International Journal of Engineering Applied Sciences and Technology, 2022
Vol. 7, Issue 9, ISSN No. 2455-2143, Pages 138-146
Published Online January 2023 in IJEAST (http://www.ijeast.com)

APPLICATION OF STATISTICAL PROCESS CONTROL CHARTS: A CASE STUDY IN DAIRY INDUSTRY

Bhakta Bahadur Bhandari
Department of Industrial Engineering
Tribhuvan University, Institute of Engineering, Thapathali Campus, Kathmandu, Nepal

Abstract— **Quality is a major part for entire industrial ecosystem when it comes to achieving, maintaining, and, improving the quality of products and services taking consideration of customer needs. Special causes responsible for controllable variations can be detected with the help of quality control charts-one of the quality management tools. Process can be improved by removing detected causes of variation bringing process under control. Statistical Process Control (SPC) Charts are quality control tools based on statistical principles which help to achieve quality of products by detecting special cause(s) of variation in the process involved. This paper incorporates a case study on application of Statistical Process Control (SPC) Charts tested at Sujal Dairy Pvt Ltd, Kathmandu, Nepal. Corresponding mean charts (X-bar charts) and range charts (R-Charts) represent data regarding quality variation for weight of milk pouch and SNF (Solid-Non-Fats) for both packaging machine 1 and machine 2. Results show that SNF variation for both machine and weight variation for machine 2 have been found to be under control whereas weight variation for machine 1 has been found to be out of control. Possible causes of variation have been grouped with the help of fishbone diagram and then compared with standard operating procedures for machine which led to detection of causes of variation. Finally, process has been better improved after removal of detected causes of variation bringing process under control.**

Key Words: **Quality, Control Charts, SNF, variation, root cause, process improvement.**

I. INTRODUCTION

The quality has become one of the major concerns for business environment in both domestic and global market for competitive advantage. Sales determined by customer needs is directly linked to revenue generation. Nowadays, customers have been more focused on products with their best fit. Controlling quality is a key to addressing customers' preferences. Out of different approaches to quality control, this paper specifically focuses on statistical approach to control quality of product determining stability of production process. At the beginning, the concepts of Statistical Process Control (SPC) ware developed by Dr. Walter A. Shewhart of Bell Laboratories in the 1920's, and were further extended by Dr. W. Edwards Deming, who introduced SPC to Japanese industry after WWII. Shewhart analyzed the problem in terms of common and special causes of variation and, on May 16, 1924, came up with his internal memo insisting the control chart as a tool for differentiating these two causes. After successful implementation in Japanese firms, Statistical Process Control has now been followed by organizations across the world as a primary tool to improve product quality by reducing process variation [1]. Today the customers have become more concerned about the quality of the products. The customers search for the products with their best fit. No products can be produced in mass production exactly similar for their quality characteristics due to variation in different input factors such as man, machine, materials, environment, technology etc. According Shewhart mainly there are two types of variations: one is common causes which occurs inherently in the system which needs fundamental changes to reduce and another is assignable causes which can be reduced by removing the causes responsible for the variation. Shewhart developed the use of control chart to distinguish assignable causes form common causes. Shewhart reported that bringing a process into a state of statistical control, where there is only chance-cause (common-cause) variation and keeping it in control was needed to reduce waste and improve quality.

In Nepal, packaged pasteurized milk is one of the popular dairy products particularly in urban areas. The quality characteristics of packaged milk such as weight, SNF and Fat for pasteurized milk is very sensitive for both the market and industrial processing. The processes involved during the pasteurization process and other processes have effects on the quality of pasteurized milk. The variation in weight of skimmed milk pouch is also a major quality variation in dairy industry. This paper focuses to carry out detailed technical application of SPC control charts to control quality of skimmed milk product of Sujal Dairy Pvt Ltd, Unit B, Thankot, Kathmandu, Nepal where quality variation has been analyzed for weight of milk pouch and SNF for both packaging machine 1 and machine 2.

II. LITERATURE REVIEW

Montgomery and Dougkas (2009) give basic introduction to SQC tools in a book. They suggest the importance of quality control charts for quality improvement for both the product and process [2]. Kothari (2004) suggests different methods and techniques used in research methodology in his book, in particular, sampling and its need in engineering research works. What's more, it explains research design methodology for execution of any research. The formula for the sample size determination was referenced from this book. It suggests that the sampling standard deviation calculated from the sampling is the best estimate for the population standard deviation. It clearly suggests researchers to use sampling standard deviation replacing with population standard deviation during the sampling [3].

Budhathoki (2071) provides the basic concepts regarding mean, range, standard deviation for population and sample, normal distribution, standard normal distribution, standard normal variate, sampling, confidence level, confidence interval and margin of error. The Z-score for confidence level of 95% is 1.96 which was used from table provided by him in his book [4]. Knowles (2011) claims that the most common sub-groups size is from 20 to 25 with 4 to 5 samples for each sub group. But it does not provide any theoretical approaches for determining the sample size. Furthermore, he includes basic introduction to SPC and control charts, variation and its types, interpretation of control charts, process control methodology, use of Demings 14 points, Juran's trilogy and Demings PDSA cycle for process improvement after finding the assignable causes [5]. Nedeltcheva, Novakova & Brun (2005) present a case study of an adaptive Shewhart-type control chart in an automotive-component production process. The application of the proposed adaptive Shewhart control had led to accurate real-time information about the state of the process has been provided [6].

