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Application of Statistical Process Control Chart in Food Manufacturing Industry

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Abstract— *Statistical Process Control (SPC) charts are simple graphical tools that allow monitoring of process results. They are used to describe the type of variance that exists within the process. They highlight areas where further investigation could be needed. The purpose of the study was to use statistical control charts to examine the production process of buff sausages in the food manufacturing industry. The mean (X-bar) chart and range (R) chart were used in the study to assess if the production process was under control. The weight of 100 packets of buff sausages was measured (in grams) using a weighing scale. In order to collect information about the manufacturing process of the buff sausage, the interview of operations manager was followed by the observation of the buff sausage production plant. The result of mean chart shows that the within subgroup variation is consistent because all the sample points fall within the three-sigma upper and lower control limits. The range chart displays that all the sample points are within the two-sigma control limits. The buff sausage manufacturing process is therefore in a state of statistical control. However, the production unit can still seek to further improve performance to maintain consistent quality of the product.*

Keywords— ***Statistical Process Control (SPC), Mean Chart, Range Chart, Control Limits, Sausage, Food Industry, Three-sigma***

I. INTRODUCTION

Statistical process control (SPC) is the process of inspecting a product or service as it is being made [1]. In manufacturing processes, statistical process control (SPC) is widely used to analyze how reliably a product performs according to its design specifications. If there is reason to think that the process has a problem, then it can be stopped and it is possible to find and fix the problem [2]. The importance of the SPC is not only to check a single sample, but also to track the consistency over a period of time. It accomplishes this by utilizing control charts to assess if the mechanism appears to be working, as it should, or whether it is 'out of control.' Control charts have long been used for methodologies such as six-sigma and total quality management in production and process improvement. A control chart's aim is to define upper and lower limits of appropriate output in the face of normal variation [3, 4].

The fact that quality food is crucial to maintaining good health is well known. People are becoming worried about the quality of the food they consume. As a result, the food industry is concerned with maintaining a high degree of quality in their processed products in order to satisfy the demands of a more sophisticated customer. Therefore, the determination of food quality requirements and the application of quality management tools are an important topic in the food industry [5].

Because of a series of food safety crises and controversies, food quality, including safety, has become a major concern for the food industry. When they pass through the product development process and supply chain, the quality of food products increasingly changes, which can lead to major social, economic and environmental consequences [6]. In the manufacturing industry, specifications for the finished product are defined. The manufacturing method that does not follow the requirements causes the production of low-quality goods that can result in losses for the company [7].

The control limits applied to the control chart display the estimated magnitude of the variance of the 'common cause.' If any points are beyond these control limits, in the sense that variance is likely to be due to assignable causes, the mechanism may be considered out of control [8]. By analyzing past variations during a time where the method was assumed to be free of any variance that could be attributed to assignable causes, these control limits could be set intuitively. But in a more statistically revealing way,

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control limits can also be set. For example, control charts are optimized for speed in industrial settings: After a process change, the sooner the control charts react, the quicker the engineers can locate the broken machine and return the device to produce high-quality goods [7, 9].

In Nepal, the total number of industries registered in fiscal year 2018/2019 was 7967 with total capital 1963,742.48 million rupees (NPR). Out of total industries, 3017 were manufacturing industries. In Bagmati province, there was 5359 numbers of industries registered in 2018/2019. In the Kathmandu district, there were 163 numbers of industries registered in FY 2018/2019 [10]. Among 17 manufacturing industries registered in 2018/2019 in Kathmandu district, one food industry was chosen for the study. The selected industry is a food manufacturing company and located in Kathmandu district. The major finished products of the industry are sausage, salami, packed meats, seafood, cured meat, and cold meat of chicken, buff, and the pork. Although the industry has used quality control tools, it is always necessary to determine the quality of a food product in different production lot [11]. Therefore, the purpose of the study was to use statistical control charts to examine the production process of buff sausages in the food manufacturing industry.

II. METHOD

The food manufacturing industry located in Kathmandu was selected purposively for the study. The most popular finished product of the industry was a meat product. Out of many meat products, the buff sausage was selected for the study. In this study, the pieces of the animal eaten as food are referred to collectively as meat. People eat meat because it is known as an important source of essential amino acids (proteins), iron, vitamin B as well as other nutrients and minerals [12].

