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PERFORMANCE CHARACTERISTICS RESPONSE OF PALM KERNEL OIL PLANTS, TO INCREASING NUMBER OF PROCESSING MACHINES, IN IMO STATE

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ABSTRACT

In queueing problems in an industry, performance characteristics are the major indicator of the operation performance. This paper presents the performance characteristics response of palm kernel oil plants to increasing number of processing machines, in Imo state. Five plants producing vegetable oil using palm kernel, in Imo state, with average installed capacity of 70 Tonnes were sampled for analysis, using queue methodology. Engagement of less than 4 processing machines per day resulted in exploded queue. Increment from 4 – 7 processing machines per day reduces the queue length and mass in the system by 99.7% and 92% respectively. Also, at the installation of 7 processing machines, the waiting time in queue and queue length were 0.07 days and 1.59Tonnes/day respectively. In addition, at 5 numbers of machines operating, there was virtually no queue in the system. In general, as the number of processing machines increased beyond 3 numbers, performance characteristics decrease.

Keywords: Machine, Performance Characteristics, Palm Kernel, Plant.

1. INTRODUCTION

Manufacturing is also described by Richard, John and Irwin (2011) as the process of converting raw materials into finished products that can be traded or sold.

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This conversion process can be carried out by mechanical, physical or chemical means, or by combination of the means. The Vegetable oil industry, like other industries is faced with many challenges which include queue problems. Queue which is a common occurrence in life is termed waiting line. Solution to queueing problems are affected through the queuing theory as a mathematical evaluation providing optimal service to customers while reducing service cost as much as possible (Higgins and Stidger, 1976) Hence, number of minimum server requirement can be determined as well as other queuing performance measures, using the determined queue operators as well as the model equation.

Performance characteristics which includes the queue functions; queue length, waiting time in queue, quantity of materials in the system and waiting time of a unit quantity in the system, depend on the operation characteristics. These operation characteristics in turn are responsive to the change in number of processing machines. According to the study of a plant by Owuama and Oguoma (2016), breakdown of a processing machine increases the queue length and waiting time in queue 3 times. In effect, the performance characteristics of the industry affected. On this note, this paper examines the response of the performance characteristics of the queue as the number of processing machines (server) increases. Hence the minimum server requirement decision enabled. The queue consideration in the industry is on the processing/store section where masses of palm kernel are processed/arrive.

2. MATERIALS AND METHODS

The data requirements include queue structure mass of palm kernel arriving per day (Tonnes), number of machines processing per day and mass of palm kernel processed per day (Tonnes). These are sourced by observations, interviews and database information from the five sampled plants. The data obtained is used to determine the queue structure hence the queue model. Using the equation; mean = Σfx/N, where x = variable, f = frequency and N = sum of frequency (Spiegel and Stephens, 2006). The mean mass of palm kernel arriving per day, mean mass of palm kernel processed per day and the mean number of machines operating per day are established. Using the equations for the multiple server single queue:

$$P_0 = \left[\sum_{n=0}^{s-1} \frac{1}{n!} \left(\frac{\lambda}{\mu}\right)^n + \frac{1}{s!} \left(\frac{\lambda}{\mu}\right)^s . \frac{s\mu}{s\mu - \lambda} \right]^{-1} \quad \text{(i)}$$

$$L_q = \left[\frac{1}{(s-1)!} . \left(\frac{\lambda}{\mu}\right)^s . \frac{\lambda\mu}{(s\mu-\lambda)^2}\right] P_0 \quad \text{(ii)}$$

$$L_s = L_q + \frac{\lambda}{\mu} \quad \text{(iii)}$$

$$W_q = \left[\frac{1}{(s-1)!} . \left(\frac{\lambda}{\mu}\right)^s . \frac{\mu}{(s\mu-\lambda)^2}\right] P_0 = \frac{L_q}{\lambda} \quad \text{(iv)}$$

$$W_s = W_q + \frac{1}{\mu} = \frac{L_q}{\lambda} + \frac{1}{\mu} \quad \text{(v)}$$

$$\gamma_s = \frac{\lambda}{s\mu} \quad \text{(vi)}$$

where, P_n = the probability that there are n units in the system, Ls = expected number of calling units in the system, L_q = expected number of calling units in the queue, W_s = expected waiting time a customer spends in the system, W_q= expected waiting time a customer spends in the queue, s = number of servers, λ = expected arrival rates of calling units, μ = expected service/processing rates per busy server, 1/λ = expected inter arrival time, 1/μ = expected service/processing time, γ = utilization factor for the service facility = λ/μ (Sharma, 2007; Placid, Chinedu and Ogochukwu, 2018; Chinedu, Placid, Ogochukwu and Martin, 2018; Madu, 2018). The queue performance characteristics of the industry are determined. This analysis is carried out considering the variation of s from 0 to 8 machines

3. RESULTS

3.1 MEASURED AND CALCULATED DATA

Determination of the mean distribution of the data (masses of palm kernel arriving and processed per day) are presented in Tables 1 to 10.

