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Using T^2 Chart to Monitor the Quality of Ash Content in Flour Production

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Short Research Article

Abstract

The quality of goods and services can be improved if data sets are collected to determine the causes of variation. In this consideration, the data sets will enable the analyst to evaluate the stability of the manufacturing process. However, the purpose of applying any control chart is to identify the occurrence of special causes of variation that emanate from external source of the normal process. Although, the vital aspect of variations is that it reveals the strength and weakness of the process thereby providing means of improving the system. This also provides opportunity to repair and adjust the system due to special causes, though if such exist. In this discussion, the x bar chart and the T^2 chart are applied to investigate the quality of ash content in flour production. The analysis is based on the data set obtained revealed that the two procedures showed that the ash content used in producing the flour is stable otherwise the process is in control.

Keywords: Ash content; control chart; process stability.

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1 Introduction

Control chart is a statistical technique used to differentiate between variations in a process resulting from common causes and variation based on special causes. It reveals graphical analysis of process stability and instability due to time. It is applied to obtain and maintain process stability. Process stability implies aprocess in which the process revealed certain degree of consistency in the past and is capable of repeating such characteristics over time or in the near future. Consistency in this regard implies a stream of data range within the control limits which depends on plus or minus three standard deviations [1]. It should be emphasize that control limit indicates limits of variation that occur from a process in a statistical control. Further emphasis lies on a system that is in a statistical control which reveals the common causes that affect the production life span. Control chart shows when the process is stable. Stable process reveals consistency over a period of time with regard to the mean point and how spread the data sets are. It avails researcher's or control specialist the opportunity to investigate the behavior of the process to determine if the system is stable or otherwise. The advantage of this procedure can be seen in the following ways; (i) it reveals how the process is performing within the time interval (ii) to monitor process variation over a period of time (iii) it helps to distinguish between common cause and special cause variations and (iv) it reveals changes over time.

Larson and Pierce revealed that control chart is a vital statistical tool to investigate variability [2,3]. Nelson et al. applied the control chart to investigate blood pressure measurement variability in the primary care setting [4]. The control chart has been used to monitor pharmaceutical products [3]. It was also applied to health care and public health surveillance [5-7]. De Vries and Reneau applied the control chart to monitor the changes in animal production. This procedure has been applied to animal production system, say: poultry, swine, dairy, feeding practice, water intake, milk production, growth monitoring, disease incidence and beef production system [8]. The control chart has been applied to mining to analyze Al_2o_3% and Sio_2% [9]. The control chart was also applied to food tasting or organoleptic food testing [10]. It is use as a measure to access food quality based on well-established standard using well trained food tasters and experience judges.

Quality control data or real data set are obtained from the laboratory or production line, see [11]. In practice, quality control data are often obtained from the analytical laboratory. In such situation, a minimum sample data is required for various measurements to determine the veracity of the data to be analyzed repeatedly. In practice, the control chart are frequently applied to access the analytical response with time [12]. Though, one basic advantage of applying statistical technique is to identify the bias due to human factor. Although this occurs if the analyst is familiar with the data collection procedures in which professional or personal interest lead to bias report. In this discussion, the focus is on applying real data set obtained in a production line to investigate if the production process is in control or out of control.

The rest of this discussion is organized as follows. The T^2 control chart is discussed in Section 2 while the X bar chart is contained in Section 3. Result and analysis is contained in Section 4. Conclusion is presented in Section 5.

2 T^2 Control Chart

The quality of goods and services can be improved if data sets are collected to determine the causes of variation. This data sets will enable the analyst to evaluate the stability and the capability(ies) of the manufacturing process [13,14]. It is pertinent to state that when the process is stable, the variation is based on common causes that always exist, in such scenario, we cannot strictly figure out the major source of variation. The objective of applying the control chart is to identify the occurrence of special causes of variation that emanate from external source of the normal process. Normal process implies when the process is stable and there exist unforeseen variations that cannot be quantified. However, the interesting aspect of variations is that it reveals the strength and weakness of the process thereby providing means of improving the system. This also provides opportunity to repair and adjust the system due to special causes, though if such exist. The unique aspect of multivariate control chart (T^2 chart) is that it provides pictorial representation of the multivariate observation in a single representation. In other words, variations are represented as a single pictorial entity. Though, it provides ways to distinguish between special and common causes of variation. The implication of the special cause variation is that the system should be investigated for possible variation and immediately initiate correction mechanism or process.