Subbulakshmi, Kachimohideen, Sasikumar & Bangusha Devi (2017) give importance to various advantages of SPC implementation in industrial sectors. They came with conclusion that the use of SPC control chart is truly beneficial to all the production industry for quality improvement [7]. Touqir, Islam & Sarkar (2010) provide the practicable case study with control and improvement of the quality of bolt by inspecting the bolt's height, diameter and weight from a bolt manufacturing company using x-bar control chart [8]. Rangel-Peraza (2014) presents the case study for use of SPC control chart for the quality improvement of tomato filling process. Importantly, this provides the methodology of root cause analysis using fishbone diagram [9]. Best and Neuhauser (2006) present a short biography of Walter A Shewhart and his research works, his contributions to the quality improvement along with history behind invention of SPC control chart in their article. It also includes a short paragraph process control using SPC under the subtitle of 'Reducing variation: statistical process control' [10]. The website Castle Inc. (2016) the information regarding interpretation of X-chart and R-chart for quality control. For interpretation of patterns, we must first determine whether or not the R chart is in control. Some assignable causes show up on both X and R charts. If both the X and R charts display a non-random pattern, the best way is to eliminate the R chart assignable causes first. After the variation in the process has been reduced, it will be easier to adjust the process variation. In many cases, despite non-random pattern on the X chart, we should not attempt to interpret the X chart when the R chart indicates an out-of-control condition. It explains further more about the various patterns for control charts including cyclic, shift, trend and stratification [11]. A website of Moresteam Group (2018) presents the methodology for implementation of SPC which explains different steps needed to be performed before and after control chart plotting. After plotting the chart, if there is presence of assignable causes, we move to find the causes and solution for correction of the corresponding problem. Then after the implementation of correct actions, we should take 7 to 10 sub-group data for the verification of improvement of the process [12]. Pokawa (2012) presents the analysis regarding effect of sample size on the SPC process. He has carried out some sampling activities for the manufacturing for different populations at Meat processing industry using statistical methods for determining the sample size with the help of permissible error, confidence level and population standard deviation. He has used the sampling standard deviation and then prepared the control chart and also by his new experiment which gave the similar result and finally concluded that sampling is also an effective approach for SPC control charts [13]. Wooluru, Yerriswamy, & Swamy (2002) present the concepts and methodology regarding process capability and its significance for quality improvement. But it is used only for the process having control stability [14].

III. RESEARCH METHODOLOGY

Relevant books, peer-reviewed research papers, articles, case studies and websites related to quality engineering and management were profoundly reviewed and followed. Additionally, standard operating manuals of the filling machines were another source of literature review to understand the operation, mechanism, maintenance and components. The logbooks of different plant sections were the primary source of daily records. A timely interaction and interview with plant manager, production officer and QC officer including operators and workers of different sections regarding performance and capacity of machines and production planning of the department was another way to carry out case study.

Direct measurements for the weight of each sample pouch of skimmed milk were recorded for assessment of weight variation in milk filling machines. In addition, the operating procedures of machines were thoroughly inspected. In the quality department, the quality testing of pasteurized skimmed milk for Fat and CLR (Corrected Lactometer Reading) required for the calculation of SNF was observed.

For sampling, the calculation regarding determination of sample size for the sampling process for every filling machine and tank was on the basis of the minimum production plan set by production department. Recording was carried out for weight variation of skimmed milk taking 4 samples and 3 samples for machine 1 and 2 respectively for 25 days following data calculated by standard sample size determination formula. For SNF variation, 2 bottles samples for each tank were taken on the basis of sample size calculated using formula. Then, collected data was processed and further analyzed using root cause analysis tool along with fishbone diagram. After detecting possible causes, necessary corrections were kept in place further reducing causes and improving the process.

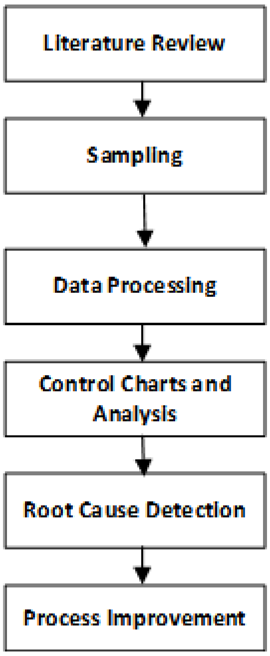

Fig.1. Research Methodology Flow Chart

IV. DATA COLLECTION AND ANALYSIS

A practical case study was performed at the factory for the seminar paper. This presents the use of SPC control charts for analysis of weight variation of skimmed milk pouches for both filling machines and SNF variation of pasteurized skimmed milk for each batch tank. The data has been taken for 25 days from August 18, 2018 to September 16, 2018 with the calculated sample size for each sampling.

For skimmed milk, the minimum daily production plan is 10400 Ltr (Litre). with production of 5200 Ltr. production per batch according to production office. Here two filling machines are used for filling skimmed milk so control chart analysis is done for each filling machine.

