THE APPLICATION OF STATISTICAL QUALITY CONTROL TECHNIQUE IN FOOD AND BEVERAGE INDUSTRY

A CASE STUDY OF HABILA FOOD AND BREVERAGES NIGERIA LTD- KANO

BY

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DECLARATION

I hereby declare that the work in this research project titled "**THE APPLICATION OF STATISTICAL QUALITY CONTROL TECHNIQUE IN FOOD AND BEVERAGE INDUSTRY, A CASE STUDY OF HABILA FOOD AND BEVERAGES NIGERIA LTD- KANO**"was carried out by me in the Department of Mechanical Engineering, Ahmadu Bello University, Zaria, Nigeria. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this Research Project was previously presented for another degree or diploma at this or any institution.

_____ _____

Abdullah Zulaikha Date

CERTIFICATION

This is to certify that this Project work titled **"THE APPLICATION OF STATISTICAL QUALITY CONTROL TECHNIQUE IN FOOD AND BEVERAGEINDUSTRY, A CASE STUDY OF HABILA NIGERIA LTD- KANO"** by Abdullahi Zulaikha have met the regulations governing the award of the degree of Master in Engineering Management of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This project is dedicated to Almighty Allah for His protection, guidance, and resources throughout the course of this program, also to my parents for their relentless efforts and prayers.

ACKNOWLEDGEMENT

I will like to acknowledge the brilliant assistance of my lecturer, coordinator and supervisor Dr. F.O. Anafi during the course of this project and also the program. Sir,I am indeed very grateful. I am very grateful to my mother Hajiya S.O. Abdullahi, my father Alhaji M.I. Abdullah, and my brothers Mamman Abdullahi, Mamman Umarfaruq, Mamman Abdulhaseeb. They have been very supportive, being part of this humble family is a blessing from God, and May Allah bless them abundantly.

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ABSTRACT

Controlling and improving Quality has become an important business strategy for many organizations, because a business that can delight customers by improving and controlling quality can dominate its competitors. Hence, this project work focused on the application of statistical quality control technique to Habila Food and Beverage Nigeria Limited, in order to control and improve the quality of their products so as to remain in the competitive market. To achieve the aim and objectives of this project work, quality control data were collected through the primary source (i.e. directly from the Quality Control Department of the company). Thereafter, the respective statistical parameters such as the Means, Ranges, Standard Deviations, Centre Line Control Limit, (CL), Upper Control Limit (UCL) and Lower Control Limit (LCL) were developed and analyzed for the company using statistical approach. The resulting Control Charts was also constructed using the parameters developed for better understanding and visibility. From the results, it was found that most of the process data collated and analyzed lies within the designed range of specifications, gives values implying that the process is capable of producing acceptable product. However, those ones out of control which are attributed to assignable causes such as lack of personal training, poor mix, mechanical fault, etc, are to be subjected to process monitoring and evaluation so as to better their products.

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CHAPTER ONE

INTRODUCTION

1.1Background tothe Study

We have all had the experience of purchasing a product only to discover that it is defective in some waysor does not function the way it was designed to; drinks in cans or bottles not properly filled up as expected.Asconsumers, weexpect the products we purchase should be able to satisfy our needs. However, producers of products knowthat it is not always possible to inspect every product andevery aspect of the production process at all times. The challenge is to design ways tomaximize the ability to monitor the quality of products being produced and eliminatedefects.One way to ensure a quality product is to built-in quality into the production process (Akinnola, 2009).

Controlling and improving quality has become an important business strategy for many organizations, manufacturers, distributors, transportation companies, financial services organizations, health care providers, private and government agencies. Quality has become one of the most important consumer decision factors in the selection among competing products and services. The phenomenon is widespread, regardless of whether the consumer is an individual, an industrial organization, a retail store, a bank or financial institution, or a military defense program, manufacturer, designer to mention but a few. Consequently, understanding and improving quality are key factors leading to business success, growth, and enhanced competitiveness. There is a substantial return on investment from improved quality and from successfully employing quality as an integral part of overall business strategy. Quality is a competitive advantage and therefore any business that can delight customers by improving and controlling quality can dominate its competitors (Douglas,2009). Competition is one of the most important factors in running a business in the world economy today. For

almost every product or service ever designed, there is more than one organization trying to make a sale. Price is, of course, one of the major issues in whether a sale is made or lost. If the cost of producing goods or services results in high prices, a firm may not be competitive. But another factor that a customer considers before buying a product is quality. In fact, a reputation for producing quality products is often a major marketing issue (Akinnola, 2009).

Douglas (2009) says, Quality is not just of concern in manufactured products, it is important in banking, hospital care, education, air travel, food industries, auto repair, postal delivery services and a host of other firms in the service industry.Quality management (QM) is the commonly used term for stressing quality within an organization. QM uses a systems perspective because it is not a program for one department, but a responsibility of everyone in the organization. To keep quality at the desirable levels, all firms employ the concept of quality control. Quality control (QC) is important not just in the production or transformation process, but earlier at the design stage and later at the service stage as well. One of the major roles of the operations manager is to make sure his or her firm can deliver a quality product to the right place at the right time and with a right price (Douglas, 2009).

Tamini and Sebastianelli (1996), says Quality can be a confusing concept, partly because people view quality in relation to differing criteria based on their individual roles in the production- marketing chain. In addition, the meaning of quality has evolved as the quality profession has grown and matured. Neither consultants nor business professionals agree on a universal definition. Accordingly, a study that asked managers of 86 firms in the eastern United States to define quality; several dozen of different responses such as: perfection, consistency, eliminating waste, speed of delivery, compliance with policies and procedures, providing a good usable product, doing it right the first time, delighting or pleasing customers, and total customer service and satisfaction were obtained. Thus, it is

important tounderstand the various perspectives from which quality is viewed in order to fully appreciate the role it plays in the many parts of a business organization.

1.2 Statement of the Problem

It is not enough to focus on the finished products that customers received. How these products are produced i.e. the processes, also needs to be addressed most especially in this era of strain on the resources and rising costs of manufacturing/production. It becomes increasing apparent that decision must be made on facts, not just opinions; consequently, data must be gathered and analyzed in order to help guild the decision making process and as such SPC technique would help in analyzing the process quality of Habila Food and Beverages Nigeria Limited so as to monitor the volume dispersion in the filling process.

1.3 The Present Research Study

This research work title;"Application of Statistical Quality Control in Foods& Beverages Industry. Acase study of Habila Food and Beverages Nigeria. Limited", aims to apply statistical process control (SPC) technique as a quality control (QC) tool to production processes of Habila Food and Beverages Nigeria. Limited. Since the best way to control quality in any manufacturing/production or non- manufacturing industry is to 'built-in quality' during the production process stages. It is of this view that this project work be carry out to ascertain whether their machining processes falls within or outside the predetermined control limits of the manufacturing process. The basic research questions that prompted this write up are:

1. Can current data be used to improve the quality of machines processes, or is it just data for the sake of data?
2. Does both bottles and cans of the products properly filled as calibrated by the machines?
3. Is Company's quality cost really known?

4. Does the company know when to perform preventive maintenance on machines?

These were some of the questions posed for this write up.

1.4 Aim and Objectives of the Study

The principal aim of this project work is to apply SPC as a QC tool to Habila food and beverages Nig. Ltd in order to monitor the volume dispersion in the filling process, thereby reducing the stress of final inspection of products produced. The specific objectives are;

1. To establish the upper and lower control limits of machines processing lines using SPC technique as QC tool
2. To construct the X – bar and R chart QC charts of the process and then use it to detect or identify the cause of variation (if any) in the production process before they result in defective products
3. To profound possible solution to causes of variation identified in (2) above
4. To determine and analyze the process capability of the filling process so as to ascertain which of them fills the bottles/containers according to specifications.

1.5 Significance of the Study

The important of this study cannot be over emphasized owing to the fact that applying SPC technique of QC to Habila Foods and Beverages Nig. Ltd would not only eliminates the need for final inspection, identify the causes of variation (if any) but equally reduces the amount of inefficient production lines alone with direct and indirect labor costs. The result is a direct increase in bottom line profitability and to improve production processes.

1.6 Scope of the Study

The scope of this project report covers only the machines processing line i.e. its processes in fruit and juice section. This research area was limited to just production process line of the company. However, the technique could be extended and applied to other process lines and other divisions of the organization where it is necessary.

1.7 Limitation of the Study

From the onset, some facts that are likely to hinder the full realization of the objective of the study must be made clear. In a country like Nigeria where the culture of reading is not well developed and imbibed by individuals and organizations, there is a strong tendency that information (data) collected will contain errors of misrepresentation especially in a study of this nature where the information (data) sought concerns the internal and operational issues of an organization as it might be rightly or wrongly thought that divulging such information will be inimical to public judgment.

The above fact is further compounded by the following limitations:

1. The study lack sufficient access verify the given data
2. All efforts to access other quality control data so as to expand the scope of this study prove abortive; hence this study is limited to (machines) production process lines only.

1.8 Company Description ata Glance

Habila Foods & Beverages Nig. Ltd is a renowned organization in Lagos and Kano metropolis. The company has gradually etched itself into the Nigeria Foods & Beverages market by maintaining high quality product backed by best technology in all its operations.

The company is fully into the manufacture and distribution of quality fruit juices and non – alcoholic beverages ranging from Pineapple juice, Orange juice, Bottle and Sachet water, Yogurt, Sobo, and many more. As part of its plans for expansion, the firm has procured a multi-million naira plant solely for the production of processed tomatoes and other food seasonings. This is aimed at lowering the cost of such products in the open market as well as offer new methods on food preservation.

Habila has nine (9) installed machines in fruit and juice section where this research work was carried out, well calibrated for filling bottles and cans drinks. Though, all the

machines were not meant to be function at a time, most often, four (4) or five (5) normally in operation while the others were on stand-by mode. Hence, this project work was carried out on processing lines of the machines in fruit and juice section of the company in order to monitor the volume dispersion in the filling processes.

CHAPTER TWO

LITERATUREREVIEW

2.1 Review of Related Literature

In this chapter, the theoretical frame works will be discussed. Area such as quality control and its tools, SPC and some other aspects of quality management system (QMS) will be considered. Moreover, they are presented in order to form a filter through which the empirical work and results will be formed and analyzed.

Although literature in this field 'Statistical Process Control' here in Nigeria has not been extensively documented according to Akinola (2009), but in as much as meeting up with quality demand is a concerned to every organization, reviewing other peoples' progress in this regard will not be a waste. However, doing so will be an eyes opener.

Marilyn and Robert (2007), says the foundation for Statistical Process Control technique as quality control tool was laid by Dr. Walter Shewart who worked at the Bell Telephone Laboratories in the 1920s when conducting research on methods to improve quality and lower costs. Accordingly, he developed the concept of control with regard to variation, and came up with Statistical Process Control Charts which provide a simple way to determine if the process is in control or not.

Accordingly, Dr. W. Edwards Deming built upon Shewart's work and took the concepts to Japan following World War II (WWII). There, Japanese industry adopted the concepts whole-heartedly. The resulting high quality of Japanese products is world-renowned. Dr. Deming is famous throughout Japan as a "God of quality". Today, SPC is used in manufacturing or a production facility around the world in order to improve the quality service delivery to the customers (Douglass, 2009).

Here in our country Nigeria, this method (SPC) has been used in some industries such as banking, Food manufacturing, and educational sector in order to improve their quality delivery. For instance, Akinola G.O. (2009), examines the characteristics of a good quality service and methods used in controlling quality of service in the Nigerian Banking industry using the technique of quality control. She found out that most banks do not use the QC technique to improve their services to the populace. Based on her finding, she recommended that banks should improve their service delivering system using statistical process control mechanism.

Obadara and Alaka (2013), investigated the impact of accreditation on quality assurance in Nigerian Universities using Statistical Quality Assurance (SQA) technique of quality control. Their findings revealed that there is significant relationship between accreditation and resource input into Nigerian universities, quality of output, quality of process, and no significant relationship between accreditation and quality of academic content. Furthermore, they noted that quality of education could be measured in terms of quality of input, quality of output, quality of content and quality of process. Therefore, these parameters were used by the study to assess quality assurance.

Payam and Reza (2009) use the application of SPC technique to examine the QC in cable industry, a case study of Copper Consumption Reduction in Nexans IKO Sweden. The study find out that the quality of cable products been produced can still be better enhanced. Furthermore, the study recommended that management must make a commitment to understand and reduce all process variation as much as possible in order to improve the quality of the product. Hence, Management must allow the local work force the time to understand process variation and make corrections, when necessary, in order to restore stability-not to just make adjustments to compensate for the lack of stability. These reviews indicate that quality is a concern to everyone, be it an organization (private or public),

individual, corporate body. Hence, it worth to look upon quality in order to remain in a competitive market.

2.2 The Definition and Dimensions of Quality

Quality can be defined and be viewed in many different ways depending on individual perspectives. Most people have a conceptual understanding of quality as relating to one or more desirable characteristics that a product or service should possess. Quality has become one of the most important consumer decision factors in the selection among competing products and services. The context of quality is vast, regardless of whether the consumer is an individual, or an industrial organization. Consequently, understanding and improving quality are key factors leading to business success, growth, and enhanced competitiveness (Douglas, 2009). The following are the dimensions of quality and some basic terminology commonly used where quality is concerned:

2.2.1 Performance:(Will the product do the intended job?) Potential customers usually evaluate a product to determine if it will perform certain specific functions and determine how well it performs them.

2.2.2. Reliability:(How often does the product fail?) Complex products, such as many appliances, automobiles, or airplanes, will usually require some repair over their service life. For example, you should expect that an automobile will require occasional repair, but if the car requires frequent repair, we say that it is unreliable. There are many industries in which the customer's view of quality is greatly impacted by the reliability dimension of quality.

