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QUALITY CONTROL IN A TYPICAL WATER PACKAGING INDUSTRY

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ABSTRACT

For the period investigated, the non-defective products is 93.57% of the total water production output with a percentage defectives of 6.42% made of production floor and defective returns from sales. The distribution pattern of defective with fractional defectives can be approximated to a normal distribution and are then used to construct a revised control chart with fractional defectives based on a confidence level of 99.73% to apply for defectives control in the sachet water production industries. From the operating characteristic (OC) curves and average outgoing quality (AOQ) curves, for varying sample sizes for a given constant acceptable percentage defectives, important sampling plan parameters such as acceptable quality level (AQL), lot tolerance percent defective (LTPD) and average outgoing quality level (AOQL) are also presented.

Keywords: Defective, non-defective, control chart, operating characteristic curve, average outgoing quality, sachet.

1. INTRODUCTION

Water packaging industries are the most common industries located in cities, towns and even villages in Nigeria. These industries are great employers of unskilled or semi-skill worker in Nigeria in addition to providing Nigerian people with clean and safe drinking water. The quality of water supplied by these industries to their consumers is carefully monitored and maintained by the National Agency for Food and Drug Administration and Control (NAFDAC) by examining and certifying through quality water analysis, regular fumigations of factory and its environment, medical tests of factory workers, uses of correct water packaging polythene materials e.g low density polythene.

Water packaging industries consist of *water supply* from boreholes or public pipe borne water. Water is the main source of raw material, usually stored in *overhead storage tank*. The *water filtration section* is made of particles/sediment filtration, reverse osmosis membrane filtration systems or cartridge fillers (of varying microns) and ultra-violet (u.v) water sterilizer system. *Water sachet production section* is where the water is sealed in sachets using automatic liquid (water) packaging/sealing machine. *Packaging storage sections* is where sealed water sachets (containing 50cl of water) are packed in plastic bags. Each plastic bag contains twenty sachet and they are stored for sale.

The only major sachet water production defect is water leakage from the sachets. The water leakages or defects are caused by (*i*) incorrect use of machines sealing temperatures it under set or overset temperatures causes poor sealed sachets and burnt sealed sachets respectively that later result to water leakage (*ii*) electric power supply fluctuating causing vary set temperature (*iii*) variation of thickness of supplied polythene during manufac-turing, requiring varying sealing temperatures to properly seal the plastic sachets (*iv*) damaged or pierced supplied caused by plastic roll during transportation or manufacturing or (*v*) dist or sticky Teflon surfaces used for sealing sachets can result to leakage or product defects.

2. THEORETICAL ANALYSIS

2.1 Control Chart for Attributes Data (p-chart)

A measurement by attributes mean taking samples and using a single decision, the item is good (acceptable) or it is bad (defective). The functional defective products (defects) in a sample or a day can be estimated by

$$P_i = \frac{di}{ni} \tag{1}$$

Where P_i = fractional defective products in a sample or day

di = the number of defective products in a sample or day

ni = the number of defective products produced in a sample or day as

$$\overline{P} = \frac{\text{Total defective bags or products}}{\text{Total no of bags or parks produed}}$$

Total lot = sum of individual sample size, ni,

$$= \sum_{i=1}^{i-m} ni \tag{2a}$$

Total defective bags or packs, $d = \sum_{i-1}^{i=m} di$ (2b)

Average defective, $\overline{P} = \frac{\sum_{i-1}^{i=m} di}{\sum_{I-1}^{I-M} ni}$ (2c)

Once $\overline{p}$ is determined the control limits can be calculated [1] from

$$\tau_p = \sqrt{\frac{\overline{P}(1-\overline{P})}{n}} \quad (3a)$$

Upper control limit ($UCLp$) = $\overline{P} + Z_p \tau_p$ (3b)

Centre line (CLp) = $\overline{p}$

Lower control limit ($LCLp$) = $\overline{P} - Z_p \tau_p$ (3c)

Where $\overline{p}$ is the fraction defective, τ_p is the standard deviation, n is the sample size and Zp is the number of standard deviation for a specific confidence level. Typical Z_p = 3 (3 – signal is 99.73% confidence level).