Capacity of filling machine 1 and 2 is 1200 lph (Litres per hour) and 1500 lph respectively. The total filling capacity per hour is 2700 Ltr.

Time for filling 10400 Ltr =10000/2700=3.85 hrs

The filling capacity of machine 1 in 3.85 hrs, =1200×3.85=4620 Ltr.

Total pouches of skimmed milk that machine 1 fills per day=44620×2=9240 pcs (Pieces).

Similarly,

The filling capacity of machine 2 in 3.85 hrs =1500×3.85=5775 Ltr.

Total pouches of skimmed milk that machine 2 fills per day=5775×2=11550 pcs.

The target value for the weight of pouch is 513 gm.

A. Sampling and Control Charts for weight variation of milk pouch in machine 1

Total population size (N) =5775

Population standard deviation (σp) is not pre calculated so the sampling standard deviation is the best estimate for population calculated as below:

Table -1 Sampling for sample standard deviation

Sample	Data	Sample	Data	Sample	Data	Sample	Data	Sample	Data
1	513	**11**	511	**21**	508.5	**31**	509.3	**41**	510
2	511.5	**12**	508.8	**22**	511.5	**32**	514.8	**42**	508.5
3	514.2	**13**	509.5	**23**	514.8	**33**	511.5	**43**	518.9
4	509	**14**	511	**24**	511.6	**34**	510.6	**44**	508.5
5	508.5	**15**	514.9	**25**	510.5	**35**	506.5	**45**	516.6
6	508.1	**16**	513	**26**	512.2	**36**	507.2	**46**	506.8
7	510.5	**17**	507.6	**27**	513.4	**37**	510.5	**47**	511.5
8	513.3	**18**	510.5	**28**	508.5	**38**	513.7	**48**	513.5
9	510.5	**19**	508	**29**	508.2	**39**	520.2	**49**	507.5
10	509	**20**	509	**30**	515.5	**40**	519.3	**50**	514.5

Total no. of sample (n) =50

Mean for the table,

$\bar{X} = \frac{\sum_{i=0}^{n} X_i}{n} = \frac{25597.7}{50} = 511.95$

Standard deviation(σ_s) $= \sqrt{\frac{\sum_{i=0}^{n}(X_i - \bar{X})^2}{n-1}}$

Where X_i is i^{th} observation data for SNF and x-bar is the mean observation value.

So, $\sigma_s = \frac{\sum_{i=0}^{n}(X_i - 511.95)^2}{n-1} = 4.6458$

According to the production office (Sujal Dairy Pvt. Ltd.), the permissible error for weight is $\pm 5ml$ or $\pm 5gm$ (according to them 500 ml=510gm at constant density of milk).

For the confidence level of 95%, using Z table,

Z-score value= 1.96

Now the sample size (n),

$= \frac{Z^2 \times N \times \sigma_s^2}{(N-1) \times e^2 + Z^2 \times \sigma_s^2}$

$= \frac{1.96^2 \times 9240 \times 4.6458^2}{(9240-1) \times 5^2 + 1.96^2 \times 4.6458^2}$

=3.1879

i.e. the higher whole number for sample size is 4.
Hence, the sample size (n) =4

Sampling interval=$\frac{3.85}{4} hr$ = 57 minutes

A.1 Control Limits:
Observation made for 25 days are as follows:

Table-2 Observation data for weight variation

Day	Data 1	Data 2	Data 3	Data 4	Mean	Range
1	509.6	510.5	508	508.5	509.15	2.5
2	511	512.2	509.4	508.6	510.3	3.6
3	510.1	510.5	507.5	514	510.525	6.5
4	507	506.5	510	512.2	508.925	5.7
5	508	516	514.4	517.4	513.95	9.4
6	512.5	510.5	514.6	516.4	513.5	5.9
7	508	508.5	502.2	514.6	508.325	12.4
8	512.2	511.6	516	514.4	513.55	4.4
9	511	513.2	513	511.5	512.175	2.2
10	512	512.5	508.8	509	510.575	3.7
11	509	514.2	516.3	509.6	512.275	7.3
12	513.5	517.8	507.5	506.5	511.325	11.3
13	508.8	509.5	510.5	516.7	511.375	7.9
14	508.9	502.4	506.8	517.5	508.9	15.1
15	510.2	512.2	516.5	508.5	511.85	8
16	513.8	516.6	517.5	521	517.225	7.2
17	509.8	509	512.2	513.3	511.D75	4.3
18	514.4	512.5	514.4	509.8	512.775	4.6
19	508	508.5	517.8	511	511.325	9.8
20	512	513.2	510	511.6	511.7	3.2
21	510.2	506.6	508.8	513.5	509.775	6.9
22	511.8	509.5	514.5	517.8	513.4	8.3
23	516	514.4	518.5	521.2	517.525	6.8
24	508	510.5	514.5	516	512.25	8
25	512.2	512.5	510.6	519.5	513.7	8.9
				Mean	511.898	6.956

From table,
Mean of means ($\bar{\bar{X}}$)=511.898
Mean of ranges ($\bar{R}$)=6.956