2.2.3. Durability: (How long does the product last?) This is the effective service life of the product. Customers obviously want products that perform satisfactorily over a long period of time. The automobile and major appliance industries are examples of businesses where this dimension of quality is very important to most customers.

2.2.4. Serviceability: (How easy is it to repair the product?) There are many industries in which the customer's view of quality is directly influenced by how quickly and economically are pair or routine maintenance activity can be accomplished.

2.2.5. Aesthetics: (What does the product look like?) This is the visual appeal of the product, often taking into account factors such as style, color, shape, packaging alternatives, tactile characteristics, and other sensory features.

2.2.6. Features: (What does the product do?) Usually, customers associate high quality with products that have added features; that is, those that have features beyond the basic performance of the competition.

2.2.7. Perceived Quality:(What is the reputation of the company or its product?) In many cases, customers rely on the past reputation of the company concerning quality of its products. This reputation is directly influenced by failures of the product that are highly visible to the public or that require product recalls, and by how the customer is treated when a quality-related problem with the product is reported. Perceived quality, customer loyalty, and repeated business are closely interconnected.

2.2.8. Conformance to Standards: (Is the product made exactly as the designer intended?)We usually think of a high-quality product as one that exactly meets the requirements placed on it. Manufactured parts that do not exactly meet the designer's requirements can cause significant quality problems when they are used as the components of a more complex assembly. An automobile consists of several thousand parts. If each one is just slightly too big or too small, many of the components will not fit together properly, and the vehicle (or its major subsystems) may not perform as the designer intended. We see from the foregoing discussion that quality is indeed a multifaceted entity.

2.3 Statistical Thinking for Quality

It is common to act on information based on past experience, perceptions or anecdotal evidence, but at times such intuition might be baseless. Reza and Payam (2009), says Data should guide decisions. That is, statistical models based on data help to understand the nature of the variation. The reduction of variation is done by actions such as eliminating special causes or designing a newly improved system with smaller variability and all these are done through statistical thinking and modeling.

Everything (manufacturing or non-manufacturing) must be regarded as a process, and there are always variations. In a manufacturing process, variation is caused by machines, materials, methods, measurements, people, and physical and organizational environment. In non-manufacturing or business processes, people contribute a lot to the total variation in addition to methods, measurement and environment. These entire variations encounter by both manufacturing and non-manufacturing process are best analyzed using statistical techniques (Tamini and sebastianeill, 1996).

The American Society for Quality Statistics Division(2004) publication Glossary and Tables for Statistical Quality Control suggests the following definition:

"Statistical Thinking is a philosophy of learning and action based on the following fundamental principles:

• All work occurs in a system of interconnected processes,

• Variation exists in all processes, and

• Understanding and reducing variation are keys to success." These definitions denotes that we must recognize the fact that any response or output is caused by variables involved in an interconnected process. The factors or variables causing output variations often interact and cannot be thought to be independent of each other as shown in figure 2.1

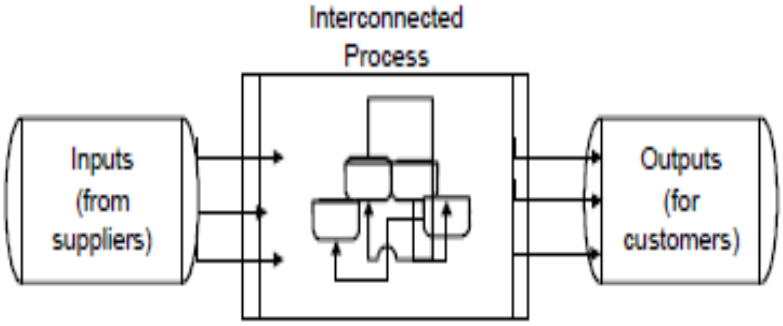


Fig 2.1: Process flow and interconnectivity (ASQ, 2004)

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2.3.1 Statistical Process Control (SPC)

Raza and Payam (2009), says Statistical Process Control is the use of valid analytical statistical methods to identify the existence of special causes of variation in a process. Statistical process control (SPC) involves using statistical techniques to measure and analyze the variation in processes. Most often used for manufacturing production processes, the intent of SPC is to monitor product quality and maintain processes to fixed targets. Statistical quality control refers to using statistical techniques for measuring and improving the quality of processes and includes SPC in addition to other techniques, such as sampling plans, experimental design, variation reduction, process capability analysis, and process improvement plans.

2.3.2. The Importance of SPC

The SPC helps companies to improve quality and productivity in all departments by improving all the area where quality is of concerned. It also gives operators a tool to determine when a statistically significant change has taken place in the process or when a seemingly significant change is just due to chance causes. Hence, it provides operating personnel a tool to identify when a special cause of variation has entered the process so that the special cause can be eliminated (if the special cause has a negative impact on the process) or built into the process (if the special cause has a positive impact on the process).

SPC feedback system helps the operating personnel to monitor the process from input stage to final stage in order to take appropriate measure where needed, figure 2.2 below is a model diagram of an SPC feedback.

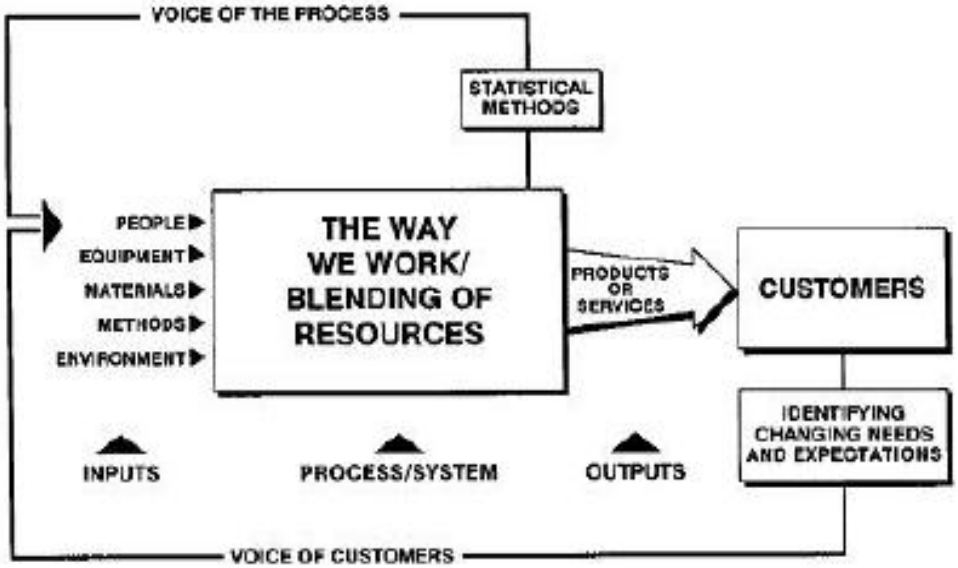


Fig. 2.2 Process Control System Model with Feedback(Reza and Payam, 2009)

As seen from the fig 2.2 above, the input parameters consists of people who get the job done, the equipment, materials, methods used and environment in which such activities are carried out. The process often referred to as system stage comprises of the way in which the work is done i.e. blending of resources, filling of bottles or cans and the output stage which consists of product or service delivered to the customers. This process control feedback system form the integral part of SPC.

Process and product quality control seems to be general trends according to Garvare (2002), which call for attention, needed for a deeper comprehension of the underlying relationship between process and product variable. Figure2.3 presents a generic production process transforming an input, such as raw material and components, into a finished product that has several quality characteristics. Example of controllable parameters are temperatures, pressures, and process time. Examples of uncontrollable or difficult to control parameters are vibrations due to play in bearing, varying air humidity, and inhomogeneous raw material (Garvare, 2002).

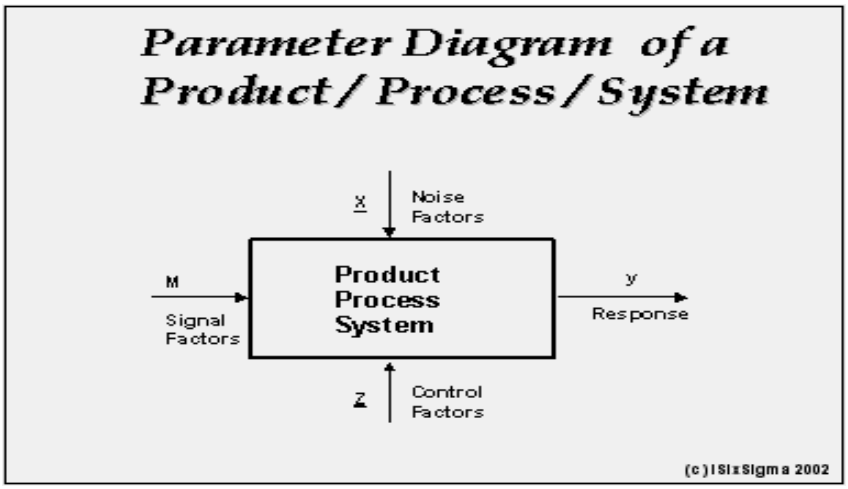


Fig 2.3 Illustration of a generic production process with a set of influencing factors

Accordingly, the development of efficient statistical methods for structured inspection and experimentation has given rise to many new potential of identifying relations between variables.

2.1.1 The Concept of Quality

Quality as a concept has been defined differently by different stakeholders. Most people have a conceptual understanding of quality as relating to one or more desirable characteristics that a product or service should possess. This is because it is multidimensional and mean different thing to different people. Obadara and Alaka (2013), says quality can be defined as "fitness for purpose". It encapsulates the concept of meeting commonly agreed precepts or standards. Such standards may be defined bylaw, an institution, a coordinating body or a professional society.

According to Akinola (2009), Quality is the ability or degree with which a product, service, or phenomenon conforms, to an established standard, and which makes it to be relatively superior to others. With respect to SPC, this implies the ability or degree with which the operating process conforms to the established standard and appropriateness, of the inputs available for the delivery of the system. Chandra (2001), says Quality can be defined

in many ways, ranging from “satisfying customers’ requirements” to “fitness for use” to “conformance to requirements.” It is obvious that any definition of quality should include customer and satisfaction which must be the primary goal of any business.

2.1.2 Quality Control and Quality Assurance

The terms Quality Control (QC) and Quality Assurance (QA) are often used incorrectly. According to International Standard of Organization (ISO) for Quality Management often referred to as IS0 9000:2005 distinguished the subjects as follows: “QC is a part of quality management focused on fulfilling quality requirements” while “QA is a part of quality management focused on providing confidence that quality requirements will be fulfilled”.

The standard further reiterated that QA involved all the planned and systematic activities implemented within the quality system that can be demonstrated to provide confidence that a product or service will fulfill requirement for quality. Conversely, QC was seen as operational techniques and activities used to fulfill requirements for quality. In other hands,

QA is concerned with defects prevention while QC is concerned with defects identification.

2.4 The Role of Statistic in Quality

Quality and its management played a crucial role in human history according to Payam and Reza (2009). Accordingly, Managing quality was important even for ancient civilizations.

Payam and Reza (2009), further says the industrial revolution began in the United Kingdom during the 18thcentury and then extended to US and other countries. Quality has become harder to manage due to mass production. Mass production was achievable by the division of labor and the use of machinery. In such a production line, workers performed repetitive tasks in a cooperative way using machinery. This resulted in huge productivity

gains. But the number of factors and variables affecting the quality of a product in a mass production line were also numerous when compared to the production of a single item by an artisan who did all work from start to end. Division of labor for mass production also took away the pride of workmanship. Hence, quality suffered in the production line and quality monitoring became an essential activity. Due to mass manufacture, engineers were forced to look beyond using standardized measurements. The causes of quality variation were numerous and hence statistical methods were needed for quality monitoring and assurance.

Accordingly, Prof Water Shewhart and Harold Dodge implemented statistical methods for quality in the mid-twenties in USA. The Second World War was the main catalyst for the extensive use of statistical quality control methods for improving America's war time production. Certain statistical methods were even classified as military secrets. Dr. Kaoru Ishikawa, a well-known Japanese quality philosophers speculated that the Second World War was won by quality control and by utilization of statistical methods. The western industries could not sustain their achievements in quality mainly due to the failure of management. The Japanese success in the quality front in the late half of the last century can be partly attributed to the wider use of some simple statistical tools together with more advanced ones such as experimental designs (Douglas, 2009).

2.4.1 The Statistical Quality Control Technique

Total Quality Management (TQM) focuses on customer-driven quality standards, managerial leadership, continuous improvement, quality built into product and process design, quality identified problems at the source, and quality made everyone's responsibility says Akinola (2009). However, talking about solving quality problems is not enough. There is need for specific tools that can help makes the right quality decisions. These tools come from the area of statistics and are used to help identify quality problems in the production process as well as in the product itself. SQC, (2006) defined SQC as a term used to describe the set of

statistical tools used by quality professionals. This definition denotes the fact that quality professionals cannot afford to address the issue of quality without using the basic statistical techniques.

2.4.2 Types of SQC Tools

As defined earlier 'Statistical quality control (SQC) is the term used to describe the set of statistical tools used by quality professionals'. According to Wiley et al (2007), SQC encompasses three broad categories of:

1. **Descriptive Statistics**: Are Statistics used to describe quality characteristics and relationships. Included are statistics such as the mean, standard deviation, the range, and a measure of the distribution of data.

   a. The Mean- measures the central tendency of a data. Mathematically;

$$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n} \text{.....(1)}$$

Where, $\bar{X}$ is the mean

Σ is the sigma denoting summation or adding up sets X_1, X_2, X_3, X_4, up to X_n.

n is the total number of items in the data

   b. The Range– is the simplest and most straight forward measure of dispersion. It is the difference between the maximum (largest) and the minimum (smallest) values in the set of data. Mathematically thus given as :

   Maximum (Largest) – Minimum (Smallest)..... (2)

   c. Standard Deviation: measures the amount of data dispersion around the mean: thus written as :

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - \bar{X} \right)^2}{n-1}}$$

..... (3)

Where, σ represents standard deviation of data.

d. Standard Error: This error of the mean of the distribution of the sample means is designated by $S_{\bar{x}}$. It is found by

$$S_x = \frac{S}{\sqrt{n}} \quad \text{….....} (4)$$

Where,

S is the standard deviation
n is the sample size

These relationships above (i.e. equation 1 to 4) allows limits to be set up around the sample means to show how much variation can be expected for a given sample size.

