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On the Application of Statistical Quality Control on Nigeria Malt Drink

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Abstract

Controlling and Improving Quality has become an important business strategy for many organizations. This is because any organization that can delight customers by improving and controlling its quality can dominate its competitors. However, this research work focused on the application of statistical quality control technique to Nigeria Malt drink, produced by Guinness Nigeria Plc, 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 research work, quality control data were collected through the secondary source (Ama Brewery Enugu quality control department) and 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 like X-Bar chart, R-chart and CUSUM chart. The variables that were controlled in this research work were sugar level, energy level, protein level, net-weight, and volume content with their standard measurement of 11grams, 243kilojoules, 0.3grams, 330milliliter and 33centiliter respectively.

The resulting Control Charts were also constructed using the parameters developed for better understanding and visibility. From the result, it was found that X-Bar chart for sugar, energy, protein, net-weight, and volume of the process data collected and analyzed lies within the designed range of specified value, implying that the process is capable of producing acceptable product. Then the R-Chart for sugar, energy, protein, net-weight, and volume of the process data collected and analyzed lies within the designed range of specification, which depict that the process is capable of producing acceptable product. CUSUM chart for sugar, energy, protein, net-weight, and volume of the process data collected and analyzed lies within the acceptable range of specified value and this imply that the process produced an acceptable product.

Keywords: Quality Control; Acceptance Regions; Non-Alcoholic Drinks; Company

Background of the Study

Brewery industry is one of the fastest growing sectors of the Nigerian manufacturing industry which plays a significant role in the national economy by contributing about twenty eight percent of the national manufactured value added (MVA). However, there are ten fully operational breweries in Nigeria in addition to two malting plants located in Aba and Kaduna with about twenty-five products which included eight brands of malt drinks Okiwelu [1]. Guinness Nigeria Plc, the producer of Malta Guinness, among other products (Alcoholic and non-alcoholic drinks) is one of the oldest brewery companies in Nigeria and the first Guinness brewery outside of the British Isles Zain [2]. It came into existence and operation on the 30th of November 1963, three years after Nigeria's independence.

Malta Guinness and malt-based drinks are non-alcoholic drink that have advanced progressively over the years for their nutritional benefit Obuzor & Ajaezi [3]. It is conventional consumed as beverage or food for the sick and children, even by all people and as well as soda or cola, either in its original carbonated form or iced ten in non-carbonated form Sarton (2005). Malt is actually a beer that has not been fermented and has a similar colour to shout but it is very sweet, generally described as tasting like molasses. Malt is prepared from cereal grain such as sorghum, wheat, corn, millet and sorghum, but barley is most frequently used Hounhouigan et al. [4].

The preparation which undergoes malting processes, produces Malt which is one of the raw materials used to prepare different alcoholic and non-alcoholic beverages, one of which is the non-alcoholic malt drink popular around the world by its trade name Malt Okonkwo & Ogbuneke [5]. Malta Guinness non-alcoholic drinks produced by Guinness Nigeria plc, comes in two forms of finished products; bottled or canned forms which has some constituted nutritional contents like; Carbohydrate, Sugar, Energy, Protein, Fat, Vitamins, etc. The label on the bottle or the Can also contains an additional information such as Net-weight, Volume, etc. It has been established that the standard level and units of Sugar, Carbohydrate, Energy, Protein, Net-weight, and Volume in Malta Guinness bottle or can 11grams, 14grams, 243kilojoule, 0.3grams, 330milliliter and 33 centiliter, respectively.

Quality control (QC) is not an optional extra in food processing; neither is something done only by large manufacturers. It is an essential component of any food processing company, which need not be time consuming, expensive, or complex and the results of quality control tests should only give the required amount of information as well as help in saving money in the long run Oladimeji et al. [6]. However, Quality Control (QC) is a method of estimating the quality of the whole products from the quality of sample product.

Statistical Quality Control has been defined as an economic and effective system of maintaining and improving the output throughout the whole operating process of specification, production and inspection based on continuous testing with random samples. Over the years people refers to Quality Control as the inspection of finished products, meaning to check whether they meet the desired requirements and specifications. Although it is not just limited to inspecting products as it might also include detecting the cause for non-conformities. Statistical quality control or statistical process control is mostly used in manufacturing industry where these techniques are used to regulate and analyze the variation of industrial process. The major reason why regulating process is very necessary in production is that the product produced meets the desired specification for which it is made.

Scholars over ages have used statistical quality control techniques to study and investigate different problems which serves as a local point in the study. Akinola [7], examined 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. The result came out that most banks do not use the QC technique to improve their services to the populace and further recommended based on the finding that banks should improve their service delivering system using statistical process control mechanism. Teren et al. [8] applied statistical quality control in monitoring, packaging, and marketing process of sachet water using p-chart, u-chart, x-bar and R-charts as well as process capability chart. The result indicated that p-chart and u-chart were not in control for production and packaging, but the reverse is the case for x-bar chart and R-chart. Yusita et al. [9] researched on methods in weaving section using statistical process control and came to conclusion that the number of defective items are out of control. Kevin et al. [10]carried a research on production process of garment at golden flower Ungaran in an effort to control the level of product damage at the end, they came to conclusion that the chart shows that the product quality control process is not in control. Nowadays, there seem to be no good checks on the quality of some products dished out to costumers for consumption, especially at the remote areas which makes one to ask if the quality standards are still made use of in an industries? This research work intends to check if the quality standards are still maintained in Nigeria Malta drink by applying Statistical quality control measures on 33cl Canned Malta Guinness. The considered variables or attributes of interest are Sugar (g), Energy (kJ), Protein (g), Net-weight (ml) and Volume (cl).

Quality Specifications

The quality of foods and beverages or ingredients can be measured in different ways, but one popular method is to describe 'quality attributes, and specification can then be written and agreed with the supplier or seller, which lists the quality attributes that are required in a food Swetman [11].

Control chart

Graphical display of the actual measurement of the characteristics on a chart showing limit which reflect the process capability on the particular quality characteristics.

Materials and Methods

Data collection

The data used in this research work were secondary data. The data were collected from the one of Nigeria brewery. Moreover, it was collected on some nutrients like sugar, protein, energy, net-weight and volume for complete 20days, that's from Monday to Friday from morning shift to evening shift in the month of August 2021. However, 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 [12], SQC encompasses three broad categories:

Descriptive Statistics: These are statistics used to describe quality characteristics and relationships. They include statistics such as

i. Mean

ii. Standard deviation

iii. Range and a measure of the distribution of data.

