvement.

The purpose of this study was to identify the main causes and effects of milk quality problems and defects in dairy industry the case of SAI. The key contributors for quality of milk defects were clotting or souring, return, breakage, and damage were identified. The key factors for these defects can be categorized into measurement, material, people (human factors), environment, machine, and methods or machine setup and operation. It is known that, raw materials for dairy industry is raw milk. But there were problems during raw milk collection, adulteration, milking material contamination, and hygiene and sanitation of raw milk collection materials. Material problems during pasteurizing milk production were packaging material quality. Measurement problems were alcohol meter calibration. Human factors were work ethics, training, material handling, fasting and commitment.

Environmental problems were environmental influence on measurements. Method and machine problems were communication, labeling, periodic maintenance, power interruption, machine spare part replacement and set up.

In conclusion the main objective of the study was to analyze the impacts of SPC application in dairy processing plant specifically in SAI. Hence this study was unique in assessing the impacts of SPC application in dairy industries in Ethiopia. It contributes by providing the basic framework of the benefit of the tools for other organization aspiring to implement and how to applicable SPC to reduce quality problems/process variations and defects for the dairy processing plants.

5.2. Recommendation

This study has proposed some recommendations for dairy industry to improve quality and productivity of pasteurized milk production and reduce product defect percentage. The following remedy suggestions motivated on quality improvement in dairy industry start from milk reception up to end products of pasteurized milk.

Sebeta agro industry is recommended to improve quality inspection system, work commitment and supervision, attitude and skill towards quality improvement and awareness about defects through provide adequate training to management and front workers, employee qualified man power with their departments and conducting ongoing education on SPC tools. Therefore teaching and learning are significant to improve quality and productivity using SPC tools in the company.

Sebeta agro industry is recommended to improve periodic maintenance of machine, replacement of spare parts and frequent follow-up for operation set up through the establishment of the regular repair, avoid power interruption and maintenance system for machines in order to reduce breakage milk quality defect. The companies can enhance practical improvement and maintenance for the machine and increase the efficiency of the machines and operation set up. It is necessary to enhance quality improvement system and pay attention to the on-line examination and control of the product quality, in order to continuously improve the quality of the product.

To provide periodic calibration on measurements such as beam balance, dairy pump, temperature display gauge, thermometer, lactose-can, lacto meter, alcohol-meter and other measurements use to check and keep the quality of raw materials start from receiving raw milk up to the end products of pasteurized milk to reduce souring/clotting and over and underweight milk quality defects.

Sebeta Agro Industry need to provide incentives to milk suppliers such as quality based payment, awareness of hygiene and sanitation of milk to encourage delivery of good quality milk for processing and to protect a big problem of milk traders to purchase unadulterated wholesome raw milk.

To provide and maintain quality improvement, SAI pasteurized milk process the day to day activities should be monitored through application of SPC tools and good manufacturing practice. Therefore the company is recommended to struggle for the application of SPC tools for quality and productivity improvement.

Dairy processing requires a considerable capital investment, trained and qualified with experienced staff, regular maintenance of sophisticated machine and comparatively high operating expenditure. Hence the factory is recommended to implement proper cleaning and sterilization of plant equipment, surfaces, premise and observing aseptic packaging are necessary to avoid milk post pasteurized contamination and to maintain the capacity of processing machine.

The occurrence of bacterial contamination in the pasteurization machinery causes souring/clotting and return milk quality defects in pasteurized milk, to survive even after pasteurization and contamination in the post pasteurized process due to poor processing, handling conditions and maintenance of substandard hygienic practices by working personnel. Hence quality control and operators are recommended to check the severity of pasteurization regime based on microbial quality of milk and the ultra violet (UV) light status to control post pasteurization contamination and to reduce milk quality defects and maintain the recommended shelf life of pasteurized milk.

The factory quality improvement system is the aggregate of the whole organizational activities that requires in formulating and implementing a total quality approach. Hence the quality control recommended to set up and apply good agricultural practice (GAP), good hygiene practice (GHP), and good storage practice (GSP), avoid contamination and consecutive inspection to control process variations and quality defects by conducting chemical, biological and physical test analysis respectively.

Quality assurance in dairy industry calls for concerned efforts from all stakeholders involved in the production chain and requires partnership approach with different concerned institution. Then the company should have close and smooth partnership with milk supplier's efforts regulatory agent and vendor efforts to fulfill customer requirements and to deliver safe, expected quality and extended shelf life pasteurized milk at national and global level.