2. Statistical Process Control(SPC)

According to Wiley et al (2007), Statistical Process Control (SPC) is 'the methodology for monitoring and optimizing the process output, mainly in terms of variability, and for judging when changes are required to bring the process back to a state of control'. Chandra (2001) says SPC is 'a statistical tool that involves inspecting a random sample of the output from a process and deciding whether the process is producing products with characteristics that fall within a predetermined range'. This strategy of control differs from other types of SQC where the process is allowed to adapt by automatic control devices by re-calibrating or re- adjustment of devices. From this view, SPC techniques aim to monitor the production process and also adjust the production process if necessary. This project work which aims to use the technique of SPC as a QC tool to Habila Foods and Beverages tends to monitor the production process and also re– adjust the processes if the need arises from the predetermined parameters. Furthermore, SPC can be summarize from this definitions as follows:

- Involves inspecting the output from a process and then make decision if necessary
- Quality characteristics are measured and charted

- Helpful in identifying in-process variations

3. Acceptance Sampling is the process of randomly inspecting a sample of goods and deciding whether to accept the entire lot based on the results. Acceptance sampling determines whether a batch of goods should be accepted or rejected (Chandra, 2001).

These tools in each of these categories provide different types of information for use in analyzing quality. Descriptive statistics are used to describe certain quality characteristics, such as the central tendency and variability of observed data. Although descriptions of certain characteristics are helpful, they are not enough to evaluate whether there is a problem with quality but acceptance sampling can. Acceptance sampling helps decide whether desirable quality has been achieved for a batch of products, and whether to accept or reject the items produced. Although this information is helpful in making the quality acceptance decision after the product has been produced, it does not help detect quality problem during the production process. All three of these statistical quality control categories are helpful in measuring and evaluating the quality of products or services.

However, statistical process control(SPC) tools are used most frequently because they identify quality problems during the production process. For this reason, this project work will devote most of the work to this category of tools.

2.5 Quality Control Charts

A control chart is one of the primary techniques of SPC (Wiley, 2007).According to Moore (2008), Control Charts are statistical tools that monitor a process and alert the

personal when the process has been disturbed so that it is now out of control. This is a signal to find and correct the cause of the disturbance. Furthermore, this chart often referred to as process chart is a graph that shows whether a sample of data falls within the common or normal range of variation. A typical control chart is shown in Fig. 2.4This chart plots the averages of measurements of a quality characteristic in samples taken from the process versus time (or the sample number).The chart has a center line (CL) and upper and lower control limits (UCL and LCL in Fig. 2.1). The center line represents where this process characteristic should fall if there are no unusual sources of variability present. The control limits are determined from some simple statistical considerations.

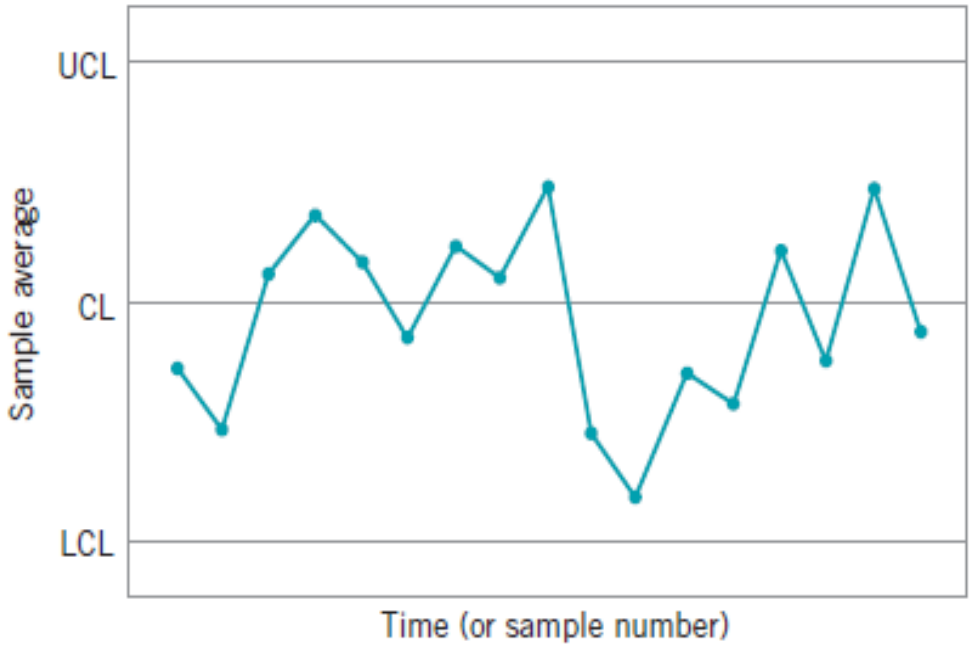


Fig. 2.4. A typical Control Chart (Wiley, 2007).

The control chart is a very useful process monitoring technique of SPC. In SPC, a process is said to be out of control when a plot of data reveals that one or more samples fall outside the control limits. For illustration purposes, Fig. 2.5shows a typical out of control situation where a sample fall above a predetermined control limit of 16.0, 15.8 and 16.2 for Control Limit (CL), Lower Control Limit (LCL) and Upper Control Limit (UCL) respectively.

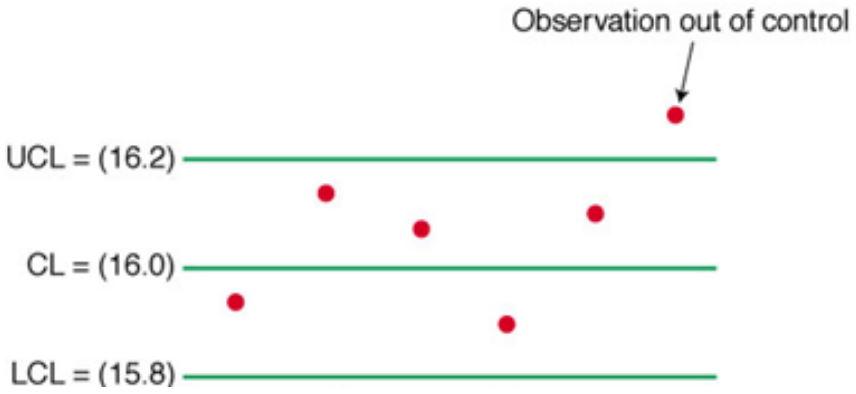


Fig. 2.5a typical Out of Control situation (Douglas, 2009)

When unusual sources of variability are present, sample averages will plot outside the control limits. This is signal that some investigation of the process should be made and corrective action to remove these unusual sources of variability taken. Systematic use of a control chart is an excellent way to reduce variability (Douglas, 2009).

2.5.1 Types of Control Charts with their Applications

The different characteristics that can be measured by control charts can be divided into two groups: variables and attributes (Reza and Payam, 2009).

2.5.2 Control Charts for Variables

Accordingly, a control chart for variables is used to monitor characteristics that can be measured and have a continuum of values, such as length, height, weight, diameter, time or volume. A soft drink bottling operation like Habila Foods and Beverages Nigeria Limited is an example of a variable measure, since the amount of liquid in the bottles or can is measured and can take on a number of different values. Other examples are the weight of a bag of sugar, the temperature of a baking oven, or the diameter of plastic tubing etc.

Two of the most commonly used control charts for variables (X–bar chart and R-chart) monitor both the central tendency of the data (the mean) and the variability of the data (either the standard deviation or the range).

Mean (x-Bar) Charts for Variables

A mean control chart is often referred to as an x-bar chart. It is used to monitor changes in the mean of a process. To construct a mean chart, first it is needed to construct the center line of the chart. To do this multiple samples are to be taken and their means computed. The center line of the chart is then computed as the mean of all $\mathcal{K}$ sample means, where $\mathcal{K}$ is the number of samples:

$$\bar{\bar{X}} = \frac{\bar{X}_1 + \bar{X}_2 + \cdots \bar{X}_{\mathcal{K}}}{\mathcal{K}}$$

..... (5)

To construct the upper and lower control limits of the chart, the following formulas are used:

$$\text{Upper Control Limit (UCL)} = \bar{\bar{X}} + Z\sigma_{\bar{X}}$$

$$\text{Lower Control Limit (LCL)} = \bar{\bar{X}} - Z\sigma_{\bar{X}}$$

Where $\bar{\bar{X}}$ = the average of the sample mean

Z = standard normal variation (2 for 95.44% confidence, 3 for 99.74% confidence)

$\sigma_{\bar{X}}$ = standard deviation of the distribution of sample means, computed as $\sigma / \sqrt{n}$

σ = population (process) standard deviation

n = sample size (number of observation per sample)

..... (5a)

Range (R) Charts for variables

Range (R) charts are another type of control chart for variables. Whereas x-bar charts measure shift in the central tendency of the process, range charts monitor the dispersion or variability of the process. The method for developing and using R-charts is the same as that for x-bar charts. The center line of the control chart is the average range, and the upper and lower control limits are computed as follows

$$CL = \bar{R}$$

$$UCL = D_4\overline{R}$$

$$LCL = D_3\overline{R}$$

……(6)

Where values for D_4 and D_3 are obtained from already established statistical tables.

Another way to construct the control limits is to use the sample range as an estimate of the variability of the process. As earlier defined, the range is simply the difference between the largest and smallest values in the sample. The spread of the range can tell the variability of the data. In this case control limits would be constructed as follows:

Upper Control Limit (UCL) $= \bar{\bar{X}} + A_2\overline{R}$

Lower Control Limit (LCL) $= \bar{\bar{X}} - A_2\overline{R}$..... (7)

Where, $\bar{\bar{X}}$ = average of the sample means

$\overline{R}$ = average range of the samples

A_2= factor obtained from standard tables. A_2 is a factor that includes three standard deviations of ranges and is dependent on the sample size being considered.

For illustarion purposes, fig. 2.6 shows how control charts for variables (X-bar and R-bar charts) are used to monitor different variables. Both charts reveal different problem. X-bar chart is used to monitor the changes in the mean of a process (central tendencies) while R-bar chart is used to monitor the dispersion or variabilities of the process as shown in fig.2.6.

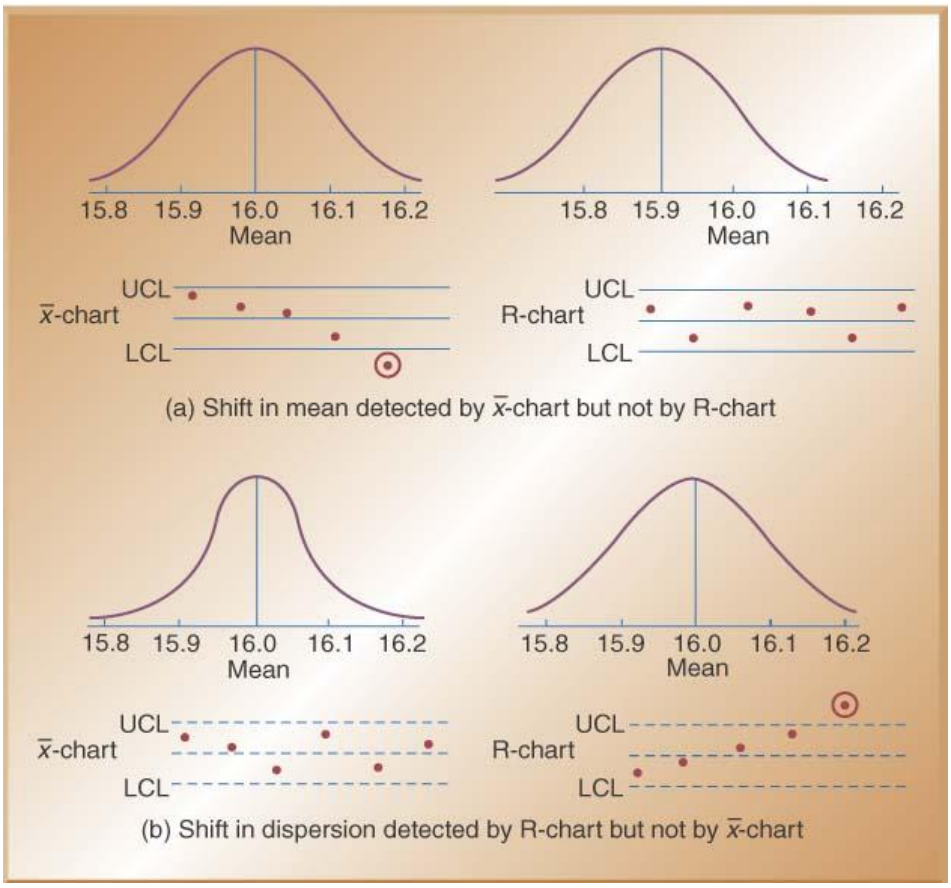


Fig. 2.6 Control charts for Variables Source: Wiley et al (2007)

From the figure 2.6 above, X –bar chart shows the shift in mean position of the process while the R- bar chart shows the shift in dispersion or often referred to as variability of the process.