The case study research design was employed in the current study as it helps to focus on the specific topic of interest. The research process was done with thorough study, meticulous and systematic way. In order to collect information about the making process of the buff sausage, the interview was conducted with the operations manager of the food industry in the month of June 2019. The interview mainly focused on the raw materials used, production process, and quality management process of a buff sausage. The interview was accompanied by an observation of the manufacturing process of the buff sausage.

2.1 Weight Measurement of Buff Sausage

A total of three packets of buff sausage were purchased from the three different supermarkets of Kathmandu, and weight of each packet was measured with digital weighing pan. The standard weight was found to be 500 gms. The production plant division allowed researcher to measure the weight of a buff sausage-using adapter weighing scale. The sample buff sausage was selected randomly from the production line in different time periods during factory visit. The weights of 100 packets of buff sausage (sample) were measured during a production process with the help of adapter weighing scale. The weight of each sausage was noted using pen and paper. The unit of measurement of sausage was in grams. The variable data is obtained from the measurements of buff sausage on a continuous scale. Statistical process control chart is applied to analyze the data, that is, weight of buff sausage.

2.2. Statistical Process Control Charts

The collected data (weight of buff sausage in grams) were entered on the excel-sheet. The statistical tools such as mean and standard deviation were calculated. Statistical Process Control (SPC) charts are simple graphical tools that allow monitoring of process results. They are used to classify within the process what form of variance occurs. They highlight areas where further investigation could be needed. The run-chart and the control chart are two of the most common SPC tools [13]. This study discusses on the control charts of variables.

2.2.1 Mean Chart and Range Chart

The statistical process control chart (X bar chart and Range chart) was presented for the quality testing procedure and to determine whether the production process is in control. The control limits for statistical control charts were calculated using the control chart template [14]. The average (X-bar) chart used to test for significant changes in the means of the sample, and the range (R) chart to test for significant changes in the variables' distribution. The R chart is always used in conjunction with the X-bar chart. The control charts were plotted using two sets of limits on control charts. The three-sigma outer limits are referred to as the action limits, i.e. a search for an assignable cause is made when a point plots outside this limit and corrective action is taken if necessary. The inner limits are called warning limits, usually at two-sigma [2, 7].

Three standard deviations either side of the population mean are widely used as control limits. This would mean that by chance reasons, there is just a 0.3 percent chance of any sample mean falling beyond these limits (that is, a

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chance of a type I error of 0.3 per cent). The control limits can be set at any distance from the average of the population, but the closer the limits are to the average of the population, the greater the chance of investigating and attempting to rectify a problem-free method. The probability of a type I error increases to around 5% if the control limits are set at two standard deviations. When the limits are set to one standard deviation, the likelihood of a type I error rises to 32%. When the control limits are set at ±3 standard deviations away from the distribution mean that defines 'normal' variation in the process, they are referred to as the upper control limit (UCL) and lower control limit (LCL) [9, 15].

The first step in calculating the control limits are to estimate the grand average or population mean and average range using m samples each of sample size n. The grand average is estimated from the average of a large number (*m*) of sample means:

$$Grand\ Average, \bar{\bar{X}} = \frac{\bar{X}_1 + \bar{X}_2 + \cdots + \bar{X}_m}{m}$$

The average range is calculated from the ranges of the large number of samples:

$$Average\ Range, \bar{R} = \frac{R_1 + R_2 \ldots . + R_m}{m}$$

The control limits for the sample mean chart are given by

Upper control limit (UCL) = $\bar{\bar{X}} + A_2 \bar{R}$

Lower control limit (LCL) = $\bar{\bar{X}} - A_2 \bar{R}$

The control limits for the range chart are given by

Upper control limit (UCL) = $D_4 \bar{R}$

Lower control limit (LCL) = $D_3 \bar{R}$

The factors A_2, D_3, and D_4 vary with sample size and the value is obtained from the table of control chart constants [7, 9,11].