Table 1: Frequency distribution of mass of palm kernel arriving per day (Tonnes) in plant A

Mass of kernel arriving per day (Tonnes)(m_λ)	Class mark	Frequency (f)	Number of variable, x_λ = m_λ (new equivalence, unitized)
26.0 – 35.9	30.95	16	0
36.0 – 45.9	40.95	16	1
46.0 – 55.9	50.95	14	2
56.0 – 65.9	60.95	13	3
66.0 – 75.9	70.95	0	4
76.0 – 85.9	80.95	1	5

Table 2: Frequency distribution of mass of palm kernel processed per day (Tonnes) in plant A

Mass of kernel processed per day (Tonnes)(m_μ)	Class mark	Frequency (f)	Number of variable, x_μ = m_μ (new equivalence, unitized)
27.0 – 36.9	31.95	15	0
37.0 – 46.9	41.95	29	1
47.0 – 56.9	51.95	14	2
57.0 – 66.9	61.95	2	3

Table 3: Frequency distribution of mass of palm kernel arriving per day (Tonnes) in plant B

Mass of kernel arriving per day (Tonnes)(m_λ)	Class mark	Frequency (f)	Number of variable, x_λ = m_λ (new equivalence, unitized)
20.0 - 29.9	24.95	4	0
30.0 – 39.9	34.95	12	1
40.0 – 49.9	44.95	12	2
50.0 – 59.9	54.95	13	3
60.0 – 69.9	64.95	9	4
70.0 – 79.9	74.95	5	5
80.0 – 89.9	84.95	3	6
90.0 – 99.9	94.95	2	7

Table 4: Frequency distribution of mass of palm kernel processed per day (Tonnes) in plant B

Mass of kernel processed per day (Tonnes)(m_μ)	Class mark	Frequency (f)	Number of variable, x_μ = m_μ (new equivalence, unitized)
20.0 - 29.9	24.95	4	0
30.0 – 39.9	34.95	12	1
40.0 – 49.9	44.95	18	2
50.0 – 59.9	54.95	18	3
60.0 – 69.9	64.95	5	4
70.0 – 79.9	74.95	3	5

Table 5: Frequency distribution of mass of palm kernel arriving per day (Tonnes) in plant C

Mass of kernel arriving per day (Tonnes)(m_λ)	Class mark	Frequency (f)	Number of variable, x_λ = m_λ (new equivalence, unitized)
00.0 – 9.9	04.95	8	0
10.0 – 19.9	14.95	9	1
20.0 – 29.9	24.95	10	2
30.0 – 39.9	34.95	13	3
40.0 – 49.9	44.95	9	4
50.0 – 59.9	54.95	7	5
60.0 – 69.9	64.95	4	6

Table 6: Frequency distribution of mass of palm kernel processed per day (Tonnes) in plant C

Mass of kernel processed per day (Tonnes)(m_μ)	Class mark	Frequency (f)	Number of variable, x_μ = m_μ (new equivalence, unitized)
00.0 – 9.9	04.95	6	0
10.0 – 19.9	14.95	14	1
20.0 – 29.9	24.95	15	2
30.0 – 39.9	34.95	14	3
40.0 – 49.9	44.95	9	4
50.0 – 59.9	54.95	2	5

Table 7: Frequency distribution of mass of palm kernel arriving per day (Tonnes) in plant D

Mass of kernel arriving per day (Tonnes)(m_λ)	Class mark	Frequency (f)	Number of variable, x_λ = m_λ (new equivalence, unitized)
00.0 – 9.9	04.95	5	0
10.0 – 19.9	14.95	13	1
20.0 – 29.9	24.95	20	2
30.0 – 39.9	34.95	12	3
40.0 – 49.9	44.95	6	4
50.0 – 59.9	54.95	3	5
60.0 – 69.9	64.95	1	6

Table 8: Frequency distribution of mass of palm kernel processed per day (Tonnes) in plant D