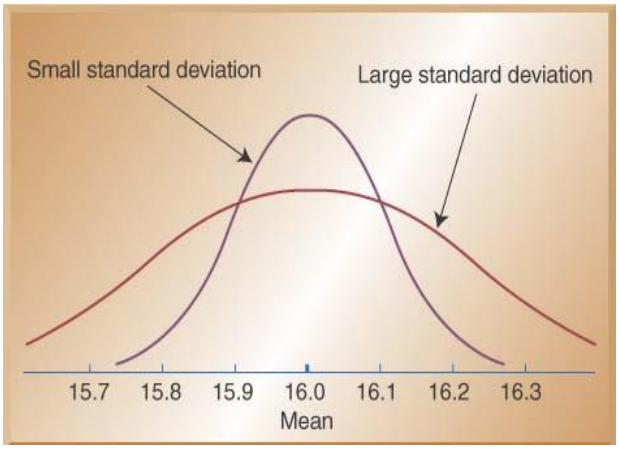
2.5.3 Control Charts for Attributes:

On the other hand, a control chart for attributes is used to monitor characteristics that have discrete values and can be counted says Marilyn and Robert (2007). Accordingly, they can be evaluated with a simple yes or no decision. The monitoring of attributes usually takes less time than that of variables because a variable needs to be measured. An attribute requires only a single decision, such as yes or no, good or bad, acceptable or unacceptable or counting the number of defects. There are two types of control charts for attribute: P-chart and C-chart.

Due to limitations and nature of this project work couples with the nature of data collated, the two types of chart for attribute will not be considered. Hence, this work will only be using the control charts for variables due to aforementioned reasons.

2.6 DISTRIBUTIONS OF DATA

In the distribution of data, small values of the range and standard deviation mean that the observations are closely clustered around the mean. Large values of the range and standard deviation mean that the observations are spread out around the mean. Figure 2.6 illustrates the differences between a small and a large standard deviation of a distribution. The figure shows two distributions, both with an assumed mean of 16 for clarification purposes only. However, in the first distribution the standard deviation is large and the data are spread out far around the mean. In the second distribution the standard deviation is small and the data are clustered close to the mean.



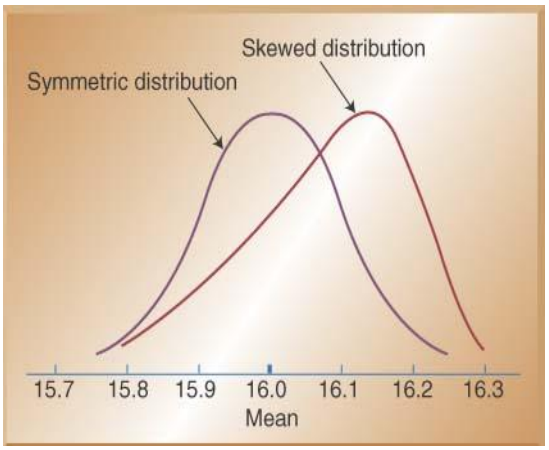


Fig. 2.7 Distribution of data Fig. 2.7 Nature of Distribution

Source: Wiley et al (2007)

A third descriptive statistic used to measure quality characteristics is the shape of the distribution of the observed data as shown in fig 2.7 above. When a distribution is symmetric, there are the same numbers of observations below and above the mean. This is what

commonly found when only normal variation is present in the data. When a disproportionate number of observations are either above or below the mean, the data has a skewed distribution. Figure 2.7 above shows symmetric and skewed distributions of data with an assumed mean of 16. The assumption is to enable us sketch the graph for better understanding.

2.7 Types and Causes of Variation in Sqc

When looking at bottles of a soft drink in a store carefully, it will be notice that no two bottles are filled to exactly the same level. Some are filled slightly higher and some slightly lower. This type of difference is completely normal. Wiley et al (2007), says 'No two products are exactly alike because of slight differences in materials, workers, machines, tools, and other factors'. These are called common, or random, causes of variation (Wiley et al, 2007**).** Wiley further say that common cause of variation are based on random causes that cannot be identify. These types of variation are unavoidable and are due to slight differences in processing.

An important task in quality control is to find out the range of natural random variation in a process. Fig. 2.8 shows the types and causes of variation in quality control management system. When all the data falls within the predetermined range of control i.e. Lower Control Limit (LCL) and Upper Control Limit (UCL) it is regarded as random or normal causes of variation as shown in fig. 2.8. This normal or random cause of variation cannot be identified because the data falls within the preset limits.

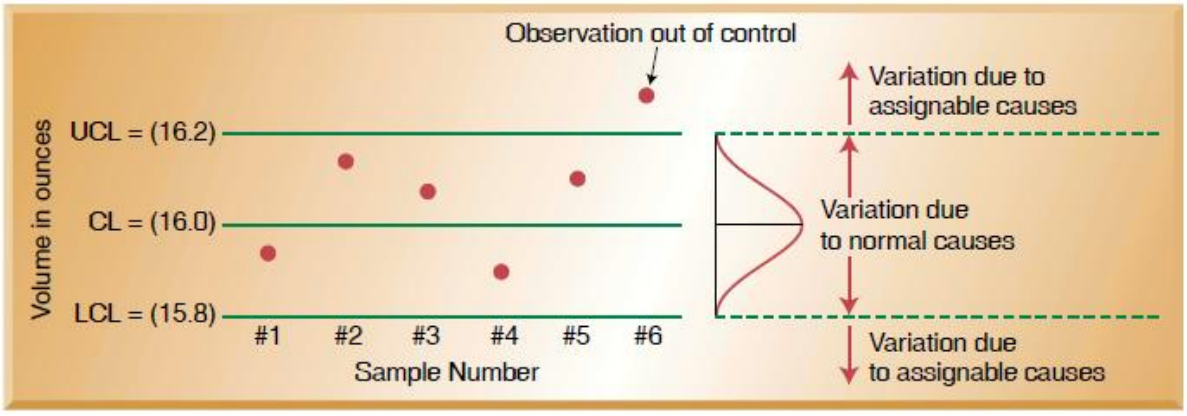


Fig.2.8 Types and Causes of Variation(Wiley et al 2007)

Wiley et al (2007) further says, the other type of variation that can be observed involves variations where the causes can be precisely identified and eliminated. These are called assignable causes of variation. Examples of this type of variation are poor quality in raw materials, an employee who needs more training, or a machine in need of repair. In each of these examples the problem can be identified and corrected. Also, if the problem is allowed to persist, it will continue to create a problem in the quality of the product. Figure 2.8 above shows out of control situation, where data falls above and below the preset control limits (LCL and UCL) indicating that a variation due to assignable causes have been developed and can be identified and also be corrected.

2.8 Process Capability(PC)

PCis a critical aspect of statistical quality control in evaluating the ability of a production process to meet or exceed preset specifications (Reza and Payam, 2009).To understand exactly what this means, let us look more closely at the term specification. Product specifications, often called tolerances say Reza and Payam, are preset ranges of acceptable quality characteristics ,such as product dimensions, volumes, heights, weights etc. For a product to be considered acceptable, its characteristics must fall within this preset range. Otherwise, the product is not acceptable. Product specifications, or tolerance limits, are usually established by design engineers or product design specialists say Reza and Payam.

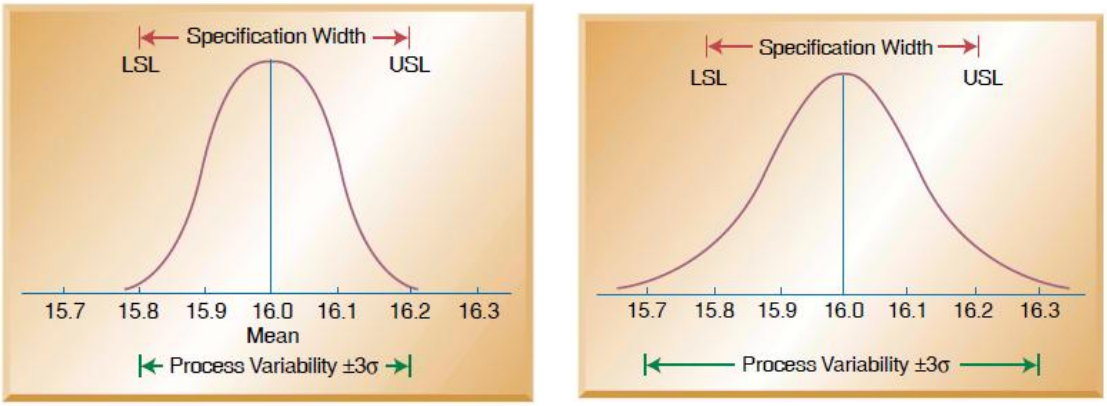
For instance, the specifications for filling up a bottle or can drinks may be specified as 15cl ±.2. This implies that the filling of the bottle or can drinks should be 15cl, though it is acceptable if it falls within the limit of 14.8cl and 15.2cl.

From this view, specifications for a product can be say to be a preset on the basis of how the product is going to be used or what customer expectations are. As reviewed earlier on, any production process has a certain amount of natural variation associated with it. To be capable of producing an acceptable product, the process variation cannot exceed the preset specifications. Process capability thus involves evaluating process variability relative to preset product specifications in order to determine whether the process is capable of producing an acceptable product.

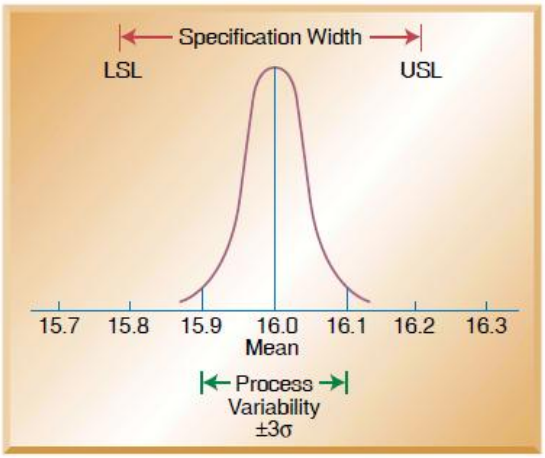
2.8.1 Measuring Process Capability

Marilyn and Robert (2007), says simply setting up control charts to monitor whether a process is in control does not guarantee process capability. Furthermore, to produce an acceptable product, the process must becapableand in control before production begins.

For the purpose of understanding, the specification for the acceptable volume of liquid is preset at 16cl±.2, which are 15.8 and 16.2cl as shown in fig. 2.9 below.



(a)Process Variability meets specification width (b)Process Outside specification width



(c) Process Variability within specification width

Fig2.9 Relationship between Process Variability and Specification width

(Marilyn and Robert 2007)

In part (a) of Fig. 2.9 the process produces the product with volumes between15.8 and 16.2cl, which implies that the process variability closely matches the preset specifications. Almost all the output falls within the preset specification range. In part (b) of Fig.2.9 above, however, the process produces the product with volumes between 15.7 and 16.3cl. The process variability is outside the preset specifications. A large percentage of the product will fall outside the specified limits. This means that the process is not capable of producing the product within the preset specifications. Part (c) of the fig. 2.9shows that the production process produces the product with volumes between 15.9 and 16.1cl. In this case the process variability is within specifications and the process exceeds the minimum capability.

2.8.2 Process Capability Index (Cp_k)

Reza and Payam (2009), says Process capability is measured by the process capability index, Cp_k. Though, defined it as an index used to measure process capability which can be computed as the ratio of the specification width to the width of the process variability:

Mathematically,

$$C_P = \frac{\text{Specification width}}{\text{Process with}} \quad \text{..... (8a)}$$

$$= \frac{USL - LSL}{6\sigma} \quad \text{..... (8b)}$$

Where the specification width is the difference between the upper specification limit (USL) and the lower specification limit (LSL) of the process. The process width is computed as 6 standard deviations (6σ) of the process being monitored. Accordingly, the reason for using six sigma (6σ) is that most of the process measurement falls within ±3standard deviations, which is a total of 6 standard deviations.

Reza and Payam further iterated that there are three possible ranges of values for *Cp* that can also be helpful in interpreting its value as far as QC is concerned: though says

Cp= 1: A value of *Cp* equal to 1 means that the process variability just meets specifications, as shown in fig. 2.9(a). This implies that one could say the process is minimally capable.

Cp ≤ 1: A value of *Cp* below 1 means that the process variability is outside the range of specification, as shown in fig. 2.9(b). This means that the process is not capable of producing within specification and the process must be improved.

Cp ≥ 1: A value of *Cp* above 1 means that the process variability is tighter than specifications and the process exceeds minimal capability, as shown in fig. 2.9(c).

According to Wiley et al, Cpis valuable in measuring process capability. However, it has one shortcoming: it assumes that process variability is centered on the specification range. Unfortunately, this is not always the case. In the fig. 2.10, the specification limits are set between 15.8 and 16.2cl, with a mean of 16.0. However, the process variation is not centered; it has a mean of 15.9. Because of this, a certain proportion of products will fall outside the specification range.

