Uniport Journal of Engineering and Scientific Research (UJESR)

Vol. 6, Issue 1, 2021, Page 194-202
ISSN: 2616-1192

(www.ujesr.org)

Modelling the Production of Special Palm Oil from Fresh Fruit Bunch

Okafor, I.T[1], Olorunleke, A[2] and Maikasuma, G.O[3]
[1]Department of Marine Engineering, Nigerian Naval College of Engineering, Sapele Delta State
[2]Mechanical Engineering Department, Igbinedion University, Okada, Edo State
[3]Department of Production Engineering, University of Benin. Benin-City, Edo State, Nigeria
*Corresponding author's email: Izunnaokafor@gmail.com

Abstract
The paucity of data in palm oil production has hindered the interest of investors to invest in this area, even when the southern part of Nigeria is blessed with this natural resources abundantly. This research was aimed at breaching this gap by predicting the extraction rate of palm oil from the processing of a given quantity of fresh fruit bunches (FFBs). To do this, simple linear regression was adopted and a model was developed and tested. From the results obtained, the developed model was found to be robust in predicting the amount of oil that can be produced from a given FFB quantity with a coefficient of determination (r^2) of 0.912.

Keywords: *Special palm oil, Fresh fruit bunch, Linear regression, Palm process*

Received: 9th November, 2021 *Accepted: 31st December, 2021*

1. Introduction

The quantity and quality of palm oil that can be extracted from a given amount of (*FFBs*) would very much depend upon the technology of milling process. In the traditional method harvested (*FFBs*) are cut and kept some where were they staying for days before the main processing for oil begins (Vogel, 2002). At this point the fruit become readily detachable from bunch sterns. This is so because there are no machines for handling the loosening of fruits from the bunch. Thus, the purpose of allowing the bunches to stay for long is for loosening. Incidentally this storage encourages formation of the oil residuals, which results to unwanted thickness as a result of the fermentation. However, with appropriate processing technology (*FFBs*) are charged into sterilizer immediately after harvest. The processing hammers from boiler facilitate the debunching of the fruit having stayed for about 90mins in the sterilizer at a temperature of over 20^{o}C. The sterilized bunches are now sent into the debunchers and pasted to the digester through a conveyor, the digested fruit pass through the centrifugal press where oil is extracted. The oil extracted is further processed in a clarifier unit which separates the oil into Special Palm Oil (*SPO*), Palm Kernel Oil (*PKO*). The sludge is separated into palm nut and fibre. The palm nut is cracked and the palm kernel is toasted and milled for PKO that is made ready for soap production Chukwu et al. (2011). The fibre is high in calorific value and can be used to fire boiler. This study predicts the quality of SPO that can be extracted from known quantity of fresh fruit bunch (*FFB)*. The prediction is considered lay relevant because an investor or an agronomist will like to know the amount of oil that can be extracted when a given quantity of *FFB* is processed. This is the bottom line that determines profitability. It should be recalled that there are two types of FFB in the market and the namely Tenera and Bere. The latter is rich in palm nut, so produces lesser amount of palm oil but greater amount of *PKO*. The former tenera, produces richer amount of SPO but lesser amount of PKO. Every species has its own merit and demerits, one cannot say one specie is better than the other.

It is generally agreed that the Oil Palm *(Elaeis guineensis)* originated in the tropical rain forest region of West Africa (Olagunju, 2008). The main belt runs through the southern latitudes of Cameroon, Côte d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, Togo and into the equatorial region of Angola and the Congo. The palm bears its fruit in bunches (Orewa et al., 2009). The individual fruit (Fig.1) ranging from 6 to 20 gm, are made up of an outer skin (the exocarp), a pulp (mesocarp) containing the palm oil in a fibrous matrix; a central nut consisting of a shell (endocarp); and the kernel, which itself contains an oil, quite different for palm oil, resembling coconut oil. (Teoh, 2000).