For sample size of 4, $A_2 = 0.729, D_3 = 0, D_4 = 2.282$

Table-3 Control limits for skimmed milk weight variation (machine 1)

X-bar chart	R-bar chart
$CL_{\bar{\bar{X}}} = \bar{\bar{X}} = 511.898$	$CL_R = \bar{R} = 6.956$
$UCL_{\bar{\bar{X}}} = \bar{\bar{X}} + A_2 \times \bar{R} = 511.898 + 0.729 \times 6.956 = 516.698$	$UCL_R = D_4 \times \bar{R} = 2.282 \times 6.956 = 15.87$
$LCL_{\bar{\bar{X}}} = \bar{\bar{X}} - A_2 \times \bar{R} = 511.898 - 0.729 \times 6.956 = 506.82$	$UCL_R = D_3 \times \bar{R} = 0 \times 6.956 = 0$

A.2 Control Charts:
Following charts have been plotted processing observation data including control limits in MS-Excel:

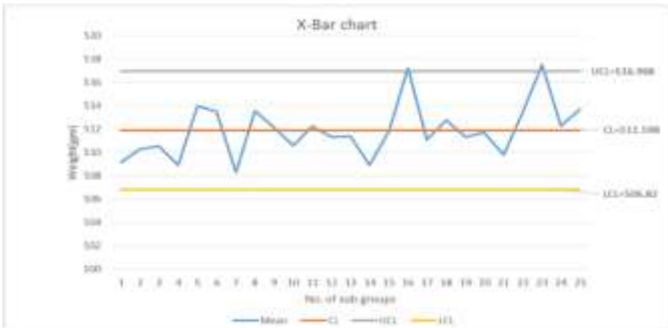

Fig.2. Mean chart for weight variation

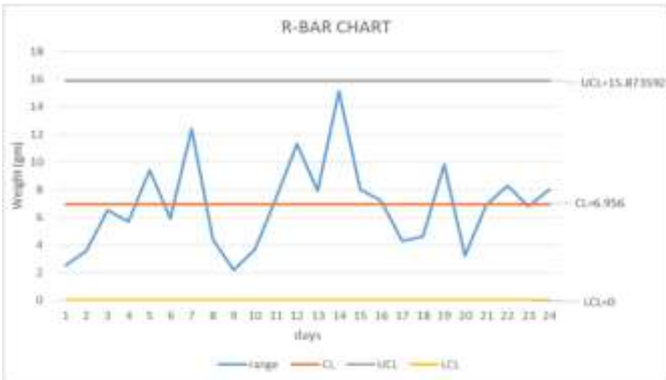

Fig.3. Range chart for weight variation

B. Sampling and Control Charts for weight variation of milk pouch in machine 2
Total population size (N) =11550

International Journal of Engineering Applied Sciences and Technology, 2022
Vol. 7, Issue 9, ISSN No. 2455-2143, Pages 138-146
Published Online January 2023 in IJEAST (http://www.ijeast.com)

Table -4: Sampling for sample standard deviation

Sample	Data	Sample	Data	Sample	Data	Sample	Data	Sample	Data
1	513	**11**	511	**21**	508.5	31	509.3	**41**	510
2	511.5	**12**	508.8	**22**	511.5	32	514.8	**42**	508.5
3	514.2	**13**	509.5	**23**	514.8	33	511.5	**43**	518.9
4	509	**14**	511	**24**	511.6	34	510.6	**44**	508.5
5	508.5	**15**	514.9	**25**	510.5	35	506.5	**45**	516.6
6	508.1	**16**	513	**26**	512.2	36	507.2	**46**	506.8
7	510.5	**17**	507.6	**27**	513.4	37	510.5	**47**	511.5
8	513.3	**18**	510.5	**28**	508.5	38	513.7	**48**	513.5
9	510.5	**19**	508	**29**	508.2	39	520.2	**49**	507.5
10	509	**20**	509	**30**	515.5	40	519.3	**50**	514.5

Total no. of sample (n) =50
Mean for the table,

$$\bar{X} = \frac{\sum_{i=0}^{n} X_i}{n} = \frac{25550.9}{50} = 511.018$$

Standard deviation(σ_s) = $\sqrt{\frac{\sum_{i=0}^{n}(X_i - \bar{X})^2}{n-1}}$

Where X_i is i^{th} observation data for SNF and x-bar is the mean observation value.

So, $\sigma_s = \frac{\sum_{i=0}^{n}(X_i - 511.018)^2}{n-1} = 3.3056$

For the confidence level of 95%, using Z table
Z-score value= 1.96
Now the sample size (n),

$$= \frac{Z^2 \times N \times \sigma_s^2}{(N-1) \times e^2 + Z^2 \times \sigma_s^2}$$

$$= \frac{1.96^2 \times 11550 \times 3.3056^2}{(11550-1) \times 5.1^2 + 1.96^2 \times 3.3056^2}$$

=2.0058
i.e. the higher whole number for sample size is 3.
Hence, the sample size (n) =3

B.1 Control Limits:
Observation made for 25 days are as follows:

Table -5 Observation data for weight variation

Day	Data 1	Data 2	Data 3	Mean	Range
1	**508.60**	509.S	514.00	510.700	5.400
2	509.00	508.60	510.40	509.333	1.800
3	**510.10**	513.S	507.50	510.367	6.000
4	507.00	510.80	510.00	509.267	3.800
5	514.00	510.S	513.50	512.667	3.500
6	512.00	508.90	516.40	512.433	7.500
7	507.80	516.S	513.60	512.633	8.700
8	509.80	512.20	512.00	511.333	2.400
9	511.50	516.40	512.20	513.367	4.900
10	510.00	514.S	516.60	513.700	6.600
11	507.90	513.30	516.50	512.567	8.600
12	512.20	512.00	514.50	512.900	2.500
13	512.20	513.30	514.40	508.000	2.200
14	511.20	512.40	509.90	514.400	2.500
15	511.20	510.00	512.20	512.500	2.200
16	513.30	514.40	516.60	514.767	3.300
17	514.40	508.80	509.00	510.733	5.600
18	511.50	514.40	509.60	511.833	4.800
19	508.50	507.80	511.20	509.167	3.400
20	509.80	514.40	516.60	513.600	6.800
21	**511.50**	508.80	508.00	509.433	3.500
22	513.70	514.40	510.50	512.867	3.900
23	514.00	512.20	508.80	511.667	5.200
24	509.50	514.40	507.70	510.533	6.700
25	512.00	508.90	515.50	512.133	6.600
			Mean	**511.716**	**4.736**

From the table,
Mean of means ($\bar{\bar{X}}$)=511.716
Mean of ranges ($\bar{R}$)=4.736 9
For sample size of 3, *A*2=1.023, *D*3=0, *D*4=2.574

Table-6 Control limits for skimmed milk weight variation

X-bar chart	**R-bar chart**
$CL_{\bar{x}} = \bar{\bar{X}} = 511.716$	$CL_R = \bar{R} = 4.736$
$UCL_{\bar{\bar{X}}} = \bar{\bar{X}} + A_2 \times \bar{R}$ $= 511.716 + 1.023 \times 4.736$ $= 516.56$	$UCL_R = D_4 \times \bar{R}$ $= 2.574 \times 4.736$ $= 12.190$
$LCL_{\bar{\bar{X}}} = \bar{\bar{X}} - A_2 \times \bar{R}$ $= 511.716 - 1.023 \times 4.736$ $= 506.87$	$UCL_R = D_3 \times \bar{R}$ $= 0 \times 4.736$ $= 0$

B.2 Control Charts:
Following charts have been plotted processing observation data including control limits in MS-Excel:

Fig.4. Mean chart for weight variation

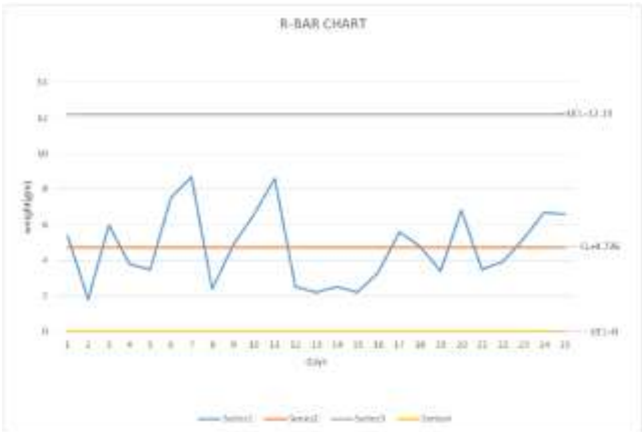

Fig.5. Range chart for weight variation

C. Sampling and Control Charts for SNF variation in tank 1

Here variation for FAT and SNF for pasteurized milk is observed. A tank with 5200 Ltr volume milk is stored after each batch but minimum two batch is produced. So sampling is done for each tank.

Sample size for tank 1,
Since a sample of bottle containing 500 ml is taken for testing these qualities,

Volume per sample=500 ml,

Population size (N) $=\frac{5200\times10^3}{500}=10400$

Table-7 Observation for calculation of sampling standard deviation (SNF)

Sample No.	CLR (%)	Fat (%)	SNF (%)
1	27.5	3.6	8.275
2	29	2.8	8.45
3	28.5	3.3	8.45
4	26	3.1	7.775

Where CLR and Fat were measured using quality process and SNF was calculated using following formula for each sampling,

SNF (%) = $\left(\frac{FAT+CLR+2}{4}\right)$

Total no. of sample (n) =4

Mean for the table,

$$\bar{X}=\frac{\sum_{i=0}^{n}X_i}{n}=\frac{32.95}{4}=8.2375$$

Standard deviation(σ_s) $=\sqrt{\frac{\sum_{i=0}^{n}(X_i-\bar{X})^2}{n-1}}$

Where X_i is i^{th} observation data for SNF and x-bar is the mean observation value.

So, $\sigma_s=\frac{\sum_{i=0}^{n}(X_i-8.2375)^2}{n-1}=0.5528$

According to quality department (Sujal Dairy Pvt. Ltd.), the permissible SNF error is $\pm1\%$.