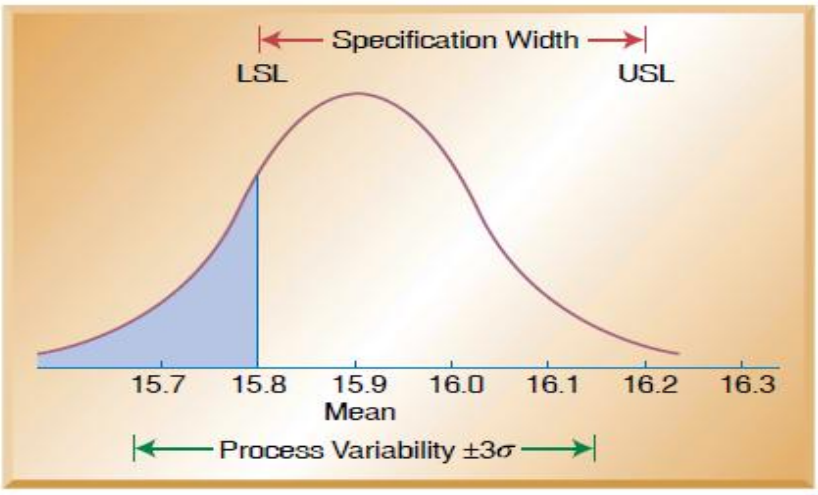


Fig 2.10 Process variability not centered across specification width

(Marylyn and Robert 2007)

The problem illustrated in fig. 2.10 is not uncommon, but it can lead to mistakes in the computation of the *C*ommeasure. Because of this, another measure for process capability is used more frequently: Though given as;

$$Cp_k = Min\left(\frac{USL-\mu}{3\sigma}, \frac{\mu-LSL}{3\sigma}\right) \quad \text{..... (9)}$$

where,μ=the mean of the process

σ= is the standard deviation of the process

This measure of process capability helps us address a possible lack of centering of the process over the specification range. To use this measure, the process capability of each half of the normal distribution is computed and the minimum of the two is used.

CHAPTER THREE

METHODOLOGY

3.1 Preview

This chapter presents the methodological approach including empirical and materials used in this research work. The chapter further established all the necessary parameters such as the Mean, Range, construction of charts and Process Capabilities index values (CP_k) needed in this work in order to achieve the stated objectives.

3.2 Items Used

The following items were used in the course of this research work;

- Raw data from primary source (the company)
- Microsoft suite (excel)
- Calculator
- Already established factors table for three sigma control limits by ASTM

3.3 Data Collection

Due to the nature of this project work being an applied research work, the accuracy of the data would go a long way to help reduce the error that might have occurred in the course of data collection and hence, the accuracy of data will give confidentiality of the results. It is of this view that the method of data collection for this research work be primary source i.e. directly from the company. Although, data collected for this work has been attached as appendix, however, all the necessary data for this research work have been extracted from the appendices for usage in this chapter.

3.3.1 Data extracted for Can filler Machines from appendix A

Table 3.1 shows data collected for thirty – one samples days taken by the Quality Control Inspector of the company with five observations (the numbers of machines) each of the volume of Can drinks filled in cl.

Table 3.1 Volume of Can filler Machines in cl. Source: Extracted from Appendix A

Machine Observations(in cl)						
Day	**Shift**	**M1**	**M2**	**M3**	**M4**	**M5**
07-1	**II**	**18.50**	**16.73**	**19.00**	**18.50**	**19.10**
07-2	**III**	**18.30**	**18.50**	**19.20**	**19.20**	**17.28**
07-3	**I**	**19.00**	**17.90**	**18.90**	**19.00**	**18.70**
07-4	**II**	**18.90**	**17.89**	**19.50**	**18.30**	**17.90**
07-5	**III**	**19.00**	**18.78**	**16.90**	**16.40**	**19.20**
07-6	**I**	**19.20**	**19.00**	**18.48**	**18.93**	**17.99**
07-7	**II**	**18.79**	**19.04**	**18.93**	**19.00**	**19.01**
07-8	**III**	**19.20**	**18.27**	**18.93**	**18.93**	**18.93**
07-9	**I**	**17.83**	**18.93**	**18.34**	**18.00**	**18.34**
07-10	**II**	**18.93**	**17.99**	**18.89**	**18.54**	**18.94**
07-11	**III**	**N/A**	**18.73**	**18.29**	**18.35**	**17.35**
07-12	**I**	**N/A**	**18.86**	**18.34**	**18.37**	**18.94**
07-13	**II**	**18.94**	**17.89**	**18.36**	**18.37**	**18.36**
07-14	**III**	**18.73**	**18.34**	**18.43**	**18.93**	**18.43**
07-15	**I**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
07-16	**II**	**17.95**	**18.93**	**19.00**	**18.93**	**19.00**
07-17	**III**	**18.40**	**19.45**	**19.65**	**18.36**	**17.60**
07-18	**I**	**18.45**	**19.40**	**18.78**	**17.98**	**18.93**
07-19	**II**	**19.00**	**N/A**	**19.00**	**18.79**	**18.59**
07-20	**III**	**18.90**	**18.90**	**18.90**	**18.90**	**18.90**
07-21	**I**	**16.70**	**18.70**	**17.89**	**19.40**	**17.60**
07-22	**II**	**19.00**	**16.70**	**N/A**	**N/A**	**18.78**
07-23	**III**	**19.01**	**19.01**	**18.90**	**17.99**	**19.01**
07-24	**I**	**17.98**	**17.98**	**17.98**	**18.99**	**19.01**
07-25	**II**	**18.73**	**18.79**	**18.93**	**19.01**	**N/A**
07-26	**III**	**N/A**	**18.54**	**18.34**	**18.24**	**18.14**
07-27	**I**	**18.67**	**19.01**	**17.89**	**18.23**	**18.24**
07-28	**II**	**18.76**	**19.01**	**17.39**	**18.99**	**18.90**
07-29	**III**	**18.93**	**18.65**	**18.34**	**18.34**	**18.90**
07-30	**I**	**18.37**	**18.37**	**18.73**	**18.35**	**19.01**
07-31	**II**	**19.01**	**18.56**	**18.74**	**18.49**	**19.01**

3.3.2 Data extracted for Bottle filler Machines from appendix B

Similarly, the data below shows that of Bottles filler machines with similarity in samples number (days) and unit (cl) as can filler, but with four observations (numbers of machines).

Table 3.2 Volume of Bottle filler Machines in cl. Source: Extracted from Appendix B

Machine Observations(in cl)					
Day	**Shift**	**M6**	**M7**	**M8**	**M9**
06-1	**II**	**32.5**	**33.01**	**32.78**	**31.99**
06-2	**III**	**33.00**	**32.78**	**32.19**	**31.99**
06-3	**I**	**32.89**	**32.78**	**32.39**	**32.88**
07-4	**II**	**32.89**	**33.00**	**32.54**	**33.01**
07-5	**III**	**32.54**	**32.89**	**33.00**	**32.21**
07-6	**I**	**31.78**	**32.00**	**32.27**	**33.00**
07-7	**II**	**32.89**	**33.01**	**32.99**	**32.93**
07-8	**III**	**32.92**	**32.91**	**32.89**	**33.01**
07-9	**I**	**32.78**	**33.01**	**32.79**	**32.98**
07-10	**II**	**N/A**	**32.89**	**32.73**	**32.90**
07-11	**III**	**32.81**	**32.78**	**N/A**	**32.31**
07-12	**I**	**31.99**	**32.89**	**32.98**	**32.31**
07-13	**II**	**32.54**	**32.89**	**32.11**	**33.10**
07-14	**III**	**32.10**	**32.78**	**32.18**	**33.00**
07-15	**I**	**31.99**	**32.00**	**32.91**	**N/A**
07-16	**II**	**32.55**	**33.01**	**32.91**	**31.89**
07-17	**III**	**32.93**	**32.89**	**32.91**	**33.10**
07-18	**I**	**33.01**	**32.75**	**32.89**	**32.85**
07-19	**II**	**33.01**	**N/A**	**31.79**	**32.91**
07-20	**III**	**32.98**	**32.04**	**32.91**	**32.92**
07-21	**I**	**32.98**	**32.93**	**32.98**	**32.98**
07-22	**II**	**32.98**	**32.74**	**33.10**	**32.95**
07-23	**III**	**32.10**	**32.36**	**32.78**	**32.97**
07-24	**I**	**32.98**	**32.95**	**32.98**	**32.92**
07-25	**II**	**32.89**	**32.98**	**33.01**	**33.10**
07-26	**III**	**N/A**	**N/A**	**N/A**	**N/A**
07-27	**I**	**32.90**	**N/A**	**32.98**	**32.56**
07-28	**II**	**33.01**	**32.67**	**32.90**	**32.91**
07-29	**III**	**32.99**	**32.98**	**33.01**	**32.98**
07-30	**I**	**33.01**	**33.00**	**32.91**	**33.01**
07-31	**II**	**32.73**	**32.81**	**32.91**	**32.90**

3.4 ESTABLISHING THE MEAN, RANGE AND STANDARD DEVIATION (S.D) USING EXCEL

Due to large number of data, the excel software was used to compute the Mean, Range and S.D for speed and accuracy.

3.4.1 The Mean, Range and S.D of Can fillers

Table below shows the computed mean, range and standard deviation using excel data used are machine observations from table 3.1

Table 3.3 Mean, Range and Standard Deviation of Can filler

	Machine Observations (Can Volume in cl)						
Sample/Day	**1**	**2**	**3**	**4**	**5**	**Average (X)**	**Range (R)**
1	**18.5**	**16.73**	**19**	**18.5**	**19.1**	**18.37**	**2.37**
2	**18.3**	**18.5**	**19.2**	**19.2**	**17.28**	**18.5**	**1.92**
3	**19**	**17.9**	**18.9**	**19**	**18.7**	**18.7**	**1.1**
4	**18.9**	**17.89**	**19.5**	**18.3**	**17.9**	**18.5**	**1.61**
5	**19**	**18.78**	**16.9**	**16.4**	**19.2**	**18.06**	**2.8**
6	**19.2**	**19**	**18.48**	**18.93**	**17.99**	**18.72**	**1.21**
7	**18.79**	**19.04**	**18.93**	**19**	**19.01**	**18.95**	**0.25**
8	**19.2**	**18.27**	**18.93**	**18.93**	**18.93**	**18.85**	**0.93**
9	**17.83**	**18.93**	**18.34**	**18**	**18.34**	**18.29**	**1.1**
10	**18.93**	**17.99**	**18.89**	**18.54**	**18.94**	**18.66**	**0.95**
11	**N/A**	**18.73**	**18.29**	**18.35**	**17.35**	**18.18**	**1.38**
12	**N/A**	**18.86**	**18.34**	**18.37**	**18.94**	**18.63**	**0.6**
13	**18.94**	**17.89**	**18.36**	**18.37**	**18.36**	**18.38**	**1.05**
14	**18.73**	**18.34**	**18.43**	**18.93**	**18.43**	**18.57**	**0.59**
15	**0**	**0**	**0**	**0**	**0**	**0**	**0**
16	**17.95**	**18.93**	**19**	**18.93**	**19**	**18.76**	**1.05**
17	**18.4**	**19.45**	**19.65**	**18.36**	**17.6**	**18.69**	**2.05**
18	**18.45**	**19.4**	**18.78**	**17.98**	**18.93**	**18.71**	**1.42**
19	**19**	**N/A**	**19**	**18.79**	**18.59**	**18.85**	**0.41**
20	**18.9**	**18.9**	**18.9**	**18.9**	**18.9**	**18.9**	**0**
21	**16.7**	**18.7**	**17.89**	**19.4**	**17.6**	**18.06**	**2.7**
22	**19**	**16.7**	**N/A**	**N/A**	**18.78**	**18.16**	**2.3**
23	**19.01**	**19.01**	**18.9**	**17.99**	**19.01**	**18.78**	**1.02**
24	**17.98**	**17.98**	**17.98**	**18.99**	**19.01**	**18.39**	**1.03**
25	**18.73**	**18.79**	**18.93**	**19.01**	**N/A**	**18.87**	**1.28**
26	**N/A**	**18.54**	**18.34**	**18.24**	**18.14**	**18.32**	**0.4**
27	**18.67**	**19.01**	**17.89**	**18.23**	**18.24**	**18.41**	**1.12**
28	**18.76**	**19.01**	**17.39**	**18.99**	**18.9**	**18.61**	**1.62**
29	**18.93**	**18.65**	**18.34**	**18.34**	**18.9**	**18.63**	**0.59**
30	**18.37**	**18.37**	**18.73**	**18.35**	**19.01**	**18.57**	**0.66**
31	**19.01**	**18.56**	**18.74**	**18.49**	**19.01**	**18.76**	**0.52**
MEAN	**17.97**	**17.9**	**17.97**	**17.93**	**17.94**	**17.96**	**1.13**

3.4.2 Establishing Control Limits, Range and Standard Error for Can filler

From table 3.3, the Average of the Mean, $\overline{\overline{X}} = 17.96$

The Average of the Range, $\overline{R} = 1.13$

The mean for machine 1, $\mu_1 = 17.97$

The mean for machine 2, $\mu_2 = 17.90$

The mean for machine 3, $\mu_3 = 17.97$

The mean for machine 4, $\mu_4 = 17.93$

The mean for machine 5, $\mu_5 = 17.94$

Standard Deviation, σ, = 1.006

Using equation 5 and 5a in chapter two above,

Centre Line (CL) = $\overline{\overline{X}}$

Upper Control Limit (UCL) = $\overline{\overline{X}} + Z\,\sigma_{\overline{x}}$

Lower Control Limit (LCL) = $\overline{\overline{X}} - Z\,\sigma_{\overline{x}}$

where Z is the constant i.e. standard normal variable in equation 5a. However, for three sigma factor, Z = 3 for accuracy of 99.97% as defined in chapter two.

The standard Error, $\sigma_{\overline{x}} = \frac{\sigma}{\sqrt{n}}$ from equation (2)

where n is the sample size i.e. number of machine (observations). Hence, it is five (5) in this case, since the number of machine is five (5).

Substituting the above variables, thus,

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}} = \frac{1.006}{\sqrt{5}} = 0.447$$

Centre Line (CL) = $\overline{\overline{X}} = 17.96$

Upper Control Limit (UCL) = $\overline{\overline{X}} + Z\,\sigma_{\overline{x}} = 17.96 + 3*0.45 = 19.31$

Lower Control Limit (LCL) = $\overline{\overline{X}} - Z\,\sigma_{x} = 17.96 - 3*0.45 = 16.61$

For- Chart,

From equation (6), CL = $\overline{R}$

$UCL = D_4\overline{R}$

$LCL = D_3\overline{R}$

where D_3 and D_4 are obtain from appendix C.