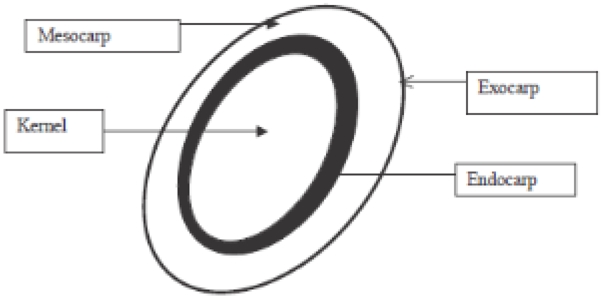

Fig 1: Structure of the Palm fruit **(**Olagunju, 2008)

The average economic life-span of the oil palm is 25 years to 30 years (Lim et al., 1999). A marked increase in the cultivation of oil palm began in 1960 (Husain et al., 2003). For which by the year 1990 onwards there was a peak in replanting. Historically, this subsector has been a source of growth in a stagnant economy because of the numerous economic potentials of the oil palm (Ilechie et al., 1986). Kei et al. (1997) highlighted the importance of the economic tree crop in providing direct employment to about 4 million Nigeria people in about 20 oil palm growing states in Nigeria and indirectly to other numerous people involved in processing and marketing. Omoti (2004) stated that Nigeria has enormous potential to increase her production of palm oil and palm kernel primarily through application of improved processing techniques. Oladipo (2008) opined that improved technologies that meet both growth and sustainability goals can be effectively used by oil palm processors.

2. Materials and methods

2.1 Data acquisition procedures

For the simple linear regression three years observation were recorded, though some observations are missing. Data were obtained from the operations log book of an oil mill procession plant located at ubulu-uku Delta State. The observations were extracted as recorded by the firm and their consent was obtained for the use of the data. Essentially two methods were used while the simple linear regression served as the analytic model and coefficient of determination was used to test the validity of the developed model.

2.2 Research Design

This is applied research crafted to use past time series data to determine the extraction rate of palm oil processes from FFB. The quantity of oil extracted represent the random variable y which depends on the quantity FFB processed and we write the mathematical expression.

$$y = a + bx \qquad (1)$$

where x is the quantity of FFB processed to yield the quantity of palm oil. The constants a and b represent the simple regression parameters calculated using Equations (2) and (3), respectively.

$$b = \frac{n\Sigma xy - \Sigma x.\Sigma y}{n\Sigma x^2 - (\Sigma x)^2} \qquad (2)$$

Since y = a + bx

$$\Rightarrow \qquad \Sigma y = na + b\Sigma$$

$$\Rightarrow \qquad \frac{\Sigma y}{n} = a + \frac{b\Sigma x}{n}$$

$$\Rightarrow \qquad \bar{y} = a + b\bar{x}$$

Given

$$a = \bar{y} - b\bar{x} \qquad (3)$$

Equations (2) and (3) show that a and bx can be determined using time series observation

2.3 Method of data analysis

The method of data analyses follow the principle of ordinary least squares OLS. Let y be the extraction rate and x the number of FFB unit in kg processed. Therefore, y = a + bx as the mathematical equation. Equation (1) can be estimated using a statistical model.

$$y' = \alpha + \beta x \qquad (4)$$

and the error in estimation is given by

$$e = y - y' \qquad (5)$$

so that the square of the error is

$$e^2 = (y-y')^2 \qquad (6)$$

Hence the error sum of square

$$SSE = \Sigma e^2 = (y - y')^2 \qquad (7)$$

To minimize the error, take partial derivative of the SSE with respect to a and b.

$$\frac{\partial(SSE)}{\partial a} = \frac{\partial[y - y']}{\partial a}$$
$$= \frac{\partial \Sigma}{\partial a}[y - a - bx]^2$$
$$= 2\Sigma[y - a - bx].(-1)$$
$$= -2[\Sigma y - \Sigma a - b\Sigma x]$$
$$Set\ \frac{\partial(SSE)}{\partial\partial} = 0$$
$$\Sigma y = \Sigma a - b\Sigma x \quad (8)$$

$$Also$$
$$\frac{\partial(SSe)}{\partial b} = -2\Sigma[y - a - bx]\bar{x}$$
$$Set\ \frac{\partial}{2\partial}(SSE) = 0$$
$$\Rightarrow \Sigma xy = a\Sigma x + b\Sigma x^2 \quad (9)$$

Knowing a and b as regression parameters. The extraction rate y can be predicted

2.4 Method of Model Validation

The model was validated using the coefficient of determination (r^2) as shown in Equation (10)

$$r^2 = \left(\frac{n\Sigma xy - \Sigma x.\Sigma y}{\sqrt{[n\Sigma x2 - (\Sigma x)2][n\Sigma y2 - (\Sigma y)2]}}\right)^2 \quad (10)$$

where r is the coefficient of correlation.

The coefficient of determination measures the extent to which independent variable x is able to account for the perceived variability in the value of dependent variable y, on the other hand the coefficient correlation tells us how strong or weak is the relationship between independent variable c and dependent variable y. It also specifies the direction of the relationship i.e. whether direct or inverse.

