

Statistical Quality Control Charts on Attributes in Fish Processing Technology

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Apart from the use of statistical quality control chart for variables or attributes of food products in a food processing industry, the application of these charts for attributes of fishery products is explained. Statistical quality control chart for fraction defectives is explained by noting defective fish sausages per shift from a sausage industry while control chart for number of defectives is illustrated for number of defective fish cans in each hour of its production of a canning industry. C-chart is another type of control chart which is explained here for number of defects per single fish fillet sampled at random for every five minutes in a processing industry. These statistical quality control charts help in the more economic use of resource, time and labour than control charts for variables of products. Also control charts for attributes exhibit the quality history of finished products at different times of production thereby minimising the risk of consumer rejection.

Kramer & Twig (1970) described in detail how statistical quality control charts can be constructed and used for quality characteristics of food products. Rao (1971) explained the utility of statistical quality control charts in shrimp canning industry. The use of control charts in fish processing industries for non-measurable quality characteristics has not been reported till date. When specifications of a fishery product are too many either in terms of variables or attributes, producer should see that such specifications are followed by the processing industry for greater consumer demands and minimising the risks of rejection. If the specifications are of measurable type, then $\bar{X}$ -R and $\bar{X}$ -s charts are ideal. Except for the minimum weight or maximum weight of any component of fish cans, fish in oil, fish fillets or frozen products, the use of this type of statistical quality control charts is limited. It is also expensive and laborious to measure the specified dimensions of a product when such dimensions are more in number. But when the quality characteristics of products are of non-measurable type—when they are attributes—it is easy to group them into two categories, namely, with a specified number of attributes and without specified number of attributes. Accordingly, they are non-defective products and defective products respectively and control charts are drawn for

the later group of products. The types of control charts to be drawn for attributes which are not conforming to specifications of a product are control chart for fraction defectives (p-chart), control chart for number of defectives (np-chart) and control chart for number of defects (c-chart). Grant & Leevenworth (1972) illustrated these types of charts in an industry to improve the quality standard of manufactured goods. As applied to fish processing industry, the above control charts can also be used during any stage of production, whenever doubt arises regarding the quality of raw materials or of fish used or at the end of production of fish cans, fillets, frozen products, fish sausages or animal meat sausages etc. The application of the above charts for attributes of fishery products is discussed in this paper.

Control chart for fraction defectives or p-chart

Fraction defective 'p' is defined as the ratio of a number of defective products in any inspection or inspection series to the total number of products actually inspected. To assess the quality of fishery products in fraction defectives in each inspected sample p-chart is constructed. This type of control chart is used when the sample of products inspected vary from sample to sample, so also the frequency of sampling—an hour, a

shift or a day. If fraction defectives are expressed in percentages so as to have a better idea of quality history of the products, then such a chart is called as p-chart or control chart for percent defectives. The method of constructing p-chart is illustrated by taking an example from sausage industry.

Illustration

The first 3 columns of Table 1 give the shift order number, the number of fish

sausage inspected for each shift over a period of 15 shifts with corresponding number of defectives. Any sausage having pin holes, air pockets, deformation or breakage of casings is counted as defective and total number of such defective sausages alone is noted in each shift. Based on this record it is to be decided whether the number of defective sausages from shift to shift is varying considerably and if so such defective numbers are within quality control statistically.

Table 1. *Fish sausages inspected in each of 15 shifts with number of defectives and control limits**

Shift order No.	No. inspected (n)	No. of defectives (x)	$\bar{p} = \frac{x}{n}$	Control limits	
				$\bar{p} - 3\left(\sqrt{\frac{\bar{p}\bar{q}}{n}}\right)$	$\bar{p} + 3\left(\sqrt{\frac{\bar{p}\bar{q}}{n}}\right)$
1	230	40	0.1739	0.0253	0.1316
2	240	28	0.1166	0.0262	0.1306
3	292	15	0.0513	0.0313	0.1255
4	140	23	0.1642	0.0103	0.1466
5	169	20	0.1183	0.0163	0.1405
6	228	21	0.0921	0.0250	0.1318
7	301	19	0.0613	0.0319	0.1249
8	192	15	0.0781	0.0202	0.1366
9	250	16	0.0640	0.0274	0.1294
10	291	17	0.0584	0.0311	0.1257
11	310	19	0.0612	0.0326	0.1242
12	298	20	0.0671	0.0317	0.1251
13	302	16	0.0529	0.0320	0.1248
14	270	14	0.0518	0.0290	0.1274
15	288	15	0.0520	0.0309	0.1259

* Negative values are not included in control limits.