The Mean: This measures the central tendency of a data. It is represented mathematically by

$$\bar{x} = \sum_{x=1}^{n} \frac{x_i}{n} \qquad (1)$$

Where is the mean, $\sum$ is the sigma denoting summation of sets of and is the total number of data set considered.

The Range: This is the simplest and most straight forward measure of dispersion. It is the difference between the maximum and the minimum values in the data set. It is denoted by:

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$$R = \max_{(xi)} - \min_{(xi)} \quad (2)$$

The Standard Deviation: This measures the amount of data dispersion or deviation around the mean or average. It is represented mathematically by:

$$\hat{\sigma} = \sqrt{\frac{\sum_{x=1}^{n} (x_i - \bar{x})^2}{(n-1)}} \quad (3)$$

Where represents standard deviation of data set and is the total number of data set.

The Standard Error: This error of the mean of the distribution of the sample means is designated by :

$$s_x = \frac{s}{\sqrt{n}} \quad (4)$$

s is the standard deviation for sample, 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.

Statistical Process Control (SPC) chart

Statistical Process Control (SPC) is an industrial standard methodology for measuring and controlling quality during manufacturing processes. Quality data in the form of product or process measurement are obtained in real time from various machine or instrument during manufacturing. The data collected is used to evaluate, monitor and control a process. The primary tools used for SPC is the control chart, a graphical representation of certain data collected or recorded for specific quantitative measurements of the manufacturing processes are tracked on various control chart in comparison to their sampling distributions. Different types of control chart that can be used to test for the causes of these variations are -chart, -chart, -chart, -chart etc, all these chart represent how quality characteristics is changing value from one sample to another. Measurable or continuous attributes or variable can be accessed by plotting either the mean of the measurement (-bar chart) or the range the measurement (-chart). -chart may also be used when the characteristic representing the quality of products is discrete and -chart when considering proportion of defectiveness in the sample means. This study considered attributes that are measurable and made use of -bar chart and -bar chart

X-bar chart

X-bar chart is made up of the central line which represent the mean of the process. This procedure generates X-bar control charts for variables. The format of the control charts is fully customizable. The data for the subgroups can be in a single column or in multiple columns. This procedure permits the defining of stages. The center line can be entered directly or estimated from the data, or a sub-set of the data. Sigma may be estimated from the data, or a standard sigma value may be entered. A list of out-of-control points can be produced in the output, if desired and means may be stored to the spreadsheet.

X-bar charts are used to monitor the mean of a process based on samples taken from the process at given times (hours, shifts, days, weeks, months, etc.). The measurements of the samples at a given time constitute a subgroup. Typically, an initial series of subgroups is used to estimate the mean and standard deviation of a process. The mean and standard deviation are then used to produce control limits for the mean of each subgroup. During this initial phase, the process should be in control. If points are out-of-control during the initial (estimation) phase, the assignable cause should be determined, and the subgroup should be removed from estimation. Determining the process capability may also be useful at this phase. Once the control limits have been established of the X-bar charts, these limits may be used to monitor the mean of the process going forward. When a point is outside limits, it indicates that the mean of the process is out-of-control. An assignable cause is suspected whenever the control chart indicates an out-of-control process. For modified charts, warning limits are introduced in addition to action limits to make it more sensitive to small shifts.

So as to be able to implement control over process, we set a limit and variability due to chance effects at approximately ±3. Since ±3 represent 79.73% of the total population, all the values recorded that falls within this range are considered to have variability due to chance causes. It simply means that fewer than 3 cases in 1000 of a measured characteristic will exceed the ±3 range by falling in the extreme tail of the distribution. This superimposes an upper and lower sigma control limit ±3 on readings taken on the product. If the process happens to be out of control due to assignable cause, there will soon be evidence of a substantial deviation from the established ±3 limits. Many a time's correction action is indicated to regain control of this process. The X-bar chart function is to check if there is a shift in the mean value of the production process using the ±3 limits.

Control chart formulas

Suppose we have subgroups, each of size *n*. Let , represent the measurement in the sample of the subgroup then the subgroup mean is calculated using

$$\bar{x} = \sum_{i=1}^{n} \frac{x_{ij}}{n} \quad (5)$$

The X-bar Chart Center Line (Grand Mean)

In the -bar Charts procedure, the grand average may be inputted directly or estimated from a series of subgroups by

$$\bar{\bar{x}} = \frac{\sum_{i=1}^{k} \sum_{i=1}^{n_j} x_{ij}}{\sum_{i=1}^{k} n_j} \quad (6)$$

However, if the subgroups are of equal size, then equation (6) reduces to

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$$\overline{\overline{x}} = \sum_{i=1}^{k} \frac{\overline{x}}{k} = \frac{\overline{x}_1 + \overline{x}_2 + ... + \overline{x}_k}{k} \quad (7)$$

R- bar chart

X-bar chart only shows whether or not the sample means are moving significantly away from the process mean, but it does not give any induction of variability within the samples, it is therefore necessary to draw a complementary chart for variability. R-chart depicts variation in the range of sample lot drawn from production. The central line, lower and upper control limits (LCL and UCL) are as

The Central line = R (8)

$UCL=D_4R$ (9)

$LCL=D_3R$ (10)

Sigma for Ranges

Range or the standard deviation of the subgroups may be used to estimate sigma, or a known (standard) sigma value may be entered directly. If the standard deviation (sigma) is to be estimated from the ranges, it is estimated as

$$\overline{R} = \frac{\sum_{i=1}^{k} R_i}{k} \quad (11)$$

$$\hat{\sigma} = \frac{\overline{R}}{d_2} \quad (12)$$

$$d_2 = \frac{E(R)}{\sigma} = \frac{\mu_R}{\sigma} \quad (13)$$

The calculation of requires the knowledge of the underlying distribution of the . Make the assumption that the follow the normal distribution with constant mean and variance, the values for are derived through the use of numerical integration. It is important to note that the normality assumption is used, and that the accuracy of this estimate requires that this assumption be valid. When is one, we cannot calculate since it requires at least two measurements. The procedure in this case is to use the ranges of successive pairs of observations, Hence, the range of the first and second observation is computed, the range of the second and third is computed, and so on. The mean of these estimated ranges is used to estimate standard deviation

$$UCL = \overline{\overline{X}} + m\left(\frac{\sigma}{\sqrt{n}}\right) \quad (14)$$

$$LCL = \overline{\overline{X}} - m\left(\frac{\sigma}{\sqrt{n}}\right) \quad (15)$$

Where is a multiplier (usually set to 3) chosen to control the likelihood of false alarms (out-of control signals when the process is in control).

CUSUM Chart

A cumulative sum (CUSUM) chart is a type of control chart used to monitor small shifts in the process mean. It uses the cumulative sum of deviations from a target. The CUSUM chart plots the cumulative sum of deviations from the target for individual measurements or subgroup means.