Basically, control charts often reported are based on univariate data as such just a single characteristic or profile is used to investigate when the process is in control or out of control. In this discussion, multivariate data set with five dimension or sample observations is used, as such, the T^2 chart is used to investigate if the process is stable or not. Although, this process often reveal the existence of correlation between the profile variables or the characteristics under consideration. The existence of correlation will control the probability of "falsely signally special cause of variation when it is scarcely observed" [13]. Succinctly, the T^2 chart is applied to monitor the stability of the multivariate observations [15,14]. The T^2 chart is defined as follows;

$$T_i^2 = (x_i - \overline{x})' S^{-1} (x_i - \overline{x}), i = 1, 2, ..., z, \tag{2.1}$$

Where

$$\begin{aligned} \overline{x}_i &= \sum_{j=1}^{n} x_j / n, \\ S_i^2 &= \sum_{j=1}^{n} (x_j - \overline{x})(x_j - \overline{x}) / (n-1). \end{aligned} \tag{2.2}$$

Then the upper control limit (UCL) that represents the cutoff point which allows decisions to be made is given by

$$UCL = \chi_k^2(\alpha), \tag{2.3}$$

where $\chi_2^2(0.05)$ is approximated if and only if the sample size $n \geq 30,$ this based on the concept of the central limit theorem. In this case $\alpha = 0.01,$ and k denotes the profile dimension. Based on this technique and comparing Equations (2.1) and (2.3), the process is unstable or out of control if

$$T_i^2 \geq UCL. \tag{2.4}$$

More succinctly, special cause variation exist otherwise the process is stable or in control if

$$T_i^2 \leq UCL. \tag{2.5}$$

Unfortunately, this procedure does not use the lower control limit, since the lower control limit is zero. This procedure does not also apply baseline technique [13,14].

3 X Bar Chart

In this consideration, we compare the x bar chart with the T^2 chart to observe if both techniques give the same results or conflicting results. In brief, the x bar chart is the control chart for mean vector. It represents the mean vectors for the profile variables. This technique involves (i) plotting the sample mean in time order, (ii) creating and plotting the sample mean of all observations and (iii) compute and plot the control limit (upper or lower), respectively. The upper and lower control limits for this procedure is defined below;

$$UCL = \bar{\bar{x}} + A_2\bar{R},$$
$$LCL = \bar{\bar{x}} - A_2\bar{R}, \quad (3.1)$$

where, A_2=0.577 [16] and $\bar{R}$ denotes the average of the range R. This procedure like the T^2 chart enable us to determine when the process is stable or not. Unlike the previous technique, this procedure has lower and upper control limits with a mean baseline.

4 Results and Analysis

This discussion is designed to investigate the quality of ash content for flour production. The objective is to investigate if the ash content used in flour production is in control or otherwise. Basically, ash content refers to the mineral content of the flour, it is based on burning a known quantity of flour under given conditions and measuring the residue. The data set used in this study was obtained from [17]. In general, twenty sample sizes with five profiles were reportedly taken. The data set is contained in Table 1 below.

Table 1. Ash content data

j / k	**1**	**2**	**3**	**4**	**5**	$\bar{x}_j$	R_j
1	14	19	19	18	29	19.80	15
2	15	29	13	21	21	19.80	16
3	16	16	12	27	24	19.00	15
4	28	26	25	18	13	22.00	15
5	11	17	18	19	10	15.00	9
6	17	23	13	20	11	16.80	12
7	22	14	14	16	17	16.60	8
8	17	11	13	15	17	14.60	6
9	27	18	18	24	10	19.40	17
10	12	22	17	14	17	16.40	10
11	10	23	24	19	18	18.80	14
12	21	27	16	14	17	19.00	13
13	28	23	26	22	20	23.80	8
14	28	27	21	26	10	22.40	18
15	29	23	15	14	16	19.40	15
16	15	11	11	16	24	15.40	13
17	26	26	10	11	20	18.60	16
18	29	17	27	13	13	19.80	16
19	14	13	25	13	13	15.60	12
20	24	28	10	28	10	20.00	18

In Fig. 1 below the UCL is 25.76, the LCL is 11.45 and the baseline (mean) is 18.61, respectively. Fig. 1 below is the x bar control chart. It indicates that the data set is stable, implying that the ash content used in producing the flour has better and improved quality. The analysis suggest that there is no special cause

Since no lower control limit for T^2 chart, we explicitly give the upper control limit as 37.57. From this, we observed that the UCL for the T^2 is greater than that of X bar chart, based on this; the pattern analysis may be similar. Fig. 2 below is the T^2 chart for this data set and it also revealed that the process is stable implying that there is no special cause. Based on Fig. 1 and Fig. 2, the pattern analysis indicates similarity.