The control limits for p-chart are calculated assuming that $\frac{x}{n}$ (fraction defective in each sample) follows binomial distribution. Using statistical theory, the final 3 σ limits are given by $\bar{p} - 3\left(\sqrt{\frac{\bar{p}\bar{q}}{n}}\right)$ and $\bar{p} + 3\left(\sqrt{\frac{\bar{p}\bar{q}}{n}}\right)$ where $\bar{p}$ is the estimate of average fraction defective in the whole lot of production and is calculated as the ratio of total number of defectives to the total number inspected, $\bar{q} = 1 - \bar{p}$. These two limits are known as 'lower control limit' (LCL) and 'upper control limit' (UCL) for p. As n varies from shift to shift, the above two limits are calculated for each shift. These are given in Table 1.

Figure 1 gives the p-chart for fish sausages in which $\bar{p} = 0.0784$, the central line about which the fraction defectives vary.

Lower control limits and upper control limits are indicated for each shift. Fraction defectives are plotted for each shift to assess the process control of sausages.

From the same figure, it is seen that two points are outside the control limits for the first and fourth shift. Though for the remaining shifts, fraction defectives are well within the control limits, they are not moving systematically about $\bar{p}$. All fraction defectives are considerably less after 6th shift and below $\bar{p}$. This calls for slight readjustment of machine. Since for two shifts p values lie outside the control limits (unless it is not by chance causes) and since p values are approaching towards lower control limit, it is necessary to calculate modified control limits for the next set of shifts. The modified control limits are to be calculated using

new $\bar{p}=0.0685$ which is got after eliminating the 1st and 4th shifts. Then the procedure of finding control limits for the next set of production process is same as in the above case. On the other hand, if $\bar{p}$ is given in advance, this value of $\bar{p}$ is used directly to get control limits.

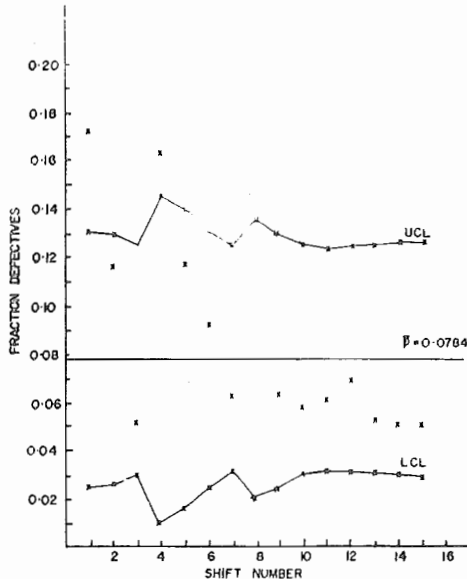


Fig. 1. *p*-chart

p-chart

In this chart fraction defectives are expressed in percentages and hence $P=100\bar{p}$, $UCL_P = P + 3\left(\sqrt{\frac{\bar{P}\bar{Q}}{n}}\right)$ and $LCL_P = \bar{P} - 3\left(\sqrt{\frac{\bar{P}\bar{Q}}{n}}\right)$. For the same example above, *P*-chart is the same as in Figure 1, wherein the graduations along vertical axis are expressed in percentages so that $\bar{P}=7.84$ and control limits change accordingly. So the object and interpretation of *P*-chart is the same as that of *P*-chart and is more readily understandable than the *P*-chart.

Control chart for number of defectives or *np*-chart

Whenever the sample size of inspected fishery products at each stage remains constant, the statistical quality control chart to be constructed is *np*-chart. Here instead of fraction defective (*p*), the actual number

of defective products (*x*) are plotted on the control chart with lower and upper control limits as $n\bar{p} \pm 3(\sqrt{n\bar{p}\bar{q}})$ respectively. Here it is assumed that the actual number of defectives (*x*) follows binomial distribution and hence the above 3σ limits are derived. The method of construction of *np*-chart is illustrated with an example from a fish canning industry.

Illustration

Table 2 gives the number of defective fish cans having seam defects, underweight, dents or deformation, for a constant inspection of 200 cans for an hourly production. Data are collected for a production period of 12 h and the appropriate control chart is drawn to assess the quality of fish cans.

Table 2. *Number of defective fish cans in an industry during a production period of 12 h*

Production order h	Sample inspected n	No. of defectives x
1	200	23
2	200	15
3	200	17
4	200	15
5	200	41
6	200	0
7	200	25
8	200	31
9	200	29
10	200	0
11	200	8
12	200	16

Since the sample size inspected at each hour is constant, it is appropriate to draw the *np*-chart. The control limits are estimated as explained earlier. Using calculated value of $\bar{p}=0.0916$, the limits work out to $LCL_{np} = 6.09$ and $UCL_{np} = 30.57$.