Results and Discussion

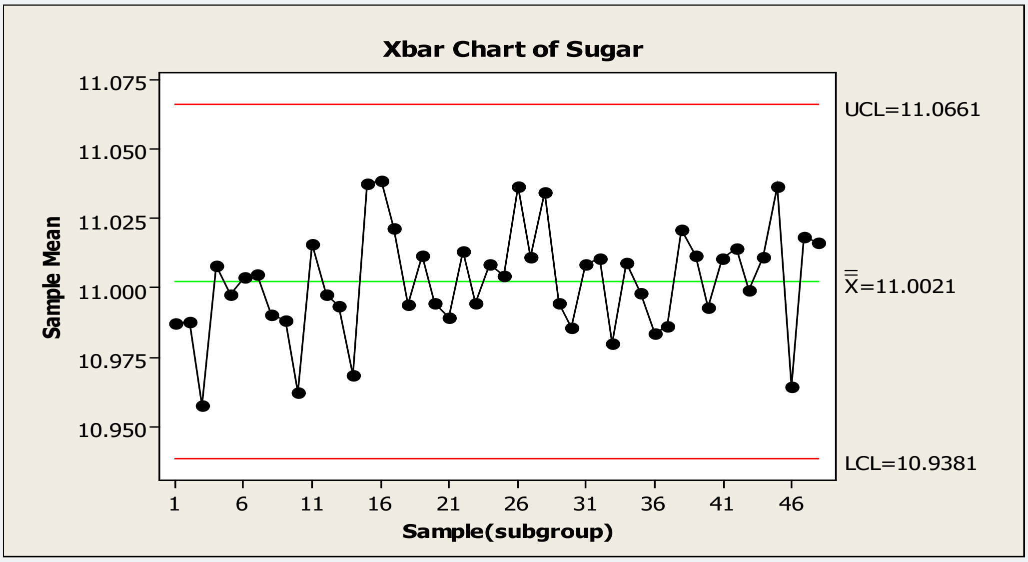

Figure 1: X-bar chart plot for sugar content (g).
Source: Authors' analysis (2022).

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The graph of (Figure 1) represents the X-bar chart for sugar. The data set collected for 20days were analyzed in R software and the upper control limits (UCL), lower control limits (LCL) and central limit(CL) or the average were estimated to be 11.0661, 10.9381 and 11.0021 respectively. The plots lie within the boundaries of both upper and lower control limits, and this suggests that the standard measurement for sugar contents as suggested by the producer of Nigeria Malta Guinness drinks is appropriate and correct. The product is under control for sugar composition as claimed by the company and this means that the appropriate and acceptable products are still being dashed out to the public for consumption .

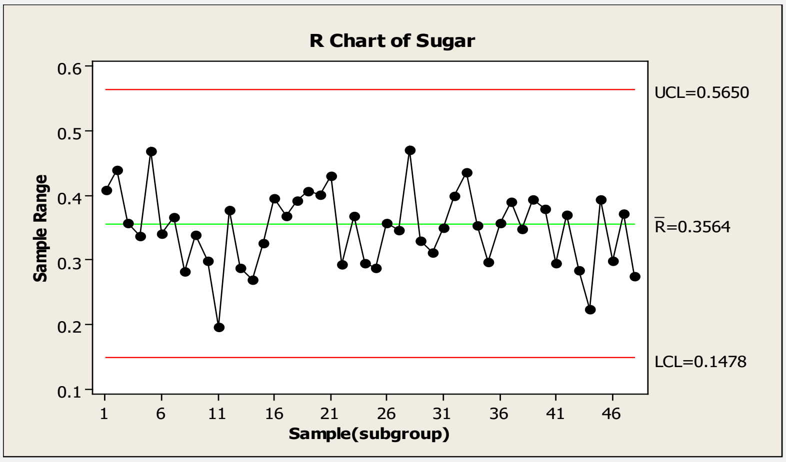

Figure 2: Plot of R-chart for sugar content (g).
Source: Authors' analysis (2022).

However, (Figure 2) depicted the plot of R-chart for the same quality or attribute, which is the sugar composition of the canned Nigeria Malta Guinness drink. The plots in the graph in (Figure 2) are all revolving within the boundary which were the upper control limit and the lower control limit with 0.5650 and 0.1478 warning signals as indicated in (Figure 2). The result indicated from the plots that the attribute which is the sugar content in (g) is within the acceptable regions and hence under control**.**

(Figure 3) represent the CUSUM chart for the attribute of sugar (g) contents in 33cl canned Nigeria Malta non-alcoholic drinks. This representation justifies that the product's production standard are still maintained over the period the data were collected and are justifiably accepted for public consumption.

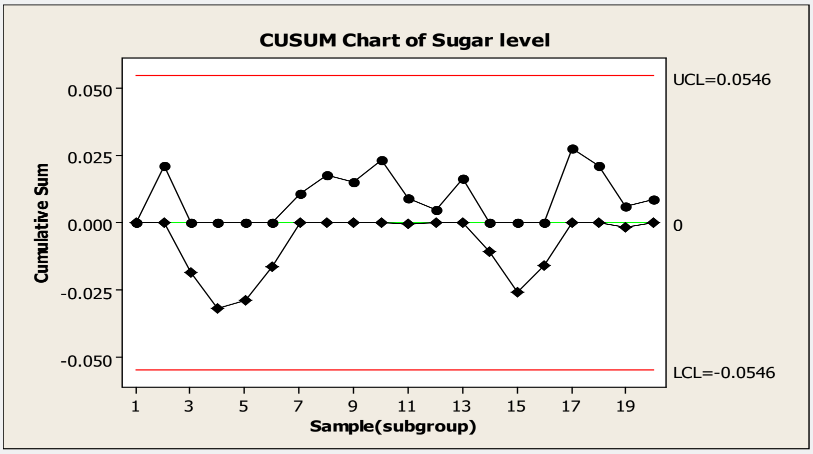

Figure 3: CUSUM chart for sugar content (g).
Source: Authors' analysis (2022).

There are no data points that is not being captured by both upper and lower control limits in (Figure 4). This (Figure 4) is the x-bar chart plots for energy (k/J) contents of the controlled product. The chart of (Figure 4), interprets that the products under investigation is in control as far as its energy composition is concerned.