3. Results

3.1 Results from Milling Centre in Ubulu-Uku Delta State

Table 1 values were obtained from a data log book of an oil milling centre in Ubulu-Uku in Delta State Nigeria. The result shows amount of fresh fruit bunch charged into the miller and the result output is depicted as the special palm oil (SPO) and palm kernel oil (PKO).

Table 1: Data from a palm oil processing mill

FFB received (m/t)	FFB milled (m/t)	SPO produced (tins)	PKO produced
126.66M/T			
10.79	6	42	2
14.69	6	42	1
14.35	6	42	3
12.4	4	30	1
12.3	6	42	3
12.87	4	30	2
8.35	6	42	3
13.21	6	42	2
7.15	6	42	1
7.66	4	30	2
11.31	6	42	1
11.18	6	42	1
12.87	4	30	3
7.91	6	42	2
12.14	6	42	2
12.29	6	42	1
12.49	6	42	1
11.69	4	30	1
6.01	4	30	2
6.88	6	42	2
8.18	4	21	2

3.63	6	41	2
5.43	2	33	2
6.12	4	23	2
4.24	4	22	1
4.32	4	34	1
3.96	6	14	1
3.51	6	29	1
5.03	6	29	2
5.17	6	29	1
5.19	4	39	2
4.53	6	39	2
5.01	4	39	1
8.49	8	39	1
5.25	6	26	3
4.12	4	48	2
6.17	4	32	1
5.74	4	68	1
4.86	6	50	1
6.06	2	34	1
7.44	6	34	1
10.32	6	34	2
10.85	6	48	1
12.62	6	16	1
10.19	6	48	1
11.8	6	48	1
9.8	6	48	1
11.66	6	48	1
10.57	6	48	1
11.23	6	48	1
14.85	6	48	1
16.94	6	48	1
14.49	2	48	1
11.84	2	48	1
9.47	6	48	1
13.01	6	16	1
7.95	4	16	1
11.71	4	45	1
9.67	4	30	1
4.93	4	30	1
5.58	6	32	1
10.79	6	32	1
9.39	4	32	1
3.14	6	45	1
3.14	6	30	3
2.81	4	45	4
2.26	6	45	3

4.38	6	30	0
4.31	3	46	0
2.95	6	21	2
3.58	6	46	3
3.14	6	43	3
3.58	6	34	2
3.14	6	36	2
3.76	6	41	2
3.18	6	32	2
4.89	6	43	2
3.63	6	22	3
2.81	2	34	3
2.99	2	34	3
13.01	6	45	2
7.95	6	43	2
11.71	4	43	2
9.67	4	43	4
4.93	4	32	1
5.58	4	21	1
10.79	6	23	2
9.39	6	23	2
3.14	4	45	2
3.14	6	45	2
2.81	6	45	2
2.26	4	43	1
4.38	6	43	2

Table 2: Data sample for a linear regression computation for a palm oil processing mill

FFB received in tons x	10.79	14.69	14.35	12.40	12.30	12.87	8.35	13.21	7.15	7.66
SPO produce in tons y	42	42	42	30	42	30	30	42	42	42

Table 3: Computing the simple linear regression

x	**Y**	**Xy**	**x^2**	**y^2**
10.79	42	453.18	116.42	1764
14.69	42	616.70	215.79	1764
14.35	42	602.70	205.92	1764
12.40	30	372	152.76	900
12.30	42	516.60	151.29	1764
12.87	30	386.10	165.64	900
8.35	30	250.10	69.72	900
13.21	42	554.82	174.50	1764
7.15	42	300.30	51.12	1764
7.66	42	321.72	58.68	1764
$\Sigma(x) = 113.77$	$\Sigma(x) = 384$	$\Sigma(x) = 4374.9$	$\Sigma(x) = 1362.84$	$\Sigma(x) = 15048$

3.2 Sample computation of extraction rate

The accompany computation tends to illustrate the application of simple linear regression to the computation of extraction rate of palm oil in processing of FFB. In doing that some data points have been purposively selected to demonstrate the application. Subsequently, the entire data set was feed into Minitab to enable the determination of the extraction rate. The data for the linear regression is shown in Table 2 while the computation is shown in Table 3.