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APPENDICES

APPENDIX A

ST. MARRY'S UNIVERSITY

SCHOOL OF GRADUATE STUDIES

INSTITUTION OF QUALITY AND PRODUCTIVITY MANAGEMENT

QUALITY IMPROVEMENT USING STATISTICAL PROCESS CONTROL TOOLS

INPROCESS CONTROL- THE CASE OF SEBETA AGRO INDUSTRY

Process variation analysis of pasteurized milk

1. Pasteurized milk cooling temperature in degree centigrade

S no.	Sample 1	Sample 2	Sample 3	Sample 4
1	7	9	6	9
2	6	9	10	6
3	7	8	8	8
4	8	8	9	7
5	8	7	6	6
6	5	7	7	8
7	8	7	8	8
8	7	6	7	7
9	8	8	8	6
10	6	11	8	8
11	8	8	7	6
12	6	7	8	7
13	8	8	8	7
14	9	8	7	8
15	8	9	8	10
16	8	4	8	8
17	8	8	9	9
18	8	7	6	7
19	8	9	6	10
20	8	6	6	6
21	9	8	8	7
22	8	8	8	8
23	7	7	8	8
24	6	8	8	6

25	7	7	8	6
26	8	7	10	8
27	8	9	10	8
28	8	9	8	7
29	8	6	6	6

2. Pasteurized milk volume/weight in ml

S no.	Sam 1	Sam 2	Sam 3	Sam 4	Sam 5	Sam 6	Sam 7	Sam 8	Sam 9	Sam 10	Sam 11	Sam 12
1	500	501	500	498	499	501	502	502	503	505	505	500
2	500	500	500	501	500	500	500	500	498	503	501	500
3	0	0	505	495	495	500	501	500	500	500	500	501
4	0	0	0	0	505	495	500	500	501	500	500	500
5	500	500	501	500	505	505	515	500	500	500	495	500
6	498	501	504	504	503	500	508	500	509	505	505	505
7	500	500	501	500	500	499	500	500	495	490	500	500
8	505	509	505	505	506	505	500	510	510	505	0	0
9	500	501	500	501	505	505	500	500	505	498	506	506
10	500	501	500	500	500	500	505	500	501	503	501	501
11	500	501	500	501	503	502	500	501	505	502	500	501
12	500	501	506	503	504	502	501	500	500	0	0	0
13	0	0	505	510	505	505	503	502	500	505	505	505
14	505	505	505	509	511	500	505	505	500	500	501	500
15	508	516	503	505	500	498	496	496	498	510	504	506
16	495	513	504	500	500	501	500	501	500	0	0	0
17	505	495	501	503	502	490	500	500	505	495	500	500
18	501	504	496	499	501	502	500	500	500	500	501	500
19	495	510	500	500	505	500	500	500	500	500	500	500
20	498	498	500	500	495	503	502	503	500	498	500	501
21	503	501	503	500	505	505	495	501	501	501	501	501
22	495	501	505	510	500	495	505	505	510	0	0	0
23	500	495	500	500	500	501	500	500	505	510	495	501
24	501	501	502	503	505	501	510	505	506	500	501	500
25	500	500	501	499	500	505	505	505	0	0	0	501
26	502	501	501	503	498	505	505	505	495	500	500	505
27	500	500	500	501	495	0	505	510	495	510	490	495
28	500	505	495	0	0	495	497	507	510	0	0	495
29	505	504	505	498	496	500	500	505	490	515	505	505

3. Pasteurized milk fat in percent

S.no.	Sample 1	Sample 2	Sample 3	Sample 4
1	2.9	2.6	1.7	2.5
2	2.7	2.5	2.2	2.6
3	2.0	2.7	2.1	2.9
4	1.9	2.6	2.0	1.9
5	2.6	2.8	2.8	2.0
6	2.1	2.7	2.1	1.9
7	2.0	2.7	1.8	2.1
8	2.6	2.8	1.9	2.3
9	2.6	1.9	2.0	2.3
10	2.7	2.4	2.1	2.0
11	2.2	2.7	1.9	1.9
12	2.5	2.7	2.3	2.5
13	2.7	2.0	1.7	2.6
14	2.7	2.8	2.3	2.1
15	2.5	2.7	1.8	2.5
16	2.0	2.7	2.1	2.3
17	1.8	2.8	2.8	2.7
18	2.5	2.3	2.0	1.9
19	2.6	2.6	1.9	2.6
20	3.0	2.7	2.0	2.6
21	1.9	2.6	2.0	1.8
22	3.0	2.0	2.0	2.1
23	2.9	2.9	2.2	2.2
24	2.8	2.7	1.8	2.4
25	2.4	2.7	2.3	2.0
26	2.6	2.8	2.1	1.9
27	2.9	2.9	2.0	2.0
28	1.7	3.0	2.3	2.4
29	2.6	2.9	2.7	2.5