For the confidence level of 95%, using Z table,
Z-score value= 1.96

Now the sample size (n),

$=\frac{Z^2\times N\times\sigma_s^2}{(N-1)\times e^2+Z^2\times\sigma_s^2}$

$=\frac{1.96^2\times10400\times0.5528^2}{(10400-1)\times1^2+1.96^2\times0.5528^2}$

=1.1739

i.e. the higher whole number for sample size is 2.
Hence, the sample size (n) =2 bottles

C.1 Control Limits:
Observation data for 25 days are as follows:

Table-8: Observation data for SNF variation

Day	Data 1	Data 2	Mean	Range
1	8.124	8.32	8.222	0.196
2	8.557	7.995	8.276	0.562
3	8.124	8.22	8.17	0.096
4	7.889	7.665	7.777	0.224
5	8.452	8.642	8.547	0.19
6	8.255	8.667	8.461	0.412
7	7.744	8.047	7.8955	0.303
8	8.664	8.127	8.3955	0.537
9	8.455	8.524	8.4895	0.069
10	8.412	8.124	8.268	0.288
11	8.321	8.268	8.2945	0.053
12	7.889	8.101	7.995	0.212
13	8.04	8.174	8.107	0.134
14	7.588	8.149	7.8685	0.561
15	8.124	8.268	8.196	0.144
16	8.225	7.668	7.9465	0.557
17	7.866	8.226	8.046	0.36
18	8.149	8.225	8.187	0.076
19	7.886	8.786	8.336	0.9
20	7.68	8.024	7.852	0.344
21	8.11	8.664	8.387	0.554
22	8.124	8.229	8.1765	0.105
23	7.68	8	7.84	0.32
24	7.886	7.996	8.127	0.11
25	8.026	7.946	7.986	0.08
		Mean	**8.154**	**0.295**

From the table,
Mean of means ($\bar{\bar{X}}$)=8.1539
Mean of ranges ($\bar{R}$)=0.29548
For sample size of 2, *A*2=1.88, *D*3=0, *D*4=3.267

Table -9 Control limits for SNF variation

X-bar chart	R-bar chart
$CL_{\bar{\bar{X}}}=\bar{\bar{X}}=8.1539$	$CL_R=\bar{R}=0.29548$
$UCL_{\bar{\bar{X}}}=\bar{\bar{X}}+A_2\times\bar{R}$ $=8.1539+1.88\times8.0.29548$ $=8.7094$	$UCL_R=D_4\times\bar{R}$ $=3.267\times0.29548$ $=0.9653$
$LCL_{\bar{\bar{X}}}=\bar{\bar{X}}-A_2\times\bar{R}$ $=8.1539+1.88\times8.0.29548$ = 7.598 $=7.6756$	$UCL_R=D_3\times\bar{R}$ $=0\times0.29548$ $=0$

C.2 Control Charts:
Following charts have been plotted processing observation data including control limits in MS-Excel:

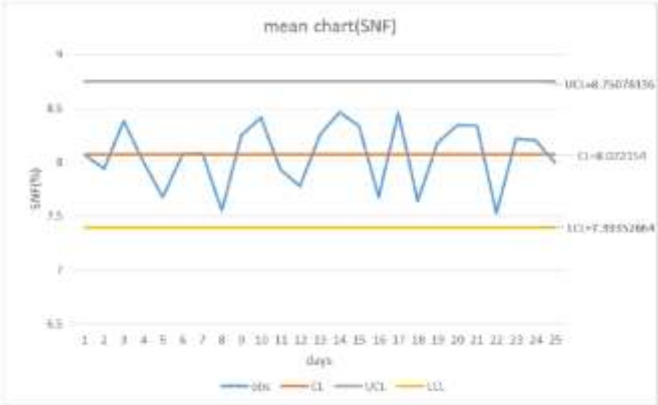

Fig.6. Mean chart for SNF variation

Fig.7. Range chart for SNF variation

D. Sampling and Control Charts for SNF variation in tank 2

Population size (N) $=\frac{5200\times10^3}{500}=10400$

Table-10: Observation for calculation of sampling standard deviation (SNF)

Sample No.	CLR (%)	Fat (%)	SNF (%)
1	28.5	3.8	8.575
2	28	2.9	8.225
3	28	4.2	8.55
4	27	2.8	7.95

Total no. of sample (n) =4

Mean for the table, $\overline{X}=\frac{\sum_{i=0}^{n}X_i}{n}=\frac{33.3}{4}=8.325$

Standard deviation(σ_s) $=\sqrt{\frac{\sum_{i=0}^{n}(X_i-\overline{X})^2}{n-1}}$

Where X_i is i^{th} observation data for SNF and x-bar is the mean observation value.

So, $\sigma_s=\frac{\sum_{i=0}^{n}(X_i-8.325)^2}{n-1}=0.5135$

According to quality department (Sujal Dairy Pvt. Ltd.), the permissible SNF error is $\pm1\%$.

For the confidence level of 95%, using Z table

Z-score value= 1.96

Now the sample size (n),

$=\frac{Z^2\times N\times\sigma_s^2}{(N-1)\times e^2+Z^2\times\sigma_s^2}$

$=\frac{1.96^2\times10400\times0.5135^2}{(10400-1)\times1^2+1.96^2\times0.5135^2}$

=1.012

i.e. the higher whole number for sample size is 2.

Hence, the sample size (n) =2 bottles.