III. RESULTS

3.1 Production Process of Buff Sausage

a) Selecting Ingredients

The finished product (buff sausage) is as good as the ingredients it contains. As an input to the manufacturing process, the raw material needed to manufacture a finished good is considered. Meat, water, salt, vitamins, vegetable oil, vegetables (onion and chilled) and spices (salt, sausage spices, ascorbic acid, phosphate, sodium nitrite) are the raw materials used by the industry to produce buff sausage. These non-meat ingredients stabilize the mixture and add special characteristics and flavors to the sausage.

b) Grinding Meat Ingredients

The next step is the efficient grinding of the ingredients by a meat-grinding machine. The grinding stage reduces raw meat ingredients to small, evenly sized fragments. In general, the grinding process will vary depending on the manufacturer and the nature of the product. Sometimes the workers do not use the grinding machine to cut the meat; rather the workers use the knife.

c) Blending the Meat and Nonmeat Ingredients

The grinded meat is blended with a blending machine. The production unit carefully monitors the blending of the meat and non-meat ingredients in order to create the desired characteristics for the formulation of the buff sausage. Ingredients such as minced meat, spices, flavoring, and salt are weighted using a weighting machine. In the blending process, the meat is finely blended to ensure uniform distribution of any non-meat ingredients within the product formulation. This blending process makes a paste of ingredients at a low temperature in a machine called a bowl chopper.

d) Stuffing and Filling

In this stuffing process, the blended ingredient paste is filled into the sausage-shaped casing with the help of the filler machine and the sausage is bound to airtight at each end with a string.

e) Smoking

The stuffed sausage is hung on the rod and sent to the smoked chamber. Smoking is used to dry and cure meat for the preparation of smoked sausages and to influence the flavors and aromas of the final product. This process constrained the growth of bacteria in the finished product. The sausage is smoked at a temperature of 60℃ to 65℃ for 30 minutes. The smoking method used to process meat is healthier and sanitary than the traditional method of smoking.

f) Packaging and Storage

The fresh buff product is packaged in a gas-impermeable plastic with a vacuum machine to lock the package. It is placed in a refrigerated storage room. The weight of the buff sausage packaging will vary depending on the needs of the consumer. After all the packaging and labeling process, the vacuum packed buff sausage will be 100% edible.

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3.2. Statistical Process Control Chart

The Mean - Range Chart is the most widely used form of control chart employed to control variables. In fact, the two charts are treated as one. The sample average or mean is monitored using a mean chart. The range chart is used to monitor the variance within the sample by calculating the range (R).

Figure 1 illustrates the mean (X bar) chart. The mean chart shows that the within subgroup variation is consistent because all the sample points fall within the three-sigma upper and lower control limits. Hence, the production process of buff sausage is in a state of statistical control. Although the production process is in control, it can be observed that the sample mean values were moving towards the upper control limit.

Figure 2 illustrates Range (R) chart. The range chart shows that all the sample points are within the two-sigma control limits and the within-subgroup variation appears to be consistent. The buff sausage manufacturing process is therefore in a state of statistical control.