For sample size n = 5 (number of machines), $D_3 = 0$; $D_4 = 2.11$ from appendix C

Substituting the variables,

$CL = \overline{R} = 1.13$

$$UCL = D_4\overline{R} = 2.11 * 1.13 = 2.3843$$

$$LCL = D_3\overline{R} = 0 * 1.13 = 0$$

Alternatively, R- chart values can be found using equation, (7), i.e. using means with constants i.e. A's factors. Thus;

$$CL = \overline{\overline{X}}$$

$$UCL = \overline{\overline{X}} + A_2\overline{R}$$

$$LCL = X - A_2\overline{R}$$

Where A_2 is a constant obtain from appendix C.

For sample size n = 5, $A_2 = 0.58$

Substituting these variables,

$$CL = \overline{\overline{X}} = 17.96$$

$$UCL = \overline{\overline{X}} + A_2\overline{R} = 17.96 + 0.58 * 1.13 = 18.62$$

$$LCL = \overline{\overline{X}} - A_2\overline{R} = 17.96 - 0.58 * 1.13 = 17.30$$

These values established above will be used to plot the X –bar and R- control chart for Can filler.

3.4.3 The Mean, Range and S.D of Bottle fillers using excel

Similarly, excel method was used to determine the Mean, Range and standard deviation of Bottle fillers. Thus, tabulated as follows:

Table 3.4 Mean, Range and Standard Deviation of Bottle filler

Machine Observations (Bottle Volume in cl)						
SAMPLE/DAY	**6**	**7**	**8**	**9**	**Average (X)**	**Range (R)**
1	**32.5**	**33.01**	**32.78**	**31.99**	**32.57**	**1.02**
2	**33**	**32.78**	**31.99**	**31.99**	**32.49**	**1.01**
3	**32.89**	**32.78**	**32.39**	**32.88**	**32.78**	**0.5**
4	**32.89**	**33**	**32.54**	**33.01**	**32.86**	**0.47**
5	**32.54**	**32.89**	**33**	**32.21**	**32.66**	**0.79**
6	**31.78**	**32**	**32.27**	**33**	**32.26**	**1.22**
7	**32.89**	**33.01**	**32.99**	**32.93**	**32.96**	**0.12**
8	**32.92**	**32.91**	**32.89**	**33.01**	**32.93**	**0.12**
9	**32.78**	**33.01**	**32.79**	**32.98**	**32.89**	**0.23**
10	**N/A**	**32.89**	**32.73**	**32.9**	**32.84**	**0.17**
11	**32.81**	**32.78**	**N/A**	**32.31**	**32.63**	**0.5**
12	**31.99**	**32.89**	**32.98**	**32.31**	**32.54**	**0.99**
13	**32.54**	**32.89**	**32.11**	**33.1**	**32.66**	**0.99**
14	**32.1**	**32.78**	**32.18**	**33**	**32.52**	**0.9**
15	**31.99**	**32**	**32.91**	**N/A**	**32.3**	**0.92**
16	**32.55**	**33.01**	**32.91**	**31.89**	**32.59**	**1.12**
17	**32.93**	**32.89**	**32.91**	**33.1**	**32.96**	**0.21**
18	**33.01**	**32.75**	**32.89**	**32.85**	**32.88**	**0.26**
19	**33.01**	**N/A**	**31.79**	**32.91**	**32.57**	**1.22**
20	**32.98**	**32.04**	**32.91**	**32.92**	**32.71**	**0.94**
21	**32.98**	**32.93**	**32.98**	**32.98**	**32.97**	**0.05**
22	**32.98**	**32.74**	**33.1**	**32.95**	**32.94**	**0.36**
23	**32.1**	**32.36**	**32.78**	**32.97**	**32.55**	**0.87**
24	**32.98**	**32.95**	**32.98**	**32.92**	**32.96**	**0.06**
25	**32.89**	**32.98**	**33.01**	**33.1**	**33**	**0.21**
26	**N/A**	**N/A**	**N/A**	**N/A**	**0**	**0**
27	**32.9**	**N/A**	**32.98**	**32.56**	**32.81**	**0.42**
28	**33.01**	**32.67**	**32.9**	**32.91**	**32.87**	**0.34**
29	**32.99**	**32.98**	**33.01**	**32.98**	**32.99**	**0.03**
30	**33.01**	**33**	**32.91**	**33.01**	**32.98**	**0.1**
31	**32.73**	**32.81**	**32.91**	**32.9**	**32.84**	**0.18**
Mean	**32.71**	**32.78**	**32.75**	**32.78**	**32.75**	**0.53**

3.4.4 Establishing Control Limits, Range and Standard Error for Bottle filler

In similar way, the parameters for Bottle filler will be determined as follows:

From table 3.3, the Average of the Mean, $\overline{\overline{X}} = 32.75$

The Average of the Range, $\overline{R} = 0.53$

The mean for machine 6, $\mu_6 = 32.71$

The mean for machine 7, $\mu_7 = 32.78$

The mean for machine 8, $\mu_8 = 32.75$

The mean for machine 9, $\mu_9 = 32.78$

Standard Deviation, σ, = 0.32

Using equation 5 and 5a in chapter two above,

Centre Line (CL) = $\overline{\overline{X}}$

Upper Control Limit (UCL) = $\overline{\overline{X}} + Z\,\sigma_{\overline{x}}$

Lower Control Limit (LCL) = $\overline{\overline{X}} - Z\,\sigma_{\overline{x}}$

Where, Z is the constant i.e. standard normal variable in equation 5a. However, for three sigma factor, Z = 3 for accuracy of 99.97% as defined in chapter two.

The standard Error, $\sigma_{\overline{X}}$, = $\frac{\sigma}{\sqrt{n}}$ from equation (2)

Where n is the sample size i.e. number of machine (observations). Hence, it is four (4) in this case, since the number of machine is four (4).

Substituting the above variables, thus,

$\sigma_{\overline{X}} = \frac{\sigma}{\sqrt{n}} = \frac{0.32}{\sqrt{4}} = 0.16$

Centre Line (CL) = $\overline{\overline{X}} = 32.75$

Upper Control Limit (UCL) = $\overline{\overline{X}} + Z\,\sigma_{\overline{x}} = 32.75 + 3*0.16 = 33.23$

Lower Control Limit (LCL) = $\overline{\overline{X}} - Z\,\sigma_{\overline{x}} = 32.75 - 3*0.16 = 32.27$

For- Chart,

From equation (6), CL = $\overline{R}$

$UCL = D_4\overline{R}$

$LCL = D_3\overline{R}$

Where D_3 and D_4 are obtain from appendix C.

For sample size n = 4 (number of machines), $D_3 = 0$; $D_4 = 2.28$ from appendix C

Substituting the variables,

$CL = \overline{R} = 0.53$

$UCL = D_4\overline{R} = 2.28 * 0.53 = 1.21$

$LCL = D_3\overline{R} = 0 * 0.53 = 0$

Alternatively, R- chart values can also be found using equation, (7), i.e. using means with A_2constants. Thus;

$CL = \overline{\overline{X}}$

$$UCL = \overline{\overline{X}} + A_2\overline{R}$$

$$LCL = \overline{\overline{X}} - A_2\overline{R}$$

Where A_2 is a constant obtain from appendix C.

For sample size n = 4, $A_2 = 0.73$

Substituting these variables,

$$CL = \overline{\overline{X}} = 32.75$$

$$UCL = \overline{\overline{X}} + A_2\overline{R} = 32.75 + 0.73 * 0.53 = 33.14$$

$$LCL = \overline{\overline{X}} - A_2\overline{R} = 32.75 - 0.73 * 0.53 = 32.36$$

These values established above will be used to plot the X –bar and R- control chart for Bottle filler.

3.5 CONSTRUCTION OF CONTROL CHARTS FOR BOTH CAN AND BOTTLE FILLER

The X- bar charts are plotted as means against the sample/days while the R- bar charts are plotted as range against sample/days. The means, ranges and samples/days used are from the excel sheet for can and bottle in table 3.3 and 3.4 respectively .Control limits used are established from the above calculations.