Therefore, to calculate b:

$$b = \frac{n\Sigma xy - \Sigma x.\Sigma y}{n\Sigma x^2 - (\Sigma x)^2} w \qquad heren = 10$$

$$\because b = \frac{10(4374.9) - 113.77.384}{10(1362.84) - (113.77)^2}$$

$$\therefore b = \frac{43749 - 43687.68}{13628.4 - 12943.61}$$

$$b = \frac{61.32}{684.79}$$

$$\therefore b = 0.08955$$

$$Buta = \bar{y} - b\bar{x}$$

$$a \qquad = 384 - 11377(0.8955)$$

$$a \qquad = 384 - 10.188$$

$$a \qquad = 373.81$$

$$\therefore y = 373.8 + 0.08955$$

where y is the extraction rate. For instance, of 15metric tons of FFB is milled:

$$y = 373.8 + 0.08955 \times 15$$

$$y = 373.8 + 1.34325$$

$$y = 375.143(tons)$$

The normal probability shown in Fig. 2 is graphical technique to identify substantive departures from normality thus includes identifying outliers, skewness, kurtosis, a new for transformations, and mixtures. Fig. 3 depicts the relationship between the charged in fresh fruit bunch (FFB) with the production rate of the special palm oil (SPO).

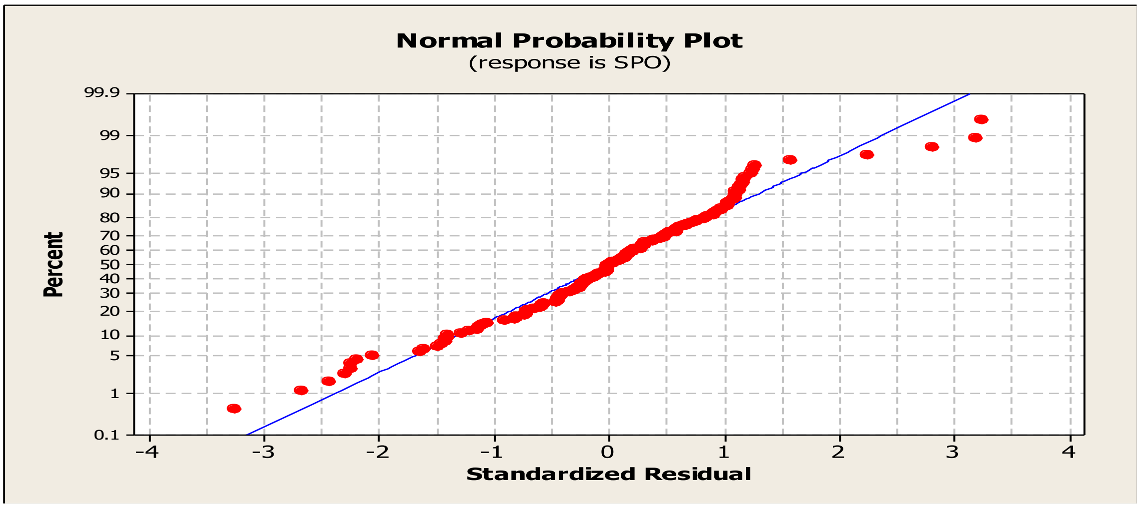

Fig. 2: Normal probability plot of special palm oil

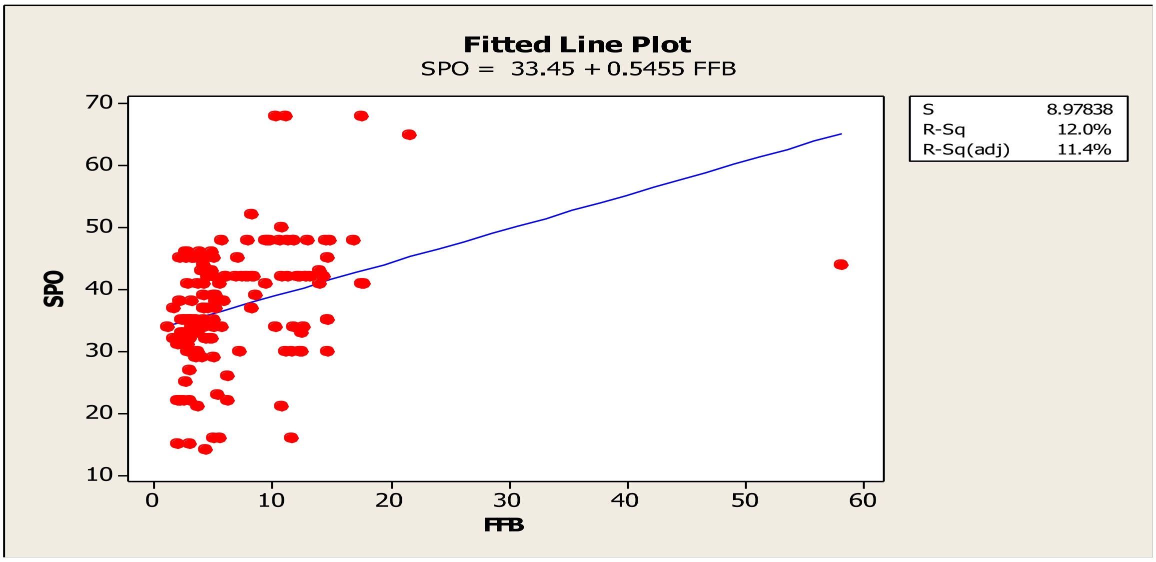

Fig. 3: Scattered diagram of special palm oil

The histogram of the SPO is the graphical representation of the data point and their frequencies of occurrence (Fig. 4). It is evident from the figure that the distribution is dumbbell shape indicating that parametric statistics can be applied to the data.

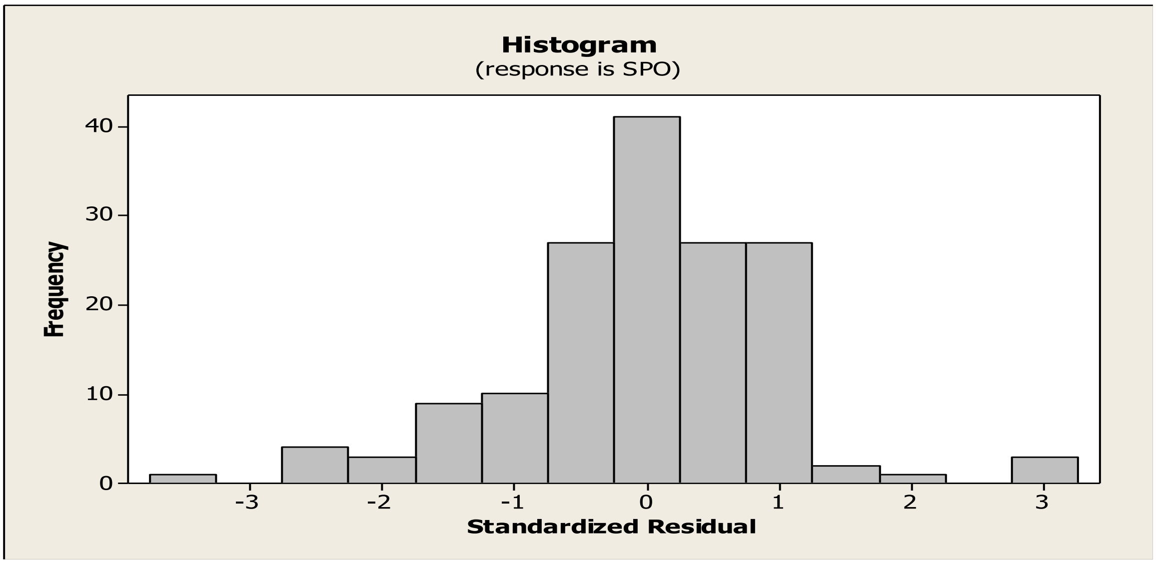

Fig. 4: Histogram distribution for special palm oil

The fitted regression diagram in Fig. 5 is showing the relationship between the fresh fruit bunch (FFB) and the special palm oil (SPO) and from all indication is evident that the relationship is quadratic, therefore confirming lack of skewness in the data observed. The slope of this line indicates the extraction rate and which means that extraction from each fresh fruit bunch (FFB) varies from bunch to bunch.