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These readings: 0.5911, 0.3729 and 0.1546 represents the signal points for the upper control limit, central limit and the lower control limit for energy in an R-chart plot. The plot shows that the readings are in under since none of them escaped the signal lines (UCL or LCL). R-chart in figure 5 supports that of X-chart in (Figure 4), justifying that energy (k/J) constituent of the product under study is intact and causes no harm to the populace when consumed. The Cumulative sum chart plot for energy (k/J) content of Nigeria Malta Guinness is represented in (Figure 6). The chart indicated that CUSUM chart is in line with other plotted charts, meaning that energy composition of the product investigated is under control. (Figure 7) This represents the x-bar chart for protein content of the investigated product. It is under control judging from the signal readings and the components of the plot.

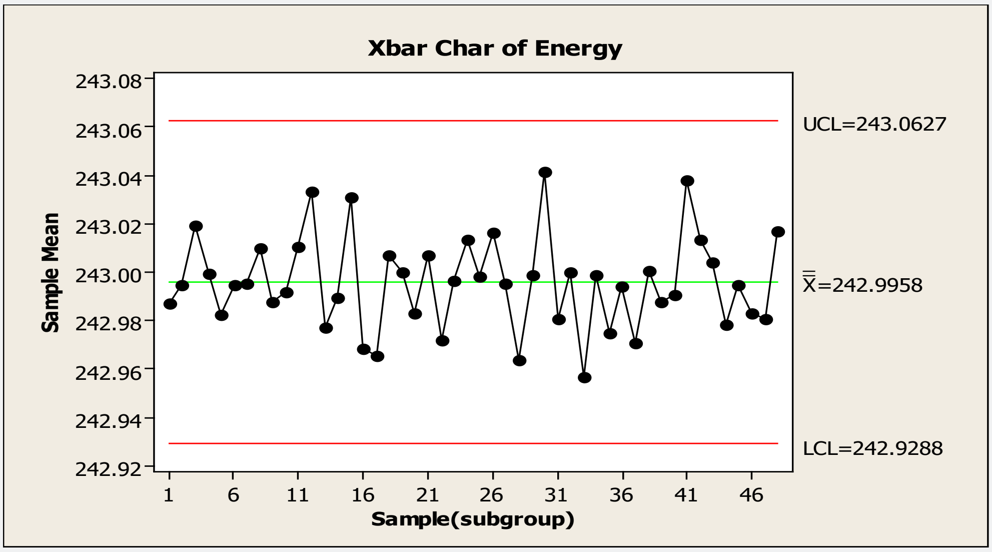

Figure 4: X-bar chart plot of energy composition (k/J).
Source: Authors' analysis (2022).

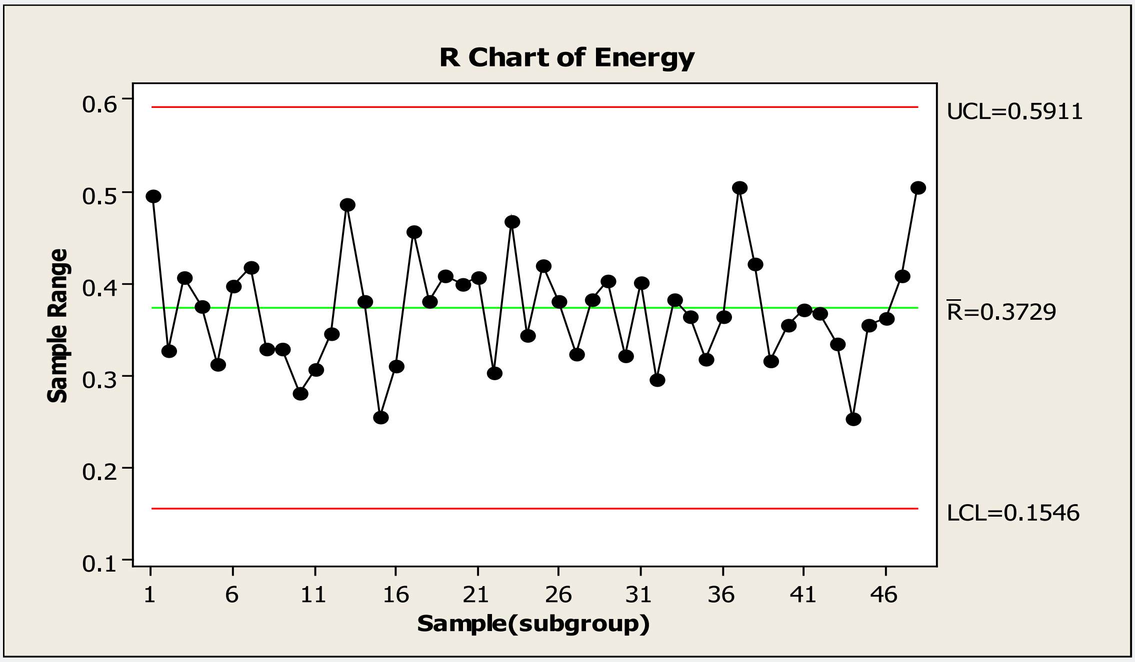

Figure 5: R-chart plot of Energy composition (k/J).
Source: Authors' analysis (2022).

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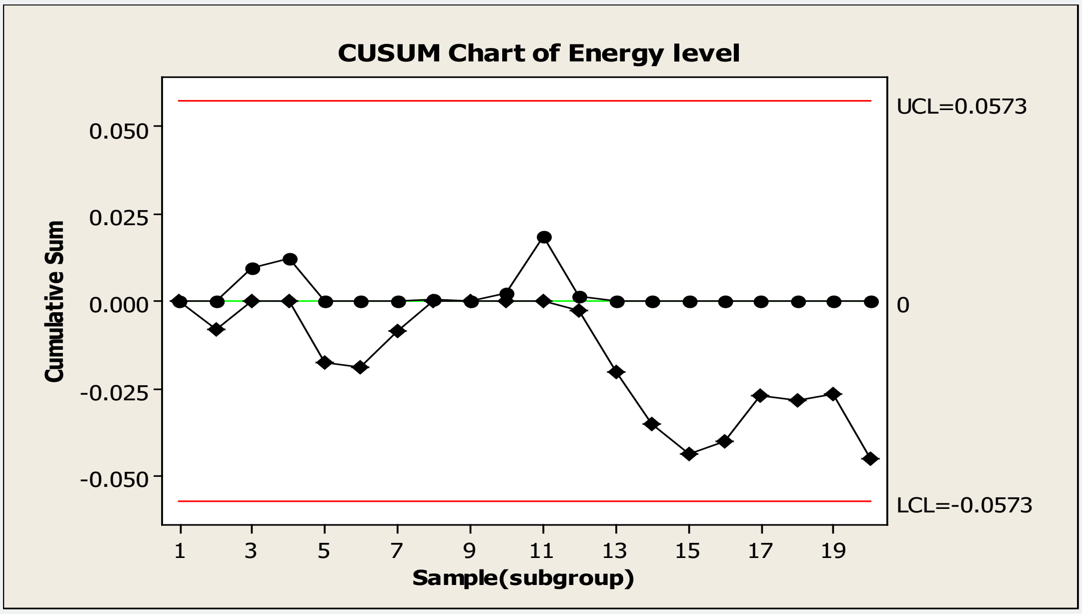

Figure 6: CUSUM chart of energy composition (k/J).