3.5.1 The resulting X-bar Control Chart for Can filler

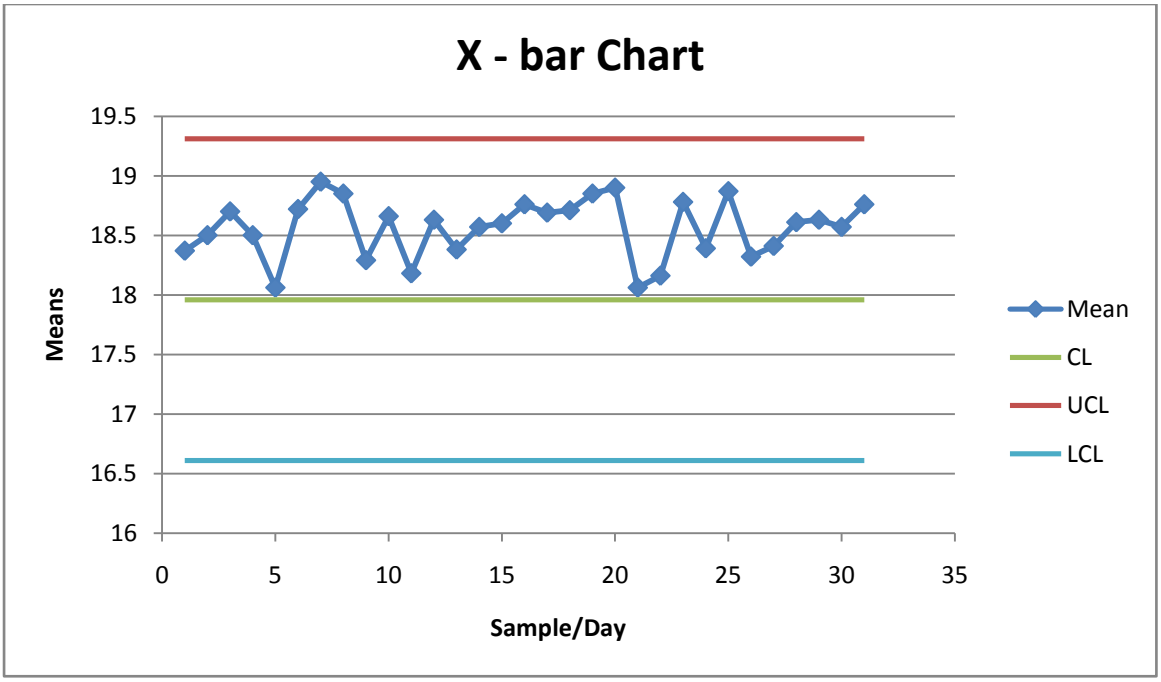


Fig. 3.1 X-bar (Mean) Chart for Can fillers

3.5.2 The resulting R-Chart Control for Can filler

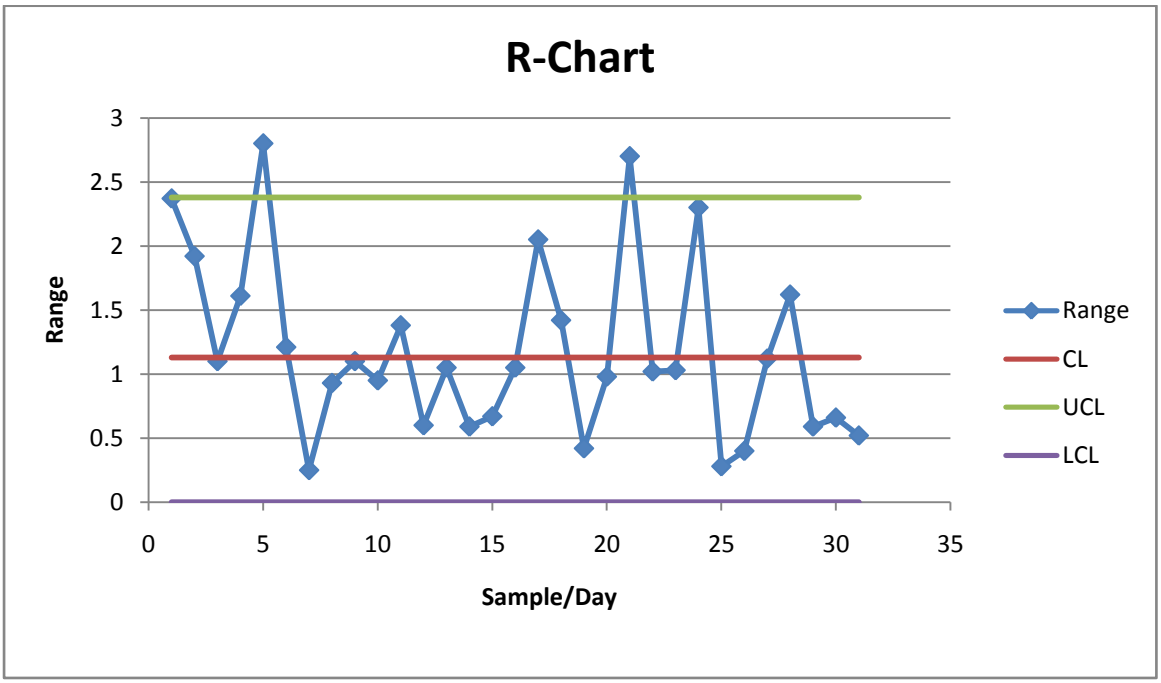


Fig. 3.2a R-Chart using the values of D's factor for Can fillers

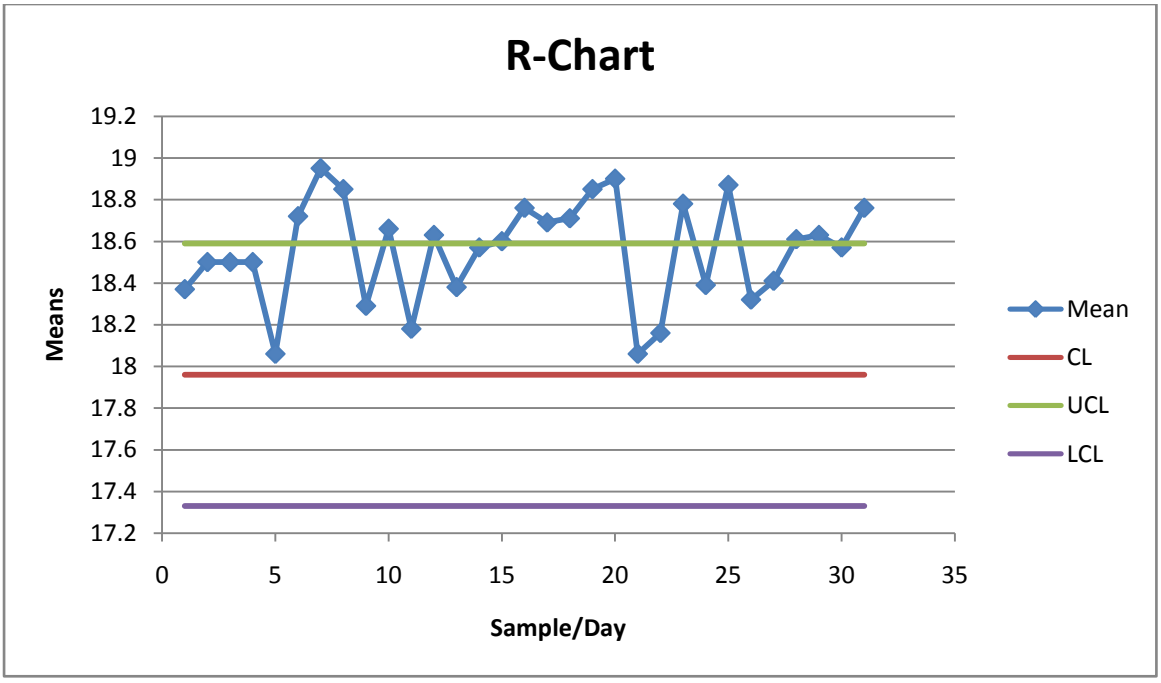


Fig. 3.2b R-Chart using the values of A's factor for Can fillers

3.5.3 The resulting X-bar Control Chart for Bottle filler

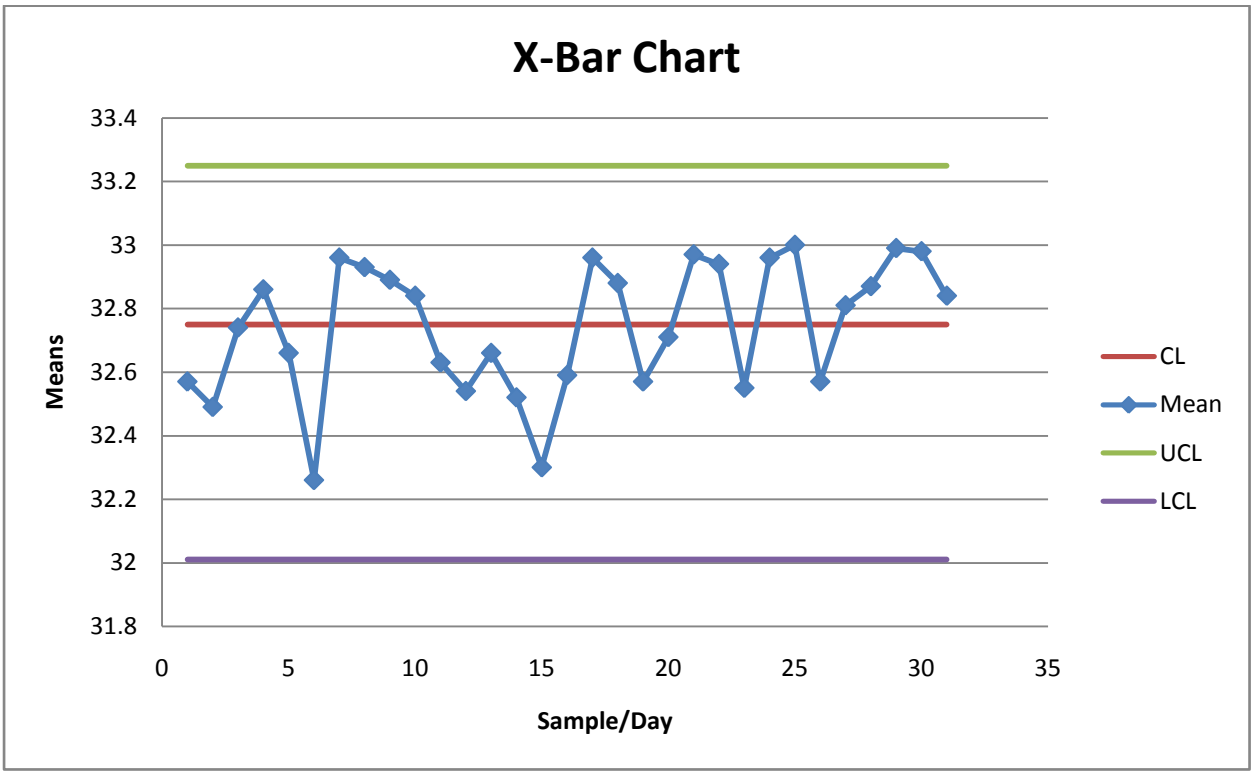


Fig. 3.3 X-bar Chart for Bottles fillers

3.5.4 The resulting R-Chart Control for Bottle filler

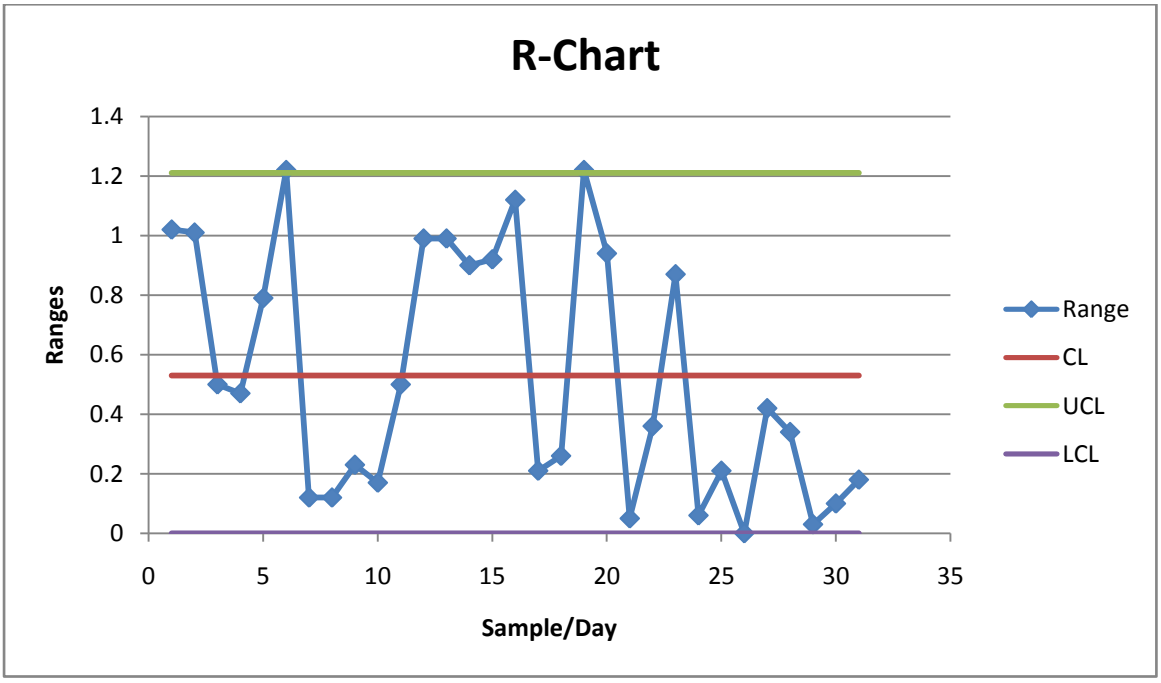


Fig. 3.4a R- Chart for Bottle filler using D's factor values

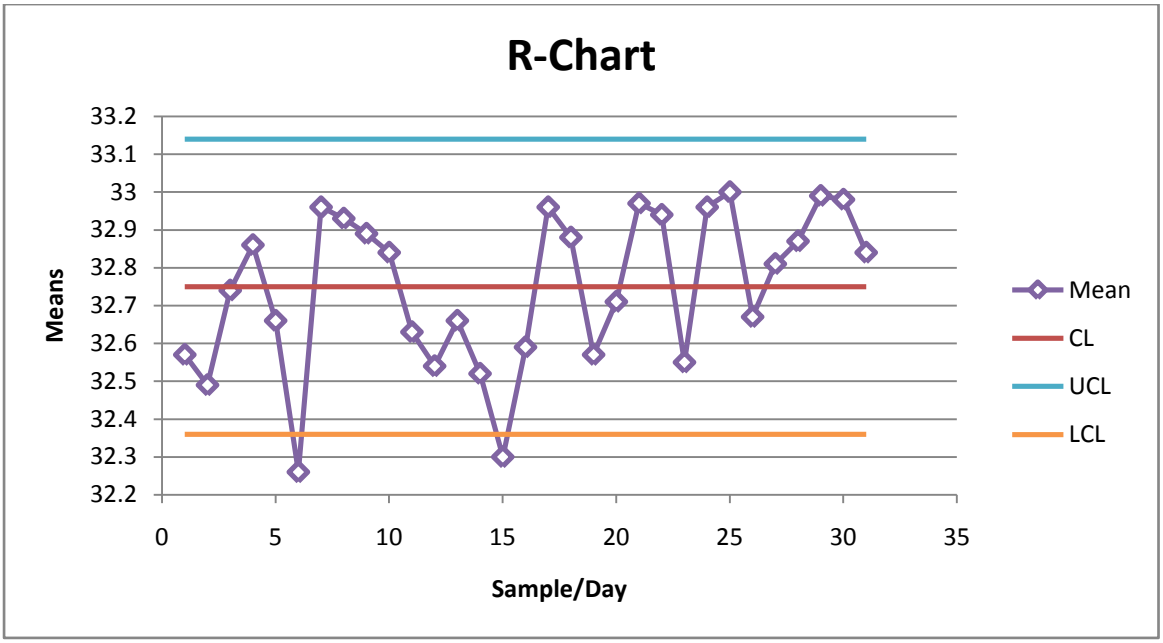


Fig. 3.4b R-Chart for Bottle filler using A's factor values

3.6 Measuring the Process Capability (Cp) Of the Machine Fillers

Equation8a, and 8b from chapter two will be used to determine the process capability of the machine process both for Can filler and Bottle filler.

3.6.1 Determining the process capability for Can Filler:

From equation8a and b,

$$C_P = \frac{specification \quad widt\,h}{process \quad widt\,h}$$

$$= \frac{USL - LSL}{6\sigma}$$

Where,

USL = UCL = 19.31

LSL = LCL= 16.61

σ = Standard Deviation = 1.006 and 6 is the constant defined in chapter two.

Substituting the values, thus:

$$= \frac{19.31 - 16.61}{6 * 1.006}$$

$$= \frac{2.7}{6.036}$$

$$= 0.447$$

3.6.2 Determining the process capability for Bottle Filler:

Similarly, from equation 8a and b,

$$C_P = \frac{specification \quad widt\,h}{process \quad widt\,h}$$

$$= \frac{USL - LSL}{6\sigma}$$

Where,

USL = UCL = 33.23

LSL = LCL= 32.27

σ = Standard Deviation = 0.32 and 6 is the constant defined in chapter two.

Substituting the values, thus:

$$= \frac{33.23 - 32.27}{6 * 0.32}$$

$$= \frac{0.96}{1.92}$$

$$= 0.5$$

3.7 Determining the Process Capability Index (Cp_k) Of the Machine Fillers

From equation 9, in chapter two

Cp_k equation is given as; minimum $\left(\frac{USL - \square}{3\sigma}, \frac{\square - LSL}{3\sigma}\right)$

Where each of the parameters has their own meaning as earlier defined.

3.7.1 Cp_k for Can fillers

From the established data, USL = UCL = 19.31

LSL = LCL = 16.61

μ is the mean i.e. 17.96

σ is the standard deviation i.e. 1.006

Substituting the values into the equation above,

$$\text{Minimum } \left(\frac{19.31 - 17.96}{3 * 1.006}, \frac{17.96 - 16.61}{3 * 1.006}\right)$$

$$= \text{Minimum } \left(\frac{1.35}{3.018}, \frac{1.35}{3.018}\right)$$

$$= \text{Minimum } (0.4473, 0.4473)$$

3.7.2 Cp_k for Bottle fillers

Similarly, from the established data for Bottle fillers,

USL = UCL = 33.23

LSL = LCL = 32.27

μ is the mean i.e. 32.75

σ is the standard deviation i.e. 0.32

Substituting the values into the equation below,

$$\left(\frac{USL-\square}{3\sigma},\frac{\square-LSL}{3\sigma}\right) \text{ from (9)}$$

$$\text{Minimum } \left(\frac{33.23-32.75}{3*0.32},\frac{32.75-32.27}{3*0.32}\right)$$

$$= \text{Minimum } \left(\frac{0.48}{0.96},\frac{0.48}{0.96}\right)$$

$$= \text{Minimum } (0.5, 0.5)$$

The analysis of all these results is carried out in the next chapter.