Sampling interval$=\frac{3.85}{4}hr$ = 57 minutes

D.2 Control Limits:
Observation data taken for 25 days are as follows:

Table-11 Observation data for SNF variation

Day	Data 1	Data 2	Mean	Range
1	8.024	8.112	8.068	0.088
2	8.02	7.86	7.94	0.16
3	8.224	8.545	8.3845	0.321
4	7.995	8.015	8.005	0.02
5	7.228	8.124	7.676	0.896
6	8.124	8.024	8.074	0.1
7	8.045	8.126	8.0855	0.081
8	8.057	7.044	7.5505	1.013
9	8.044	8.457	8.2505	0.413
10	8.478	8.355	8.4165	0.123
11	7.865	7.998	7.9315	0.133
12	7.258	8.299	7.n85	1.041
13	8.159	8.357	8.258	0.198
14	8.269	8.667	8.468	0.398
15	8.0147	8.647	8.33085	0.6323
16	7.658	7.689	7.6735	0.031
17	8.257	8.657	8.457	0.4
18	7.598	7.684	7.641	0.086
19	7.689	8.666	8.1775	0.977
20	8.568	8.124	8.346	0.444
21	8.11	8.57	8.34	0.46
22	7.589	7.468	7.5285	0.121
23	7.988	8.456	8.222	0.468
24	8.287	8.122	8.2045	0.165
25	7.869	8.124	7.9965	0.255
		Mean	8.07215	0.36097

From table,

Mean of means ($\overline{\overline{X}}$)=8.072

Mean of ranges ($\overline{R}$)=0.3609

For sample size of 2, $A_2=1.88, D_3=0, D_4=3.267$

Table-12 Control limits for SNF variation

X-bar chart	**R-bar chart**
$CL_{\bar{\bar{X}}}=\bar{\bar{X}}=8.072$	$CL_R=\bar{R}=0.263$
$UCL_{\bar{\bar{X}}} = \bar{\bar{X}} + A_2 \times \bar{R} = 8.072 + 1.88 \times 0.3609 = 8.7508$	$UCL_R = D_4 \times \bar{R} = 3.267 \times 0.263 = 0.8593$
$LCL_{\bar{\bar{X}}} = \bar{\bar{X}} - A_2 \times \bar{R} = 8.072 - 1.88 \times 0.3609 = 7.3935$	$UCL_R = D_3 \times \bar{R} = 0 \times 0.263 = 0$

D.2 Control Charts:

Following charts have been plotted processing observation data including control limits in MS-Excel:

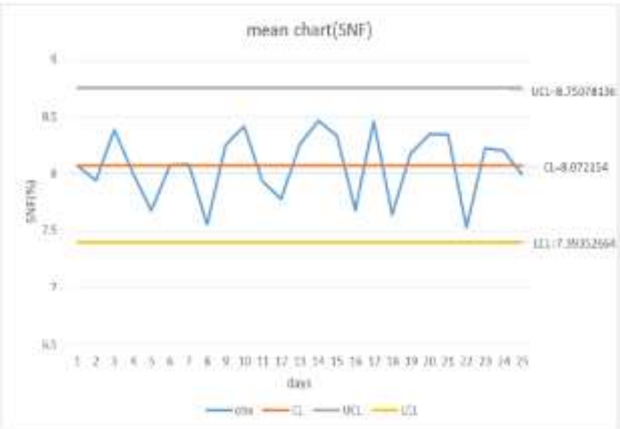

Fig.8. Mean chart for SNF variation for Tank 2

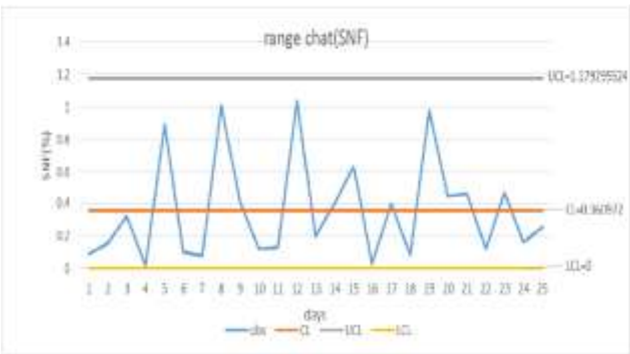

Fig.9. Range chart for SNF variation Tank 2

Almost all of the above figures show all the data within control intervals only except mean chart for weight variation in machine 1.