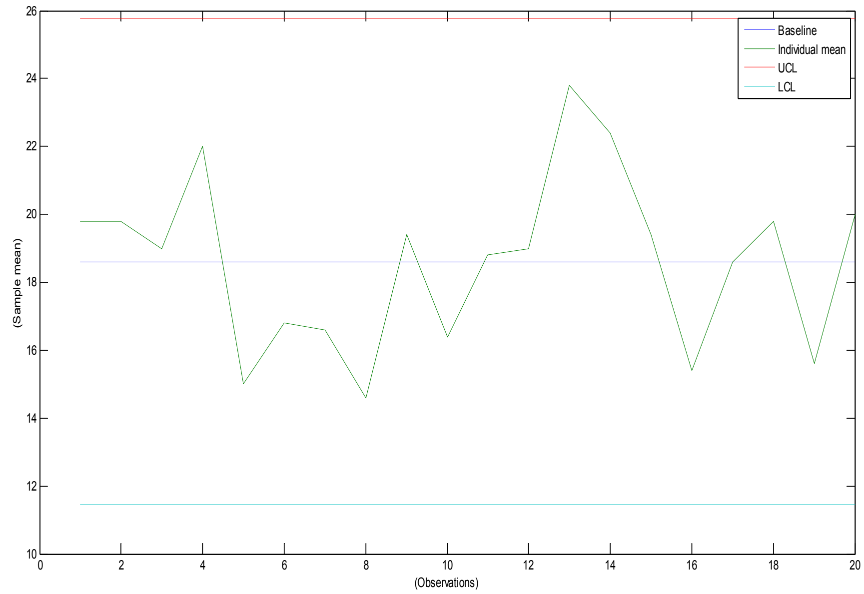

Fig. 1. X bar chart for monitoring the quality of ash content

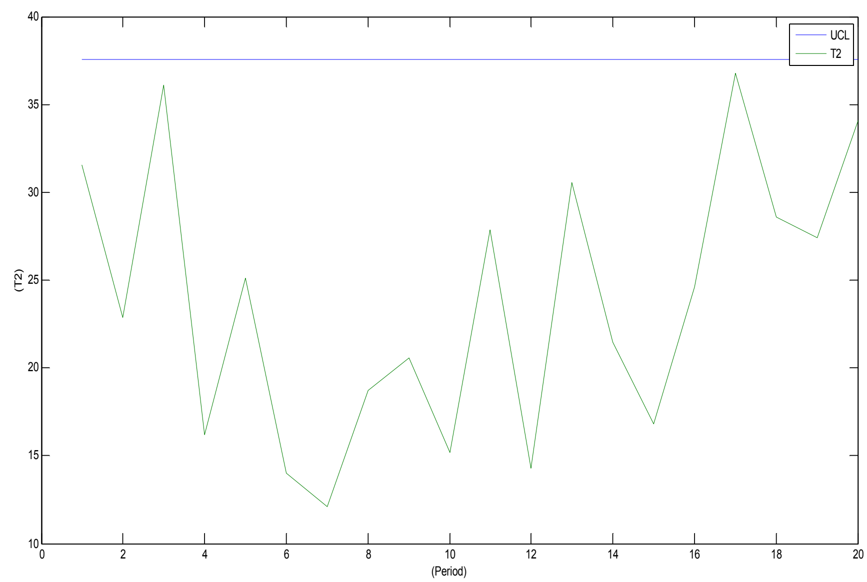

Fig. 2. T^2 chart for monitoring the quality of ash content

5 Conclusion

Based on Fig. 1 and Fig. 2, we conclude that the data set fall within a band bounded by the control limits. This implies that the process is stable. Stability in this regard implies that the constant variation shown by the data set revealed that the process is stable. This also indicates that the likelihood of a data set falling outside the band will be infinitesimal, based on this, such observation is considered as a sign of special cause of variation. However, such is not in the case under consideration. The interesting aspect of this process is that both techniques indicated that the entire data set fall within the control band and as such we conclude that the process is stable. On the contrary, if all the data set is within the control band, special cause variation may likely be observed. Conclusively, both techniques have similar pattern with all data set within the control band.

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Competing Interests

Authors have declared that no competing interests exist.

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