CHAPTER FOUR

DISCUSSIONOF RESULTS

4.1 Collected Data

Table 3.1 and 3.2 shows the quality control data collated from quality control department of the company. The former gives the volume of Can fillers calibrated at specification limit of 18.51cl minimum with a maximum target of 19.0cl for Can filler, while the latter was calibrated at specification limit of 32.5cl minimum with a maximum target of 33.0cl for bottle fillers. Observations were made on the machines from numbering 1 to 5 and 6 to 9 for Can fillers and Bottle fillers respectively. The detail of the tables has been attached in form of appendix for further referencing.

4.2 Analyzing the Established Parameters

Extracted data from the collated values were used to establish the quality control parameters using excel software and calculator for computation as shown in chapter three of this research work.

For Can fillers machine with five (5) observations (number of machines), the average of the means was found to be 17.96 with range of 1.13. The mean of each of the machine are 17.97, 17.90, 17.97, 17.93, and 17.94 for machine 1, 2, 3, 4, and 5 respectively with standard deviation of 1.00. The Centre Line (CL) was computed to be 17.96 with Upper Control Limit (UCL) of 19.31 and Lower Control Limit (LCL) of 16.61. Furthermore, R-chart was also established using the range values with a statistical constant of D_3, D_4 and A_2. For R-chart, the CL was computed to be 1.13 with the UCL of 2.3843 and the LCL of zero (the zero is due to the fact that the constant value of D_3at n = 5 is zero as stated in chapter three). Alternative values for R-chart was also computed using a constant statistical value of A_2 combining with the established mean. The CL was computed to be 17.96, UCL to be 18.62 and LCL to be 17.30. All the means computed with CL, UCL and LCL above indicates the point at which

the quality of the product will be centered i.e. measure of central tendency while the established the ranges with their respective CL, UCL and LCL shows the level of dispersion or variability of the quality of the process.

Similarly, for bottle fillers, the average of the means was computed to be 32.75 with mean of 32.71, 32.78, 32.75 and 32.78 for machine number 6, 7, 8, and 9 respectively. The average range was also computed to be 0.53 with standard deviation of 0.32. For the CL, UCL and LCL, they were computed to be 32.75, 33.23 and 32.27 respectively. For R-chart, CL, UCL and LCL was also computed to be 0.53, 1.21 and 0 respectively. (The zero value is due to a constant D_3 for n = 4 as earlier explained). Also, for alternative value, i.e. A_2 value, CL, UCL and LCL was computed to be 32.75, 33.14, and 32.36 for CL, UCL and LCL respectively. As mentioned thereon, all these parameters computed above enable the quality personnel to establish the point at which quality of the process will be built at i.e. centered. Any variation or dispersion above the UCL or below the LCL will be called for attention as indicated in the charts. These computations enable the chart to be plotted in order to sight any discrepancy between the set target and what is been obtained.

4.3 The Control Charts

The charts were constructed using the respective established values for Can and Bottle fillers. The means and range values are plotted against the sample/day for X-bar (mean) and Range chart respectively.

Fig.3.1 shows the resulting X-bar (mean) chart for Can fillers. From the chart no point lie outside the control limits i.e. the all the process (data) falls within the predetermined parameters. This further implies that none of the machine process falls out of control, indicating that all the processes are within the specification. However, in Fig. 3.2a which shows the R-chart, out of the 31 samples analyzed, sample 5 and 21 lies outside the established control limits as shown in the chart in fig. 3.2a. This out of control implies that

special cause of process variability has occurred. Therefore, sample 5 and 21 with their respective machining process be subjected to process monitoring in order to fix the issues. Furthermore, Fig. 3.2b shows the combined X-bar and R-chart values using A's statistical constant. Though, this method does not actually interested weather the process is out of control or in controls but rather measures the central tendency and process variability of the samples. From Fig. 3.2b above the samples shows the presents of process variability and dispersion from the established control limits.

Fig. 3.3, 3.4a and 3.4b shows the resulting control charts for bottle fillers using X-bar (mean), Range and the combined values respectively. From fig. 3.3, no point lies outside the established control limits which further indicate that there is no variation or defect in the processes. Also, from Fig. 3.4a, no point lies outside the control limit implies that R-chart and X-bar chart are in conformity with the specification processes. However, in Fig. 3.4b, there is little variation in sample 6 and sample 15 that are out of control due to special or assignable causes such as lack of proper training, mixing error and so many factors that could have been caused by human nature.

4.4 Analyzing the Process Capability Values

The process capability has been established as minimum (0.447, 0.447) and minimum (0.5, 0.5) for Can and Bottle fillers respectively, while their respective process capability index was found to be minimum (0.4473, 0.4473) and minimum (0.5, 0.5). Taking the minimum process capability (Cp) and process capability index (Cpk) values from both fillers i.e. 0.447 and 0.5 for Can and Bottle fillers respectively, it can be deduced that the process used through this establishment, that the processes are similar indicating that the processes are capable of producing good product as earlier review in chapter two of this work when the values are in this range.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The concept of Quality management has been taught to be a hub or core value of every organization wishes to remain in the competitive market either at the process level, the services or the products, because when customers get maximum satisfaction with good product or services, the organization tends to stand above others. Experience has clearly demonstrated that quality is one of the most important factors for business success and growth. Hence, it is important that the issue of quality is taken seriously by every individual and organization alike. According to research, Statistical quality control provides the statistical techniques necessary to assure and improve the quality of products. Based on this view, this project work is carried out on Habila Foods and Beverages Nigeria Limited using statistical technique to check-mate their production (filling) process in order to draw necessary conclusion. The research work is based on materials taught in a Master-level course titled Quality Control, Reliability and Ergonomics in the Department of Mechanical Engineering, Ahmadu Bello University, Zaria -Nigeria. To achieve the set up objectives of this work, quality control data was collated from the Quality Control department of the organization; and thereafter, statistical approach was used to analyze the data, starting from establishment of control limits to construction of charts for visual purposes.

5.2 Conclusion

Based on the findings in this Project work, the following conclusions can be drawn:

1. The control limits for Can and Bottle filling processes was able to be established from the collated data using statistical technique
2. The X-bar (means) and R-charts (ranges) we reconstructed using the control limits established

3. The process capability of the processes and its index were also determined.

In conclusion, the X-bar charts for both Can and Bottle fillers shows that there is no points lie outside the established limits, which further implies that the processes are within the specifications, capable of producing brim filled products i.e. minimum and maximum targets. In other hands, R-charts for bottle also show no point outside the established limits, which is a confirmative to X-bar charts. However, R-charts for Can fillers shows otherwise, hence, out of control sample be subjected to monitoring process. The process capability index established indicates that the processes are capable of filling the products to specifications.

5.3 Recommendations

The researcher strongly recommends based on the finding and analysis carried out in this research work that:

1. Quality control research work should be extended to other section of the organization aside the filling process e.g. the production process, delivery process etc.
2. Since the causes of variation as established by this project work shown by R-charts can be attributed to assignable cause, it is therefore recommended that the operators and personnel should be well trained, educated and sensitized so as to sustain the quality of their products.
3. Out of control samples as shown by R-charts which are due to assignable causes should be subjected to process monitoring and be fix appropriately
4. Management, staff and individual of the organization should be sensitize, enlighten on how important is the concept of quality to their organization performance in the competitive market by taking quality control courses on scheduling bases.

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APPENDICES

Appendix A: Can filler machine observation in centiliters

HABILA FOODS AND BEVERAGES NIG. LTD

Quality Control Department

Can Filler Machines: 1, 2, 3, 4, 5
Shift Circle : I, II, III
Operator: Mr. M.S. Oseni

Date: July, 2014
Specification: 18.5cl Minimum
Target: 19.0cl

Observations							
Machine							
Day	Shift	1	2	3	4		5
07-1	II	18.50	16.73	19.00	18.50	19.10	
07-2	III	18.30	18.50	19.20	19.20	17.28	
07-3	I	19.00	17.90	18.90	19.00		18.70
07-4	II	18.90	17.89	19.50	18.30	17.90	
07-5	III	19.00	18.78	16.90	16.40	19.20	
07-6	I	19.20	19.00	18.48	18.93	17.99	
07-7	II	18.79	19.04	18.93	19.00	19.01	
07-8	III	19.20	18.27	18.93	18.93	18.93	
07-9	I	17.83	18.93	18.34	18.00	18.34	
07-10	II	18.93	17.99	18.89	18.54	18.94	
07-11	III	N/A	18.73	18.29	18.35	17.35	
07-12	I	N/A	18.86	18.34	18.37	18.94	
07-13	II	18.94	17.89	18.36	18.37	18.36	
07-14	III	18.73	18.34	18.43	18.93	18.43	
07-15	I	N/A	N/A	N/A	N/A	N/A	
07-16	II	17.95	18.93	19.00	18.93	19.00	
07-17	III	18.40	19.45	19.65	18.36	17.60	
07-18	I	18.45	19.40	18.78	17.98	18.93	
07-19	II	19.00	N/A	19.00	18.79	18.59	
07-20	III	18.90	18.90	18.90	18.90	18.90	
07-21	I	16.70	18.70	17.89	19.40	17.60	
07-22	II	19.00	16.70	N/A	N/A	18.78	
07-23	III	19.01	19.01	18.90	17.99	19.01	
07-24	I	17.98	17.98	17.98	18.99	19.01	
07-25	II	18.73	18.79	18.93	19.01		N/A
07-26	III	N/A	18.54	18.34	18.24		18.14
07-27	I	18.67	19.01	17.89	18.23	18.24	
07-28	II	18.76	19.01	17.39	18.99	18.90	
07-29	III	18.93	18.65	18.34	18.34	18.90	
07-30	I	18.37	18.37	18.73	18.35	19.01	
07-31	II	19.01	18.56	18.74	18.49	19.01	

Appendix B: Bottle filler machine observation in centiliters

HABILA FOODS AND BEVERAGES NIG. LTD

Quality Control Department

Bottles Filler Machines: 6,7, 8, 9
Shift Circle : I, II, III
Operator: Mr. K. L. Jubril

Date: July, 2014
Specification: 32.5cl Minimum
Target: 33cl

Observations					
Machine					
Day	**Shift**	**6**	**7**	**8**	**9**
07-1	**II**	**32.5**	**33.01**	**32.78**	**31.99**
07-2	**III**	**33.00**	**32.78**	**32.19**	**31.99**
07-3	**I**	**32.89**	**32.78**	**32.39**	**32.88**
07-4	**II**	**32.89**	**33.00**	**32.54**	**33.01**
07-5	**III**	**32.54**	**32.89**	**33.00**	**32.21**
07-6	**I**	**31.78**	**32.00**	**32.27**	**33.00**
07-7	**II**	**32.89**	**33.01**	**32.99**	**32.93**
07-8	**III**	**32.92**	**32.91**	**32.89**	**33.01**
07-9	**I**	**32.78**	**33.01**	**32.79**	**32.98**
07-10	**II**	**N/A**	**32.89**	**32.73**	**32.90**
07-11	**III**	**32.81**	**32.78**	**N/A**	**32.31**
07-12	**I**	**31.99**	**32.89**	**32.98**	**32.31**
07-13	**II**	**32.54**	**32.89**	**32.11**	**33.10**
07-14	**III**	**32.10**	**32.78**	**32.18**	**33.00**
07-15	**I**	**31.99**	**32.00**	**32.91**	**N/A**
07-16	**II**	**32.55**	**33.01**	**32.91**	**31.89**
07-17	**III**	**32.93**	**32.89**	**32.91**	**33.10**
07-18	**I**	**33.01**	**32.75**	**32.89**	**32.85**
07-19	**II**	**33.01**	**N/A**	**31.79**	**32.91**
07-20	**III**	**32.98**	**32.04**	**32.91**	**32.92**
07-21	**I**	**32.98**	**32.93**	**32.98**	**32.98**
07-22	**II**	**32.98**	**32.74**	**33.10**	**32.95**
07-23	**III**	**32.10**	**32.36**	**32.78**	**32.97**
07-24	**I**	**32.98**	**32.95**	**32.98**	**32.92**
07-25	**II**	**32.89**	**32.98**	**33.01**	**33.10**
07-26	**III**	**N/A**	**N/A**	**N/A**	**N/A**
07-27	**I**	**32.90**	**N/A**	**32.98**	**32.56**
07-28	**II**	**33.01**	**32.67**	**32.90**	**32.91**
07-29	**III**	**32.99**	**32.98**	**33.01**	**32.98**
07-30	**I**	**33.01**	**33.00**	**32.91**	**33.01**
07-31	**II**	**32.73**	**32.81**	**32.91**	**32.90**

Remarks: This QC information thereto are confidential and cannot be used by third party. However, it could be used for internal purpose only.

Abdulkareem K. S

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QC Officer

Appendix C: Factors for Three –sigma control Limits of X-bar and R-charts

Sample Size n	Factor for $\bar{x}$-Chart A_2	Factors for R-Chart D_3	D_4
2	1.88	0	3.27
3	1.02	0	2.57
4	0.73	0	2.28
5	0.58	0	2.11
6	0.48	0	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.34	0.18	1.82
10	0.31	0.22	1.78
11	0.29	0.26	1.74
12	0.27	0.28	1.72
13	0.25	0.31	1.69
14	0.24	0.33	1.67
15	0.22	0.35	1.65
16	0.21	0.36	1.64
17	0.20	0.38	1.62
18	0.19	0.39	1.61
19	0.19	0.40	1.60
20	0.18	0.41	1.59
21	0.17	0.43	1.58
22	0.17	0.43	1.57
23	0.16	0.44	1.56
24	0.16	0.45	1.55
25	0.15	0.46	1.54

Source: Factors adapted from the ASTM manual on Quality Control for materials and process