The outlier in X-bar chart for weight variation in machine 1 showed that there is problem in filling machine 1. Weight variation is directly related to the volume control. The probable causes for weight variation are shown by following fishbone diagram:

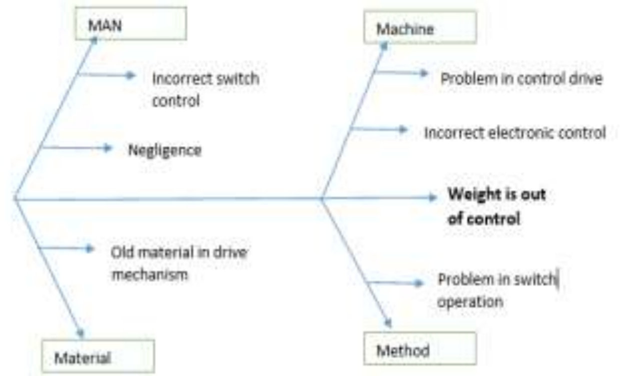

Fig.10. Fishbone Diagram

Table-13 Analysis of possible root causes

Causes	**Observation**	**Standard**	**Remarks**
Switch control	Switch control is working properly	Switch must work properly	No problem
Negligence	Operator is not caring for the volume problem	Operator should observe the machine time and again	Operator should be supervised by manager and told to supervise with regular report
Old material in drive	The operator was changing the gear drive manually after the detection of more volume	Only slight volume adjustment is done with manual gear drive	There was a problem in belt drive so it should be overhauled and the drive should be corrected
Problem in control drive	The belt was not tightly aligned which causes volume variation	The belt should work properly	The belt drive should be overhauled and fixed the problem
Problem in electronic control	The switch and control was working properly	The electronic control must work properly	No problem
Problem is switch operation	There was no problem in operation	The switch operation must be done correctly	No problem

After figuring out two major problems, correction was done through overhaul of gear drive and control drive. As a result, machine started operating without problems.

V. RESULT AND DISCUSSION

For the observations for weight variation in machine 1, the range control chart had no outliners showing process under control but the mean chart had 16th and 23rd points outside the limits showing that process out of control which means that there were some assignable causes those could be detected and reduced (or removed). For the observations for weight variation in machine 2, the charts showed no points lying outside the limits indicating the process under control.

But interestingly both SNF variation of tank 1 and tank 2 showed no points lying outside control limits. Meaning, only the common causes were responsible for the variation. Moreover, the weight gradually moving away from central line in mean chart for weight variation in machine 1 suggested that weight variation was going away from control limits. In the SNF variation mean chart, curve had downward trend indicating SNF quality of pasteurized milk moving away from central line. Root cause analysis suggested some problems related to mechanism, material in drive mechanism and operator's performance had been found to be most responsible causes for detected process variation.

VI. CONCLUSION

Using SPC charts is truly beneficial and technically practicable when it comes to improving quality of products and processes. This case study has led to conclude that SPC control charts are easy to use and gives more precise and effective statistical approach to solve quality-related problems in various industrial production processes. Furthermore, different root cause analysis tools and benchmarking approaches can also be applied which definitely makes analysis easier and more effective. Literature review suggested that researches in the field of quality engineering and management are hardly found in Nepal. This was one of the reasons we faced challenges since the very beginning. However, with the help of various reference materials and sources it had been easier to carry out this case study successfully. Hence, with proper technical guidance, SPC charts can be used effectively as quality control tools to improve quality in industrial sectors.

VII.REFERENCES

[1] Best, M., & Neuhauser, D. (2006, July 20). Walter A Shewhart, 1924, and the Hawthorne factory, (pp. 142-143).

[2] Montgomery, & C., D. (2009). An Introduction to Statistical Quality Control. John Wiley & Sons, Inc., https://doi.org/10.11120/msor.2001.01020030.

[3] Kothari, C. (2004). Research Methodology: Methods and Techniques. NEW AGE INTERNATIONAL (P) LIMITED, (pp.135-140).

[4] Budhathoki, T. B. (2071). Probability and statistics for engineers. Kathmandu: Bhundipuran Publication, (pp. 98-120).

[5] Knowles, G. (2011). Quality Management. New Delhi: R.M.Publication, (pp. 90-108).

[6] Nedeltcheva, Novakova, G., & Brun, A. (2005). ADAPTIVE CONTROL CHARTS: A CASE STUDY FROM AN AUTOMOTIVE PRODUCTION PROCESS, (pp. 4-6).

[7] Nedeltcheva, Novakova, G., & Brun, A. (2005). ADAPTIVE CONTROL CHARTS: A CASE STUDY FROM AN AUTOMOTIVE PRODUCTION PROCESS, (pp. 4-6).

[8] Touqir, F. A., Islam, M. M., & Sarkar, L. K. (2010). A CASE STUDY OF QUALITY CONTROL CHARTS IN A MANUFACTURING INDUSTRY', (pp. 357-364).

[9] Touqir, F. A., Islam, M. M., & Sarkar, L. K. (2010). A CASE STUDY OF QUALITY CONTROL CHARTS IN A MANUFACTURING INDUSTRY', (pp. 357-364).

[10] Best, M., & Neuhauser, D. (2006, July 20). Walter A Shewhart, 1924, and the Hawthorne factory, (pp. 142-143).

[11] Castle Inc. (2016). Retrieved from http://castle.eiu.edu: http://castle.eiu.edu/pingliu/int4843/resources/Control_chart.

[12] Moresteam Group. (2018, October 10). Retrieved from www.moresteam.com. https://www.moresteam.com/toolbox/statistical-process-control-spc.cfm

[13] Pokawa, I. (2012). Effect of sample size in SPC, https://doi.org/10.1093/oxfordhb/9780199934874.013.001.

[14] Wooluru, Yerriswamy, & Swamy, D. (2002). The process capability analysis - A tool for process performance measures and metrics - A case study, https://doi.org/10.3403/30314228u.