Source: Authors' analysis (2022).

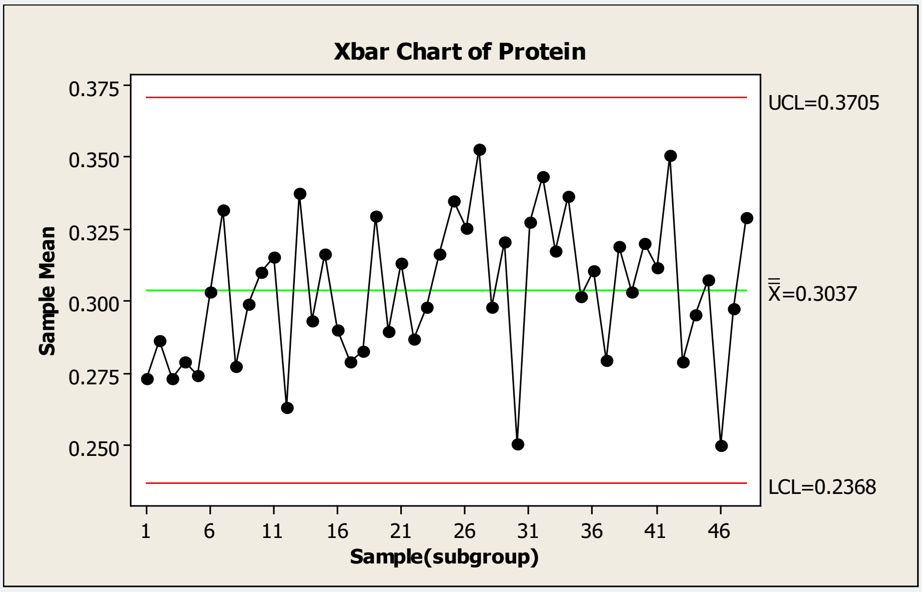

Figure 7: X-bar chart plot of protein composition (g).
Source: Authors' analysis (2022).

This chart of (Figure 8) also showed that the composition of the product under investigation is in acceptable region and is therefore accepted for public consumption. (Figure 9) This is a representation of protein content of Nigeria Malta drink in a CUSUM chart. The result of the chart matches with the other charts and proves that the quantity of protein as contained in the case product is within the required standard.

The -bar chart plot for net-weight (ml) of the product under study is presented in (Figure 10). According to (Figure 10), the charts plots are within the upper and lower control signals. This shows that the attribute under investigation is in control.

(Figure 11) This is the quality control chart of net-weight (ml) of the product under being studied, presented in an R-chart. The chart plots were seen clustered within the acceptable region of

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interest as can be attributed by the other chart of (Figure 10). The CUSUM chart for the net-weight of the product under review is presented in (Figure 12). The chart attributed that the net-weight of the product is under control. (Figure 13) The chart examined whether the product under study is in control or out of control. The volume (cl) of the product considered is in control and this judgment was based on the plots in the charts. No plot is seen outside both the upper control limit and lower control limit. R-chart plot for volume attribute of the controlled product is displayed in (Figure 14). The upper control limit, average for R and the lower control limit are 0.5809, 0.3664 and 0.1520, respectively. All the plots are seen within the acceptance region of the graph, and this suggests that the attribute of the product under control is in control. In addition, the CUSUM chart for volume attribute of the controlled product is depicted in (Figure 15). The plots suggested that the product is acceptable for public consumption.

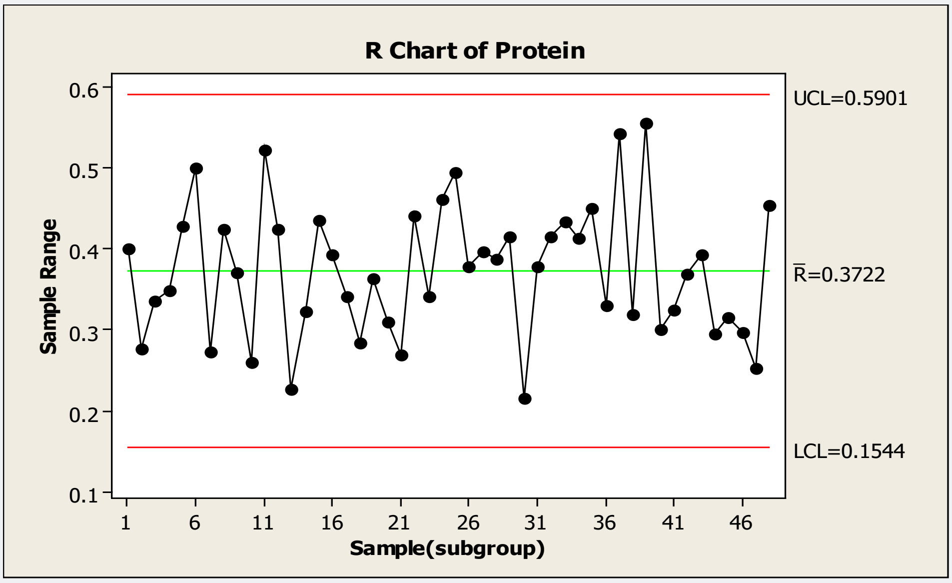

Figure 8: Plot of R-chart for protein content (g).
Source: Authors' analysis (2022).