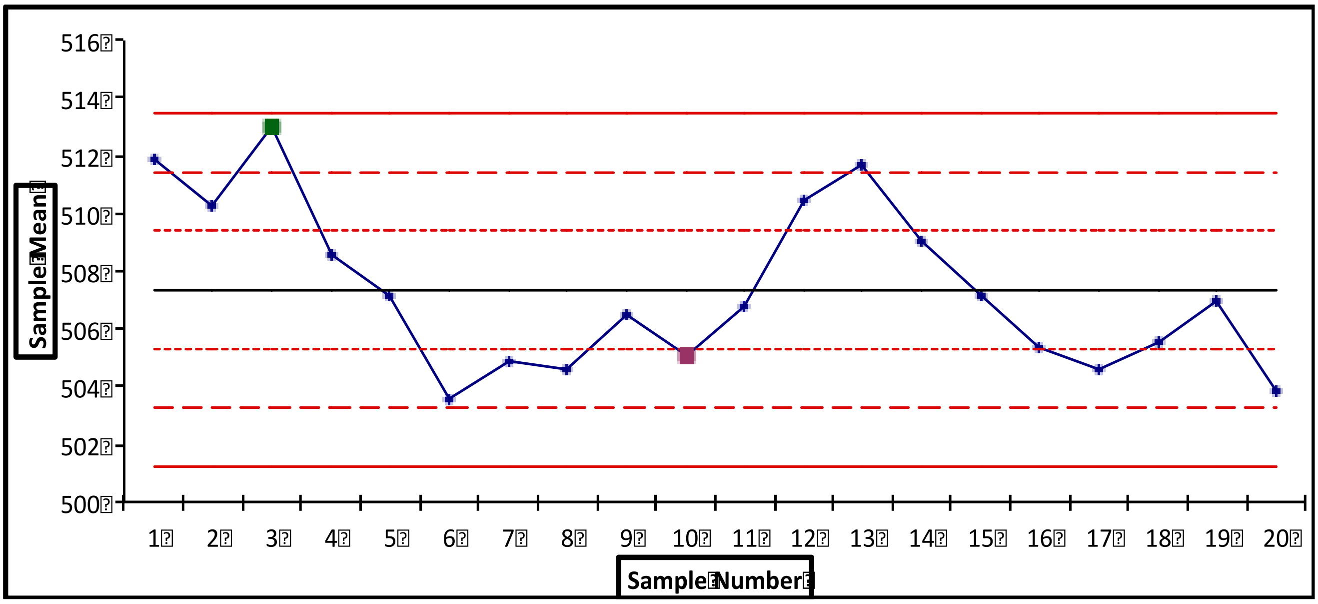
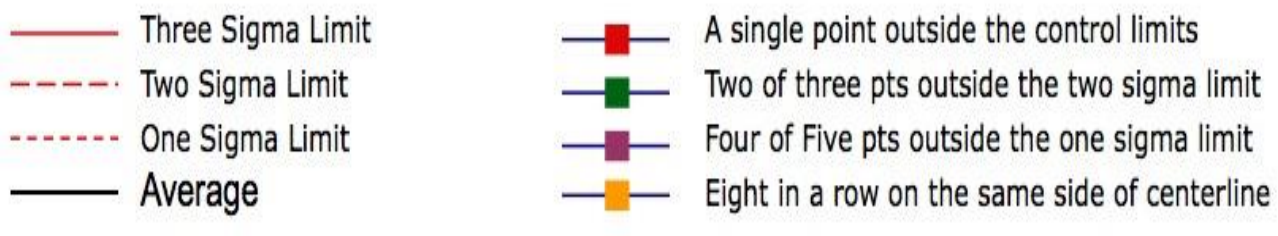


Fig. 1: Mean (X-bar) Chart



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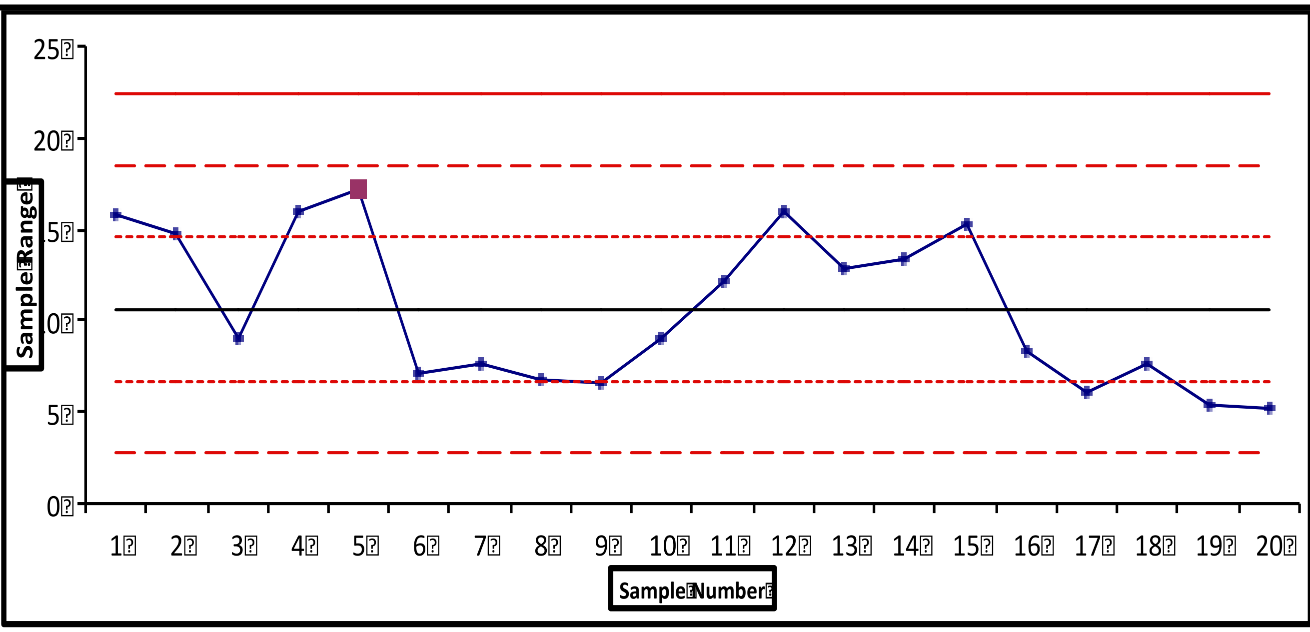