2.2 Acceptance Sampling by Attributes

2.2.1 Operating Characteristic (O.C) Curve

When a lot of material of size, N, is submitted for inspection, a sample of n items may be selected at random from the lot and subjected to inspection or testing for defects. In acceptance sample by attributes each of these n items is classified as good (acceptable) or bad (defective) after the test or inspection. It is a common criterion that if more than c% defective items are found from the sample of n, the lot will be rejected, but the lot will be accepted if there is c% or less defective.

If among the lot of size, N, the actual fraction of defective is P, then the total number, x, of defectives items in the sample of size n, is described by hypergeometric distribution and the probability [2]

$$g(p) = \frac{\sum_{x=0}^{c} \binom{Np}{x}\binom{Nq}{n-x}}{\binom{N}{n}} \quad (4)$$

Where $q = 1 - P$

If n is small relative to N, then it can be shown [3] that $g(p)$ in eqn4 above can be approximated to

$$g(p) \cong \sum_{x=0}^{c} \binom{n}{x} p^x q^{n-x} \quad (5)$$

Involving the binomial distribution, equation (5) can be re-written as

$$g(p) = 1 - \sum_{x=r+1}^{n} \binom{n}{x} p^x q^{n-x} \quad (6)$$

Where $\sum_{x=r+1}^{n} \binom{n}{x} p^x q^{n-x}$ can be found in tables or by binomial coefficients. The function of $g(p)$ of equation (5) is referred to as the OC curve equation.

Whenever the lot size, N, is very large relative to the sample size, n, and the fraction of defective, p, is also very small, Poisson distribution can be approximated [4] to equation (4) by

$$P_{(x)} = \frac{\lambda^x l^{-\lambda}}{x!} \quad (7)$$

where $\lambda = np$

n is the sample size

p is the fraction of defectives

x is the percent number of defectives

2.2.2 Average Outgoing Quality (AOQ) Curve

Average outgoing quality curve is a plot of the expected fraction of defective units in the accepted product (after inspection) as a function of assumed fraction of defectives units in the submitted lot. In order word, the AOQ curve indicates the degree of protection offered by the inspection programme by providing information on the average quality of the accepted product.

Consider an inspection plan where each defective unit is replaced by an acceptable one. If the lot submitted for inspection consists of (100p)% defective units, the average fraction of these lot that will be accepted is given by $g(p)$ of equation (5), where as the average [2] that will be rejected is given as $(1 - g(p))$. Among the accepted lots, the fraction of defective units is p, with the lots that were rejected screened and returned as perfect products by replacement of defective ones,

Hence, the average fraction of defective units in the final product is given [2] by:

$$AOQ = pg(p) + 0(1 - g(p))$$

$$AOQ = pg(p) \quad (8)$$

The AOQ will attain its maximum value. This value of AOQ is called the average outgoing quality level ($AOQL$), representing the maximum possible fraction of defective units in the resultant products associated with this quality control plan. Using this acceptable inspection procedure, we have to ensure that the fraction of defectives in the overall quality will be less than the $AOQL$.

3. MATERIALS AND METHODS

3.1 Material

The main source of raw material is water, usually obtained from boreholes and/or public pipe borne water.

The low density polythene (LPDE) is used for sachet water packaging, as recommended by NAFDAC. Each sachet contains 50cl of processed water. Each pack or bag of processed water is made of plastic and contains twenty sachets of water.

3.2 Data Collection

Daily production data comprising of useful output products, and defectives, made of production floor and sales return defectives were collected and recorded for 86 days of production.

4. RESULTS AND DISCUSSION

4.1 Material Input-output Balance

The total quantity of material input must be balanced with the sum of non-defectives products i.e useful output products, defectives on production floor and defectives returns from sales. For the period of investigation covered, the percentage defective is 6.42%, made of 3.46% defective from sales while non-defective products accounts for 93.57% of the total production. Figure 1 shows the pie chart, representing the non-defective, defective from the production floor and defectives return from sales.

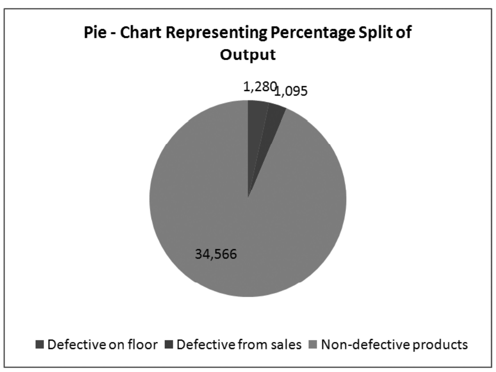

Figure 1: Pie-chart Representation of Production Split

For the investigation period, the 6.42% defective indicates that for every 100 packs, about 6½ packs is due to defective products caused especially by sachets leakage.