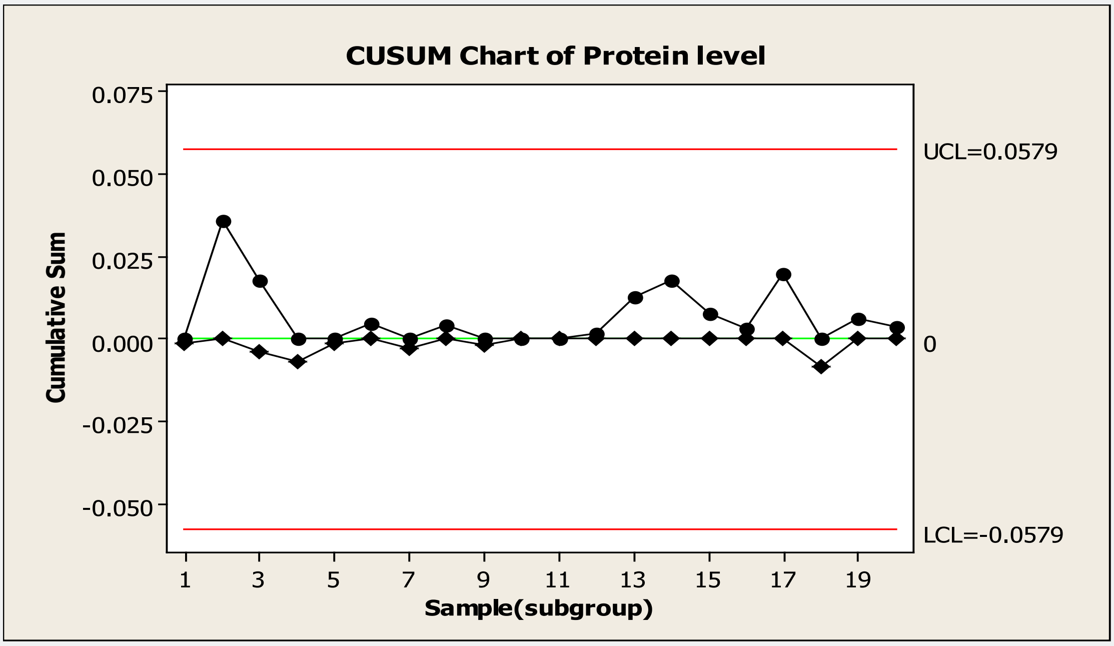

Figure 9: CUSUM chart of Protein composition (g).
Source: Authors' analysis (2022).

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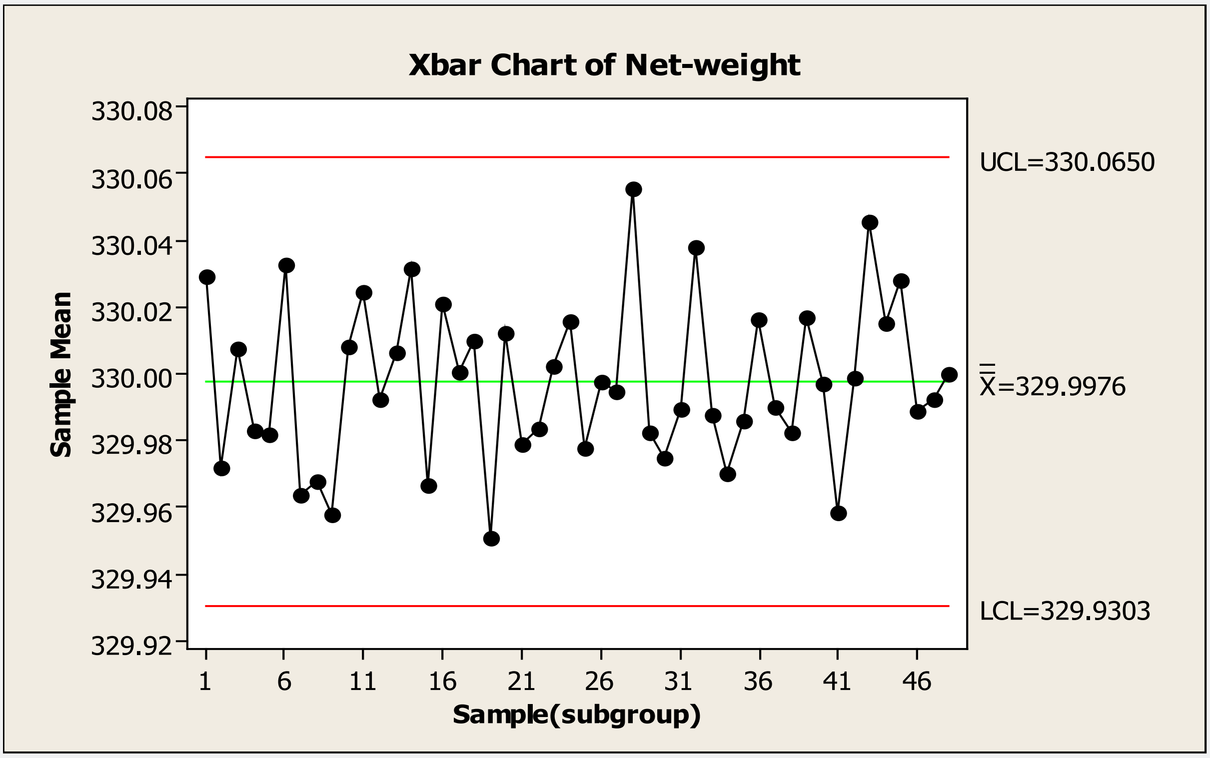

Figure 10: X-bar chart plot of net-weight (ml).
Source: Authors' analysis (2022).

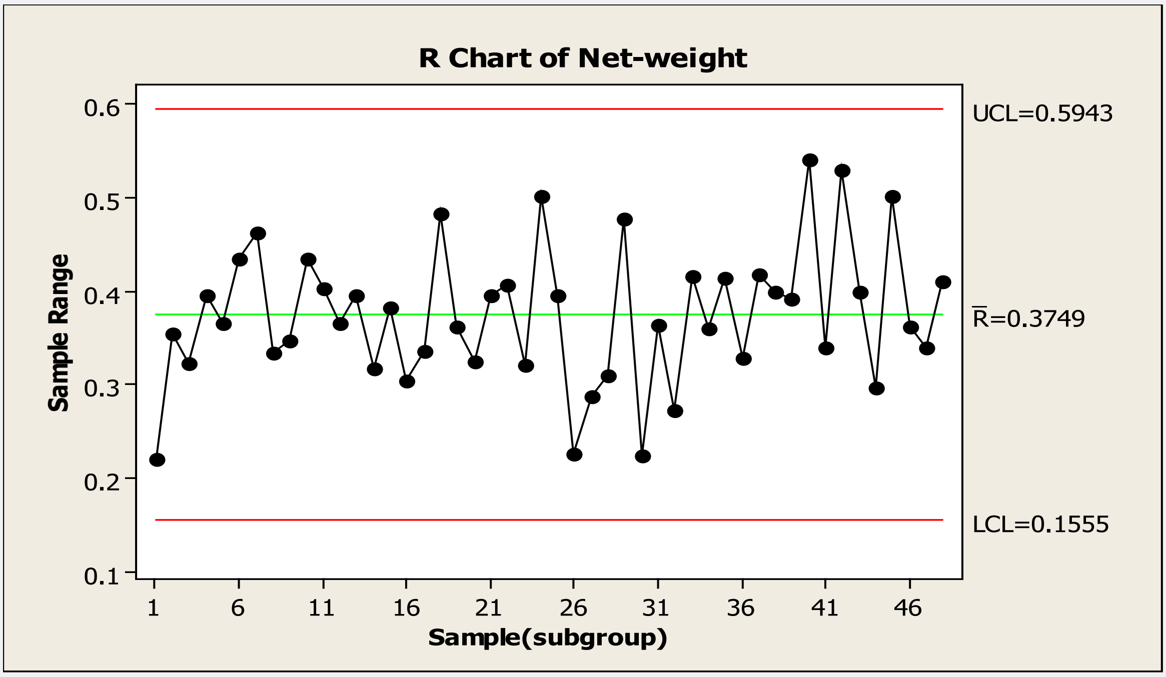

Figure 11: Plot of R-chart of net-weight (ml).