Fig. 2: Range (R) Chart

507.3	Xbar/IMR Chart Avg	509.38	Xbar one Sigma Upper Limit	14.5	Rbar one Sigma Upper Limit
10.6	Range Chart Avg	511.42	Xbar two Sigma Upper Limit	18.5	Rbar two Sigma Upper Limit
4.6	Rbar/d2	513.46	Xbar three Sigma Upper Limit	22.4	Rbar three Sigma Upper Limit
100.0	Number of Samples	505.3	Xbar one Sigma Lower Limit	6.7	Rbar one Sigma Lower Limit
5.0	Subgroup Size	503.27	Xbar two Sigma Lower Limit	2.7	Rbar two Sigma Lower Limit
20.0	Number of Subgroups	501.23	Xbar three Sigma Lower Limit	n/a	Rbar three Sigma Lower Limit

IV. DISCUSSION

Nepal Bureau of Standards and Metrology (NSBM) has provided Nepal Standard (NS) certification to the food industry under study. Nepal Bureau of Standards & Metrology is the National Standards Body of Nepal [16]. The food technologist of Nepal government also visits the industry every three to four months to check the quality.

The raw materials such as beef, spices, and oil are bought from the local market. The workers test the quality by seeing, touching and smelling it while purchasing the meat at the initial stage. Using the standard chemicals such as phosphate, sodium nitride, ascorbic acid given by the Nepal Government, the quality of the food industry is maintained.

The industry has a licensed supplier that guarantees raw material quality. The industry has always been about supplying meat and food items of high quality for everyday consumption. The well-equipped factory consists of the new meat processing equipment from Germany and a well-trained and experienced staff.

There are different items, such as buff sausage, buff cocktail sausage, buff salami roll, and burger patty buff, from the food industry. The output produced with the assistance of the production process mentioned in this study is Buff sausage. The finished product is then sent for distribution to different stores, such as Bhat-Bhateni Supermarket, Salesberry, and Big Mart. There are several external variables that have an impact on the food industry's transformation process. As machines do much of their job, electricity is one of the external factors influencing the process of transformation. During the time of load shedding, the generator is used to begin the transformation process.

In the absence of any goods, such as meat, spices, etc., the food industry will attempt to buy them at a high price from other suppliers. There was a shortage of buff meat recently, for instance, so they tried to buy buff from other sellers. During the scarcity of meat, they also attempted to supply products that are more buff. The entire production process will be stopped during the sudden breakdown of any machine. The production process continues after the machine has been repaired. Some of the components that affect the transformation process of the industry are

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machine and staff. The transformation process includes various machines. The industry uses a variety of machines such as mincer, weighing machines, bowl chopper, filler, and smoked chamber. There are 40 people working in the production plant in two shifts morning and day shift and among them 25 were female and 15 were male. The operations manager collects feedback about the quality of a product from the quality inspectors, and the workers from the production unit. If there is any quality related problems the quality control team will resolve it.

The statistical process control charts (mean and range chart) enable the monitoring of the process level and identification of the type of variation in the process over time with additional rules associated with the control limits. The mean chart and range chart show the production process of buff sausage is in statistical control as all the observed samples were between the upper and lower control limits.

V. CONCLUSION

The buff sausage as an output of food industry was considered for the study. The production process of the buff sausage was observed in the industry. The weight of buff sausage was measured and analyzed using statistical process control charts. It can be concluded that the production process of buff sausage is under statistical control that is no special cause variation is observed. The production system is operating at an appropriate level and hence no action is necessary. However, the production unit can still seek to further improve performance to maintain consistent quality of buff sausage.

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