Figure 2 explains the *np*-chart. A glance at the *np*-chart points out that except for the production order number 5, 6, 8 and 10, all other *np* values are within statistical quality control limits. Moreover, the abrupt movements of *np* values forced the producer to stop the process for search of assignable

causes. Meanwhile, modified control limits are calculated excluding the above said production hours. Therefore, revised $\bar{p}=0.0925$ so that modified control limits are given by $LCL_{np}=6.206$ and $UCL_{np}=30.764$. These modified control limits are slightly wider than the earlier and serve to have a better

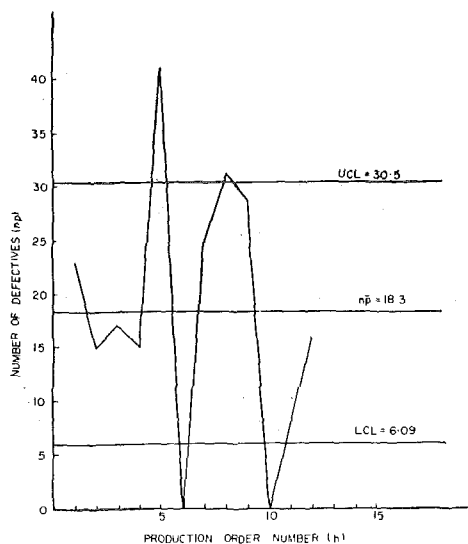


Fig. 2. np -chart

quality of cans after setting right the assignable causes like resetting of seaming machine or of its part, proper dressing of raw materials, keeping watch on labourers etc. The procedure of finding control limits is continued to improve the quality of cans by reducing the number of defectives. This type of chart can also be applied to any stage of canning process for improving the quality of fish cans.

c-chart

This type of chart is used where it is possible to keep the record of a number of defects which fail to satisfy the given specifications of a product. The main object of this type of statistical quality control chart is to have a systematic variation in number of defects from lot to lot. Since there are many chances for a product to have defect(s) and the probability of occurrence of such defects is very small, the control limits for this type of chart are derived using the poisson distribution. The principle of getting the

control limits remains the same using 3σ -limits. Thus the control limits for c -chart is given by $LCL_c = \bar{c} - 3\sqrt{\bar{c}}$ and $UCL_c = \bar{c} + 3\sqrt{\bar{c}}$, where $\bar{c}$ is the mean number of defects. The working method of calculating and constructing statistical quality control limits is made clear by an illustration from a fish processing factory, where lots of dressed fish are ready for producing fillets.

Illustration

As a part of an overall quality improvement programme in a processing factory for fish fillets, it is decided to construct c -chart to minimise the number of defects like cuts, bruises, off-flavour, physical deformation, discolouration and over or undersized fishes. A dressed fish is sampled for every 5 minutes at random, for the above, in the order of their supply ready for processing. The inspection is carried out for the whole lot of fishes and quality is assessed based on the data obtained as in Table 3.

Table 3. Number of defects in fish sampled for every 5 minutes interval

Fish serial number	Number of defects c
1	3
2	2
3	1
4	3
5	1
6	2
7	3
8	2
9	2
10	1
11	3
12	1
13	1
14	2
15	1

To construct c -chart the mean number of defects is estimated as $\bar{c}=2$ so that $LCL_c=0$ and $UCL_c=6.242$. The number of defects are plotted against each fish with the above control limits as in the c -chart in Figure 3. From this figure it is clear that number of defects per fish are not exceeding the control limits. Hence, there is no need to take any

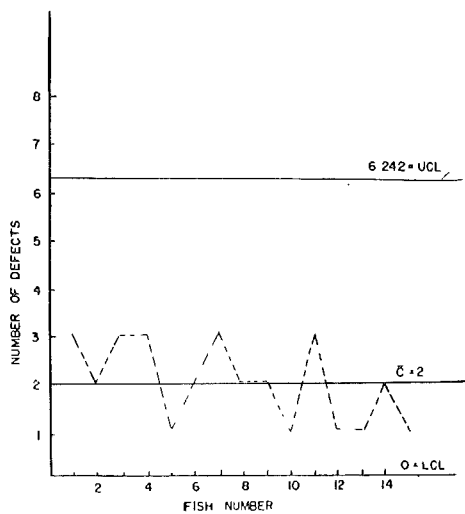


Fig. 3. c-chart

action in processing them for fillets. As no point goes out of control limits, revision of control limits is also not necessary.

The above type of control charts are very ideal and useful in any industry from producer's point of view. These control charts give clear picture of quality of incoming materials if they are used at right stage of processing of fish, animal meat or any other food items or of products if they are used at the end of production. By drawing the control charts on the quality of fish products from beginning to end, one can

know when the machine or process is manufacturing the best quality that can be accepted. This helps in the guarantee of the products at the production stage itself thereby reducing customer complaints or acceptance of products without any inspection or with minimum inspection. On the other hand, any deviation of plotted points from previous records is an indication of trouble by telling the production personnel when to look and where to look for assignable causes. This in turn saves unnecessary rework cost of processing machines. As a whole, these type of control charts for attributes are tools in the hands of processors to establish sound relations among engineers, production personnel and purchasers.

The author wishes to thank Shri K. V. Saralaya for going through the manuscript and offering some suggestions. Thanks are also due to Prof. H. P. C. Shetty for his constant encouragement.

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