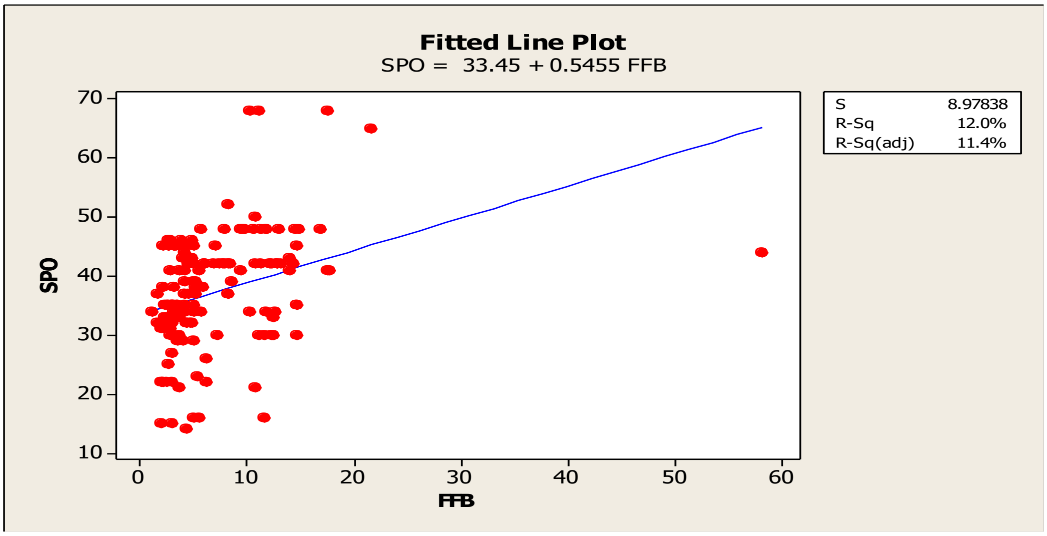

Fig. 5: Fitted regression line of SPO and FFB

The failure rate versus the observation order in Fig. 6 shows the incoherent nature of the process at each point, in order to determine the level of deviation from the process data against observed result, and from all indication the failure rate can be adjudged.

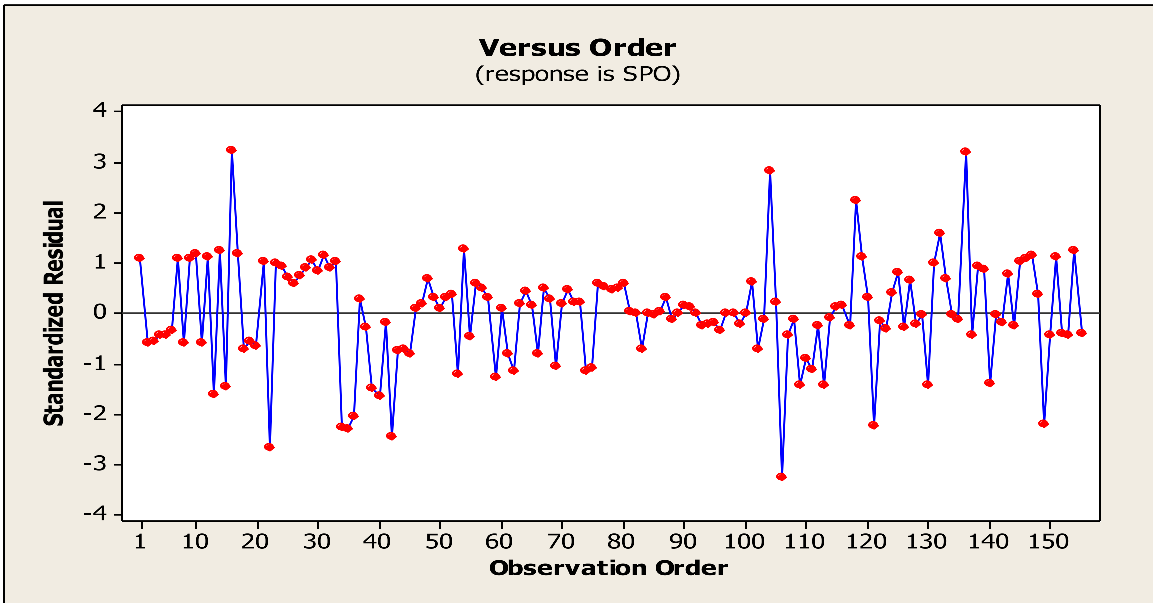

Fig. 6: Failure rate versus the observation order

4. Discussion

The model applied appears to be robust in determining the extraction rate of special palm oil (SPO). The sample was able to give a practical amount of SPO that can be extracted if a certain amount of fresh fruit bunch (FFB) is charged into the processing chamber. Also, the multivariate regression parameters generated was able to give the relationships between various components obtained in the FFB.

5. Conclusions

This study has fruitfully applied simple linear regression to analyze the output to be generated if a certain amount of FFB is processed. Our conclusion is that the organization should maintain a data sheet on the production record at given time and given amount of FFB in order to maximized this natural resource. This study has breached the gap of paucity of data bedevilling the poor investment in the manufacture of SPO due to inappropriate data record. The coefficient of determination (r^2) of the developed model was obtained as 0.912 which present the model as a sure-fire for predicting extraction rate of SPO.

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