4. Pasteurized milk titrable acidity in Dornic degree

S no.	Sample 1	Sample 2	Sample 3	Sample 4
1	1.3	1.6	1.4	1.0
2	1.3	1.7	1.2	1.2
3	1.4	1.4	1.3	1.7
4	1.2	1.6	1.2	1.8
5	1.7	1.6	1.4	1.7
6	1.4	1.6	1.2	1.1
7	1.2	1.6	1.3	1.3
8	1.6	1.7	1.0	1.8
9	1.7	1.1	1.2	1.7
10	1.6	1.4	1.1	1.6
11	1.6	1.1	1.1	1.8
12	1.4	1.5	1.3	1.9
13	1.7	1.5	1.2	1.6
14	1.8	1.3	1.1	1.5
15	1.5	1.5	1.0	1.2
16	1.1	1.6	1.1	1.8
17	1.4	1.7	1.5	1.0
18	1.1	1.6	1.0	1.6
19	1.5	1.6	1.3	1.4
20	1.9	1.4	1.4	1.2
21	1.1	1.6	1.0	1.7
22	0.9	1.8	1.2	1.8
23	1.1	1.8	1.6	1.5
24	1.5	1.4	1.2	1.3
25	1.7	1.5	1.3	1.6
26	1.7	1.7	1.6	1.6
27	1.2	1.9	1.7	1.1
28	1.1	1.8	1.3	1.2
29	1.8	1.7	1.8	1.8

APPENDIX B

Pasteurize milk defects analysis

Defects-cause check sheet

Date	Actual packages per liter (L)	Breakages per liter (L)	Returns per liter (L)	Damages per liter(L)	Souring per (L)	Over weight/ L	Unwritten exp.date/L	Under weight/L	Temperature out of standard/L	Microbial load out of standard/L	PH out of standard/L
01/02/2020	46653	40	342	95	—						
02/02/20	42327	200	171	121	80						
03/02/20	40570	70	105	101	1446						
04/02/20	37565	200	—	180	224						
05/02/20	41910	260	—	90	678						
06/02/20	41566	200	345	100	69						
07/02/20	42639	50	63	86	105						
08/02/20	44302	50	175	72	—						
09/02/20	41611	60	405	104	247						
10/02/20	48138	200	121	61	347						
11/02/20	45809	100	603	99	50						
12/02/20	48731	180	—	95	—						
13/02/20	42705	100	—	94	—						
14/02/20	44954	50	—	71	2164						
15/02/20	46529	170	—	82	1000						
16/02/20	45140	100	—	103	—						
17/02/20	44838	90	—	91	—						
18/02/20	37487	20	—	99	4496						
19/02/20	47126	200	32	71	—						
20/02/20	45405	50	513	95.5	1425						
21/02/20	44927	170	211	80	—						
22/02/20	42532	100	145	110	—						
23/02/20	45339	120	190	127	262						
24/02/20	37507	50	100	109	1209						
25/02/20	42666	120	350	93	95						
26/02/20	48463	50	180	90	500						
27/02/20	42424	50	203	80	300						
28/02/20	37547	100	—	83	421						
29/02/20	30757	70	709	99	3942						

Total	**1,248,167**	**3220**	**4963**	**2781.5**	**19060**	**1114**	**430**	**1598**	**506.5**	**291**	**675**
01/03/2020	35041	70	903	50	13044						
02/03/20	36432	100	678	104	670						
03/03/20	35420	50	842	95	622						
04/03/20	37986	170	500	120	935						
05/03/20	35877	250	1242	60	388						
06/03/20	33324	80	721	150	142						
07/03/20	32528	60	543	150	—						
08/03/20	32873	100	705	350	—						
09/03/20	41495	250	2538	150	1000						
10/03/20	36268	160	456	50	—						
11/03/20	33628	50	900	200	104						
12/03/20	31874	170	1002	130	170						
13/03/20	35722	280	398	115	—						
14/03/20	31676	45	590	50	213						
15/03/20	35700	150	1500	95	108						
16/03/20	33702	170	600.5	50	170						
17/03/20	33007	50	1045	66	1363						
18/03/20	37346	50	900	110	575						
19/03/20	32708	220	700	90	729						
20/03/20	24740	300	950	40	1289						
21/03/20	36915	200	889	80	—						
22/03/20	37884	150	752	108	119						
23/03/20	32391	200	655	90	599						
24/03/20	21772	100	888	100	—						
25/03/20	22352	70	776	86	200						
26/03/20	28909	180	1050	90	136						
27/03/20	30470	100	1000	120	138						
28/03/20	26475	150	1050	140	280						
29/03/20	31033	400	820	50	400						
30/03/20	14290	250	749	70	37						
31/03/20	29505	150	777	65.5	3667						
Total	999,343	4725	27119.5	3224.5	27098	1330	610	1175	313	411	289
Total	**2,247,510**	**7945**	**32082.5**	**6006**	**46158**	**2444**	**1040**	**2773**	**819.5**	**702**	**964**