Using the daily production data, the fraction of defective products for each day can be calculated by using equation (1). By plotting the daily fractional defectives, a graph of figure 2 shows that the defective distribution pattern can be approximated to that of normal distribution, with maximum central value, occurring at fractional defective of 0.064. This therefore allows us to be able to use binomial or Poisson distribution formulation for the analysis.

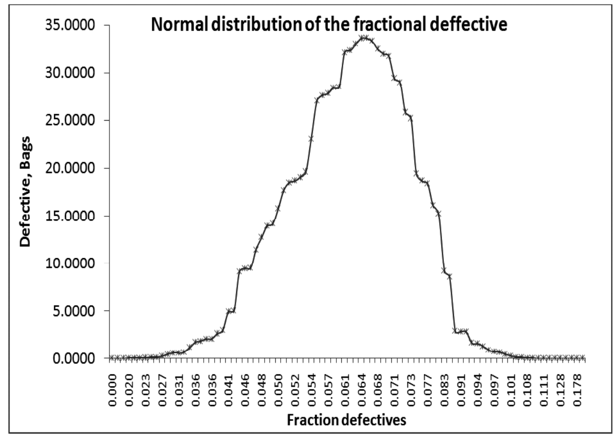

Figure 2: Approximate Normal Distribution Pattern for the Fractional Defective

4.2 Control Chart

The control chart of figure 3 represents a total of 86 days investigated fractional defectives with a confidence level of 99.73%. The plot indicates that twenty four (24) points are found to be out of control.

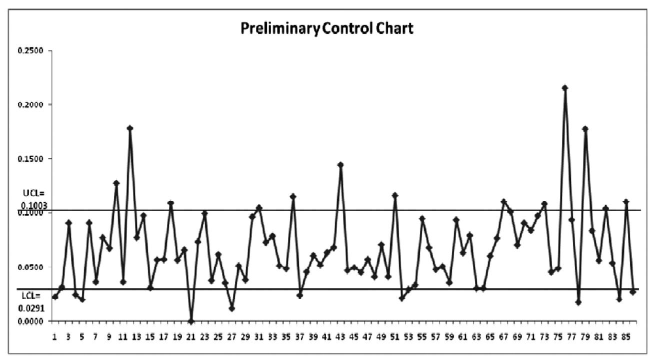

Figure 3: Preliminary Control Chart Indication 24 Points Out of Control Based on 3-Sigma

The final revised control chart based on 99.73% confidence level i.e 3 sigma is obtained by removing the out of control points and to recalculate the new revised control chart limits by using equations (2) and (3) for the remaining points. The value (5) of the final revised control chart limits are determined as

Centre line, $CL = 0.0547$

Upper control limit, $UCL = 0.087$

Lower control limit, $LCL = 0.023$

Figure 4 shows the remaining 52 points (days) that fall within the range of upper and lower control limits, indicating the process are under control. Thus, the values of the upper and lower limits associated with it can be used for the quality control of sachet water production under the same conditions for a confidence level of 99.73%.

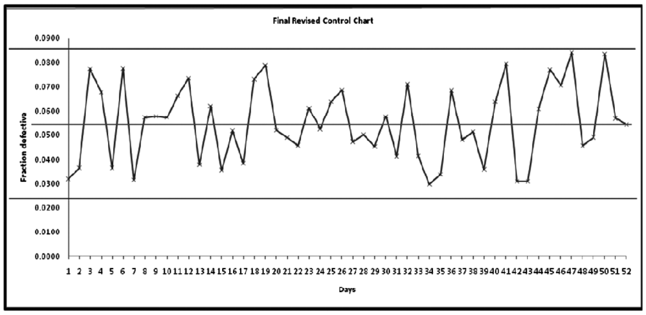

Figure 4: Final Control Chart for the Packaging of Sachet Water

4.3 Operating Characteristic (OC) Curve

By using equation (7), the probabilities of acceptance, $p(x)$, for various fraction defectives, p, are calculated for varying sample sizes of 250, 350 ad 450 packs per day at a constant defective acceptance of $c = 2\%$. Figure 5 shows the *OC* curves for sample sizes of 250, 350 and 450 packs under a constant acceptable defective, $c = 2\%$.