Source: Authors' analysis (2022).

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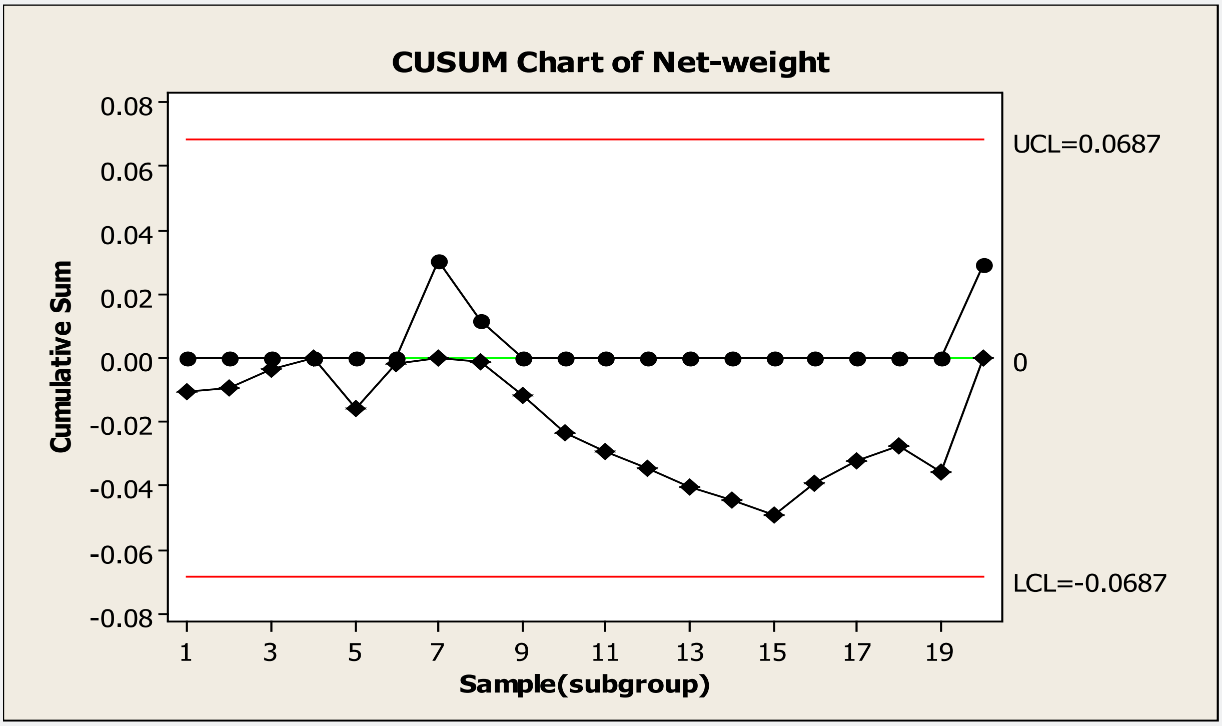

Figure 12: CUSUM chart of net-weight (ml).

Source: Authors' analysis (2022).

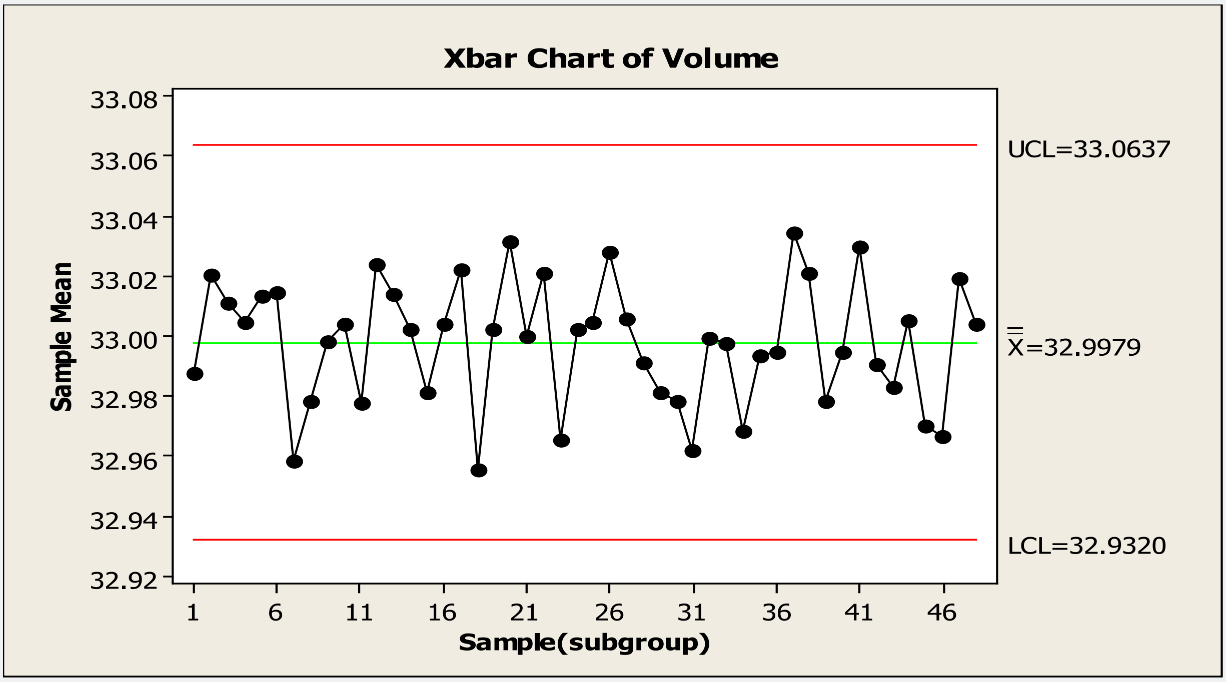

Figure 13: Plot of X-chart for volume (cl).

Source: Authors' analysis (2022).