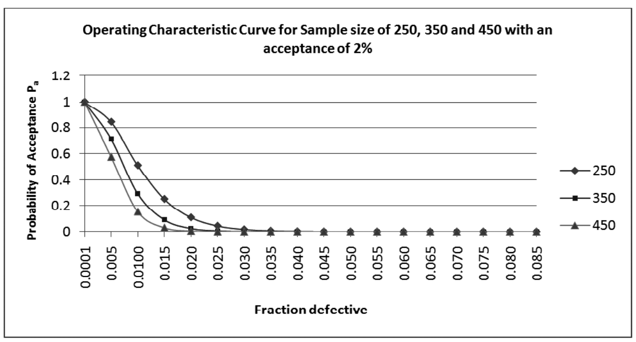

Figure 5: Operating Characteristic Curve for Varying Sample Plans

Each of the OC curves is found to be steep i.e has an infinite slope (vertical in the region of most interest lots). If the defective acceptable, $c = 2\%$ is kept constant, OC to move more vertical and closer to the origin (see figure 5).

By using the operating characteristic curve, the optimum inspection sampling plans so that the plan has to be accepted by both the supplier and the receiver of the supplied lot.

The supplier's risk of rejecting good quality lots are referred to respectively as the *producer's* risk, α, and consumer's risk, β.

The usual practice is that the producer's risk α and consumer's risk β, are taken [6] to be acceptable on 5% and 10% respectively. Using these and OC curve of figure 5, the acceptable quality level (AQL) for high quality supplied lots and the lot tolerance percent defective (LTPD) for low quality supplied lots are calculated and tabulated in table 1 for varying sample sizes, n and as constant acceptable defective $c = 2\%$.

Table 1
Important Sampling Plan Parameters

Sample size (n)	*AQL*	*LTPD*	*AOQL (fractional defect)*
250	0.003	0.21	0.0052 (0.0095)
350	0.0015	0.015	0.0037 (0.006)
450	0.001	0.011	0.0028 (0.0051)

Both the AQL and LTPD values (5) increase with decreasing sample sizes at a constant acceptable defectives $c = 2\%$ see (table 1)

4.4 Average Outgoing Quality

By using equation (7) and (8), the average fractional defectives of outgoing defectives for varying samples sizes, n, and constant acceptable fraction defective, $c = 2\%$ are calculated and plotted to give figure 6. Table 1 shows the average outgoing quality level (AOQL) with their corresponding fractional defective. The AOQL values (5) are found to decrease with increasing sample sizes at a constant acceptable defective of 2%.

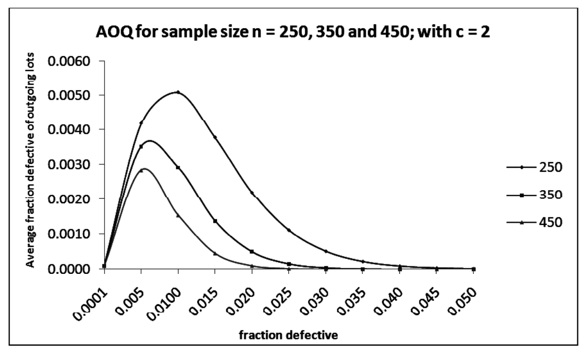

Figure 6: Average Outgoing Quality Level (AOQL)

5. CONCLUSION

(*a*) For the given period of investigation, the non defective product is 93.57% of the total production output with the percentage defectives is 6.42%, made up of 3.46% defective from production floor and 2.96% defective returns from sales.

(*b*) The distribution pattern of defectives with fractional defectives, P, can be approximated to a normal distribution with a mean central value of about 0.064, which then allow the applications of binomial or Poisson distribution for the analysis.

(*c*) A final revised control *p*-chart is constructed by eliminating the out of points from the control *p*-chart to give control limits of upper lower control limits of 0.087 and 0.023 fractional defective respectively.

(*d*) From the operating characteristic (OC) curves and average outgoing quality (AOQ) curves obtained from varying sample sizes and given constant acceptable defective, c = 2%, important sampling plan parameters such as acceptable quality level (AQL), lot tolerance percent defective (LTPD) and average outgoing level (AOQL) are determined and presented.

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