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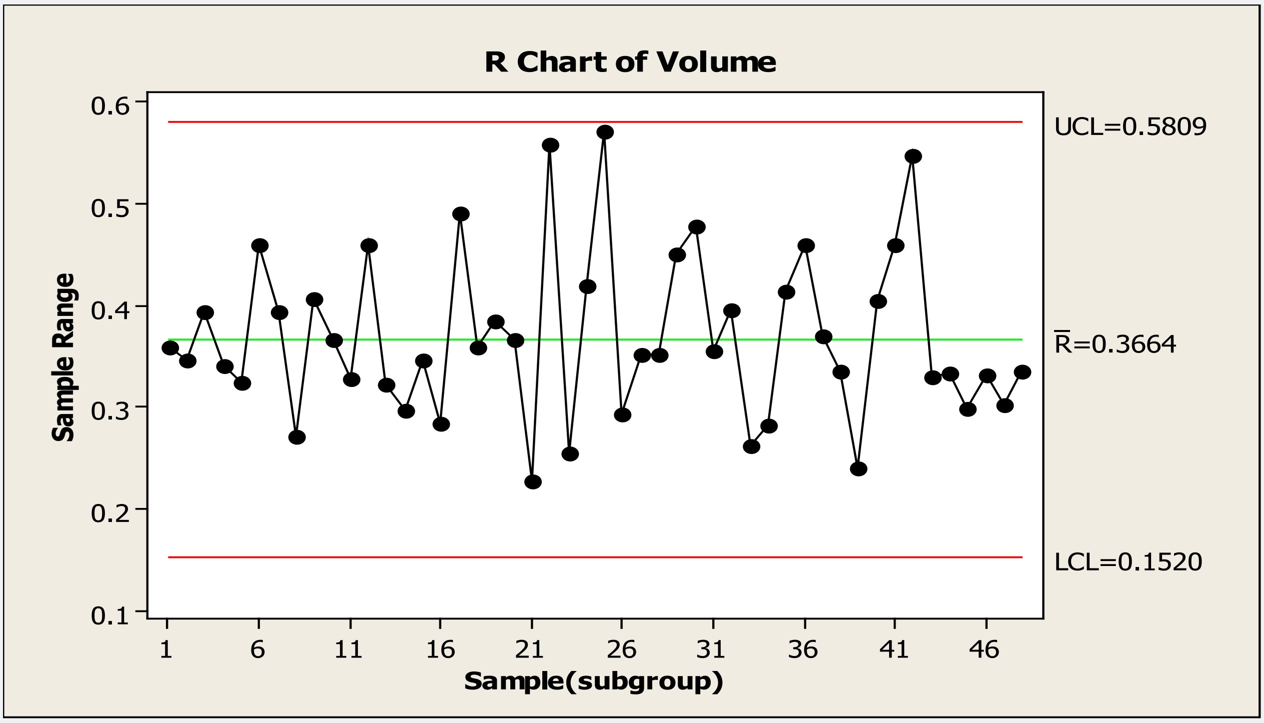

Figure 14: R-chart for volume (cl).

Source: Authors' analysis (2022).

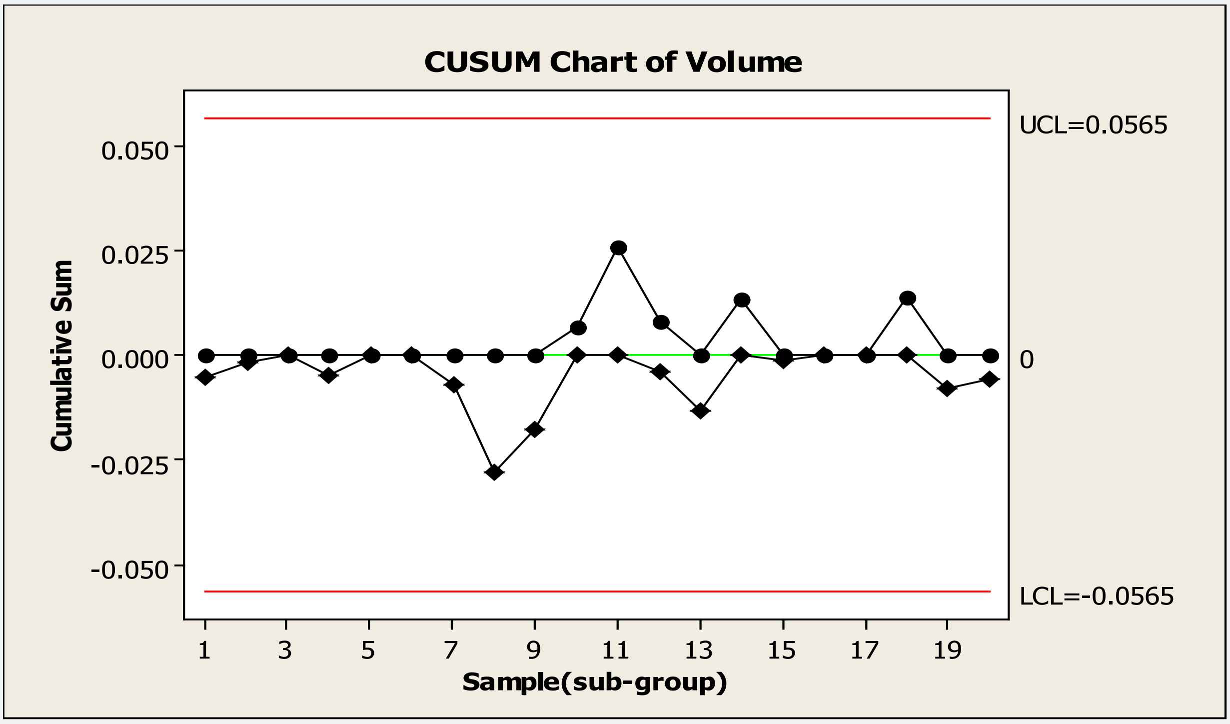

Figure 15: CUSUM chart for volume (cl).

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Conclusion

The concept of Quality management has been taught to be a hub or core value of every organization if it 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 products 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.

A product manufactured by Nigeria Guinness Company was controlled for some of its attributes like sugar, energy, protein, net-weight, and volume using statistical quality control. The analysis performed with an R software clearly proved that all the graphs/charts plotted for those considered attributes were under control. The result of this study indicated that Nigeria Guinness Malta drink is massively demanded in the market. There could have been other attributes to be evaluated in the product under study, but the considered attributes were chosen by choice. The product under consideration in this study competes favorably in the market because the quality control section of the production plays a commendable work in making sure that all products, they manufacture especially Malta Guinness is accurately accessed.

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