Mass of kernel processed per day (Tonnes)(m_μ)	Class mark	Frequency (f)	Number of variable, $x_\mu = m_\mu$ (new equivalence, unitized)
00.0 – 9.9	04.95	6	0
10.0 – 19.9	14.95	18	1
20.0 – 29.9	24.95	23	2
30.0 – 39.9	34.95	9	3
40.0 – 49.9	44.95	4	4

Table 9: Frequency distribution of mass of palm kernel arriving per day (Tonnes) in plant E

Mass of kernel arriving per day (Tonnes)(m_λ)	Class mark	Frequency (f)	Number of variable, $x_\lambda = m_\lambda$ (new equivalence, unitized)
00.0 – 9.9	04.95	10	0
10.0 – 19.9	14.95	11	1
20.0 – 29.9	24.95	15	2
30.0 – 39.9	34.95	9	3
40.0 – 49.9	44.95	8	4
50.0 – 59.9	54.95	6	5
60.0 – 69.9	64.95	1	6

Table 10: Frequency distribution of mass of palm kernel processed per day (Tonnes) in plant E

Mass of kernel processed per day (Tonnes)(m_μ)	Class mark	Frequency (f)	Number of variable, $x_\mu = m_\mu$ (new equivalence, unitized)
00.0 – 9.9	04.95	12	0
10.0 – 19.9	14.95	18	1
20.0 – 29.9	24.95	13	2
30.0 – 39.9	34.95	11	3
40.0 – 49.9	44.95	6	4

The equation of mean is used to estimate the mean distributions of the data presented in Tables 1 to 1 and the results presented in Tables 11 and 13.

Table 11: Mean distributions of the mass of palm kernel arriving and mass of palm kernel processed per day.

Plant	Mean mass of palm kernel arriving per day ($\dot{m}_\lambda$)	Mean mass of palm kernel processed per day ($\dot{m}_\mu$)
A	45.6	42.45
B	52.95	47.78
C	32.12	20.95
D	27.28	22.78
E	25.28	21.78

Considering the unitized mean distribution of the palm kernel arriving and palm kernel processed in the various plants sampled per machine as well as the average number of machines (servers) per day as presented in Table 12.

Table 13. The industry's mean mass units of palm kernel arriving per day and mean rate of processing per machine unit per day.

Industry	Mean mass units of palm kernel arriving per day (λ_m)	Mean number of machines processing per day ($\dot{s}_m$)	Mean rate of processing per machine unit per day (μ_m)
Vegetable oil industry in Imo State	2.252	3.6	0.574

Table 12. Mean distributions of the mass of palm kernel. arriving and mass processed when unitized

Plant	Mean mass units of palm kernel arriving per day (λ_{plnt})	Mean mass units of palm kernel processed per day (μ_{splant})	Mean number of machines processing per day ($\dot{s}$)	Mean rate of processing per machine unit per day (μ_{plant})	$\frac{\lambda_{industry}}{\mu_{industry}}$
A	1.47	1.10	5	0.22	6.682
B	2.80	2.28	5	0.46	6.087
C	2.72	2.20	3	0.73	3.699
D	1.97	1.93	3	0.64	3.078
E	2.30	1.63	2	0.82	2.805

The industry's mean distribution of the mean unitized mass of palm kernel arriving per day, mean rate of processing per machine unit per day, and mean number of machine units processing per day are obtained in Table 13.

3.2: PERFORMANCE CHARACTERISTICS

Using the values of the mean unit of palm kernel arrival rate, mean units of processed palm kernel per day per server and mean number of machines (servers) per day. Appling the equation of the model $M_1/M_2/s$; the values of queue length, units of mass of palm kernel in the system, time spent in the system and in queue per unit mass are evaluated and presented in Table 14 below. This is evaluated for various number of machine input. The response of the performance characteristics, to increase in number of processing machine units, is shown in Table 14 and Figure 1a and 1b respectively.

Table 14. Calculated mean performance characteristics: Palm kernel processing industry in Imo State

Number of processing machines(units) (s)	Utilization factor for processing units (γm)	Probability of processing unit idle (P_0)	Expected queue length (L_q)	Expected number of palm kernel units in the system (L_s)	Expected waiting time per palm kernel unit in queue (W_q)	Expected waiting time per palm kernel unit in system (W_s)
0 – 3	$\frac{\lambda}{s\mu} > 1$					
4	0.981	0.0019	50.0784	54.0017	22.237	23.979
5	0.785	0.0146	1.9131	5.8451	0.850	2.592
6	0.654	0.0182	0.5030	4.4260	0.223	1.965
7	0.560	0.0193	0.1589	4.0819	0.071	1.813
8	0.490	0.0196	0.0515	3.9745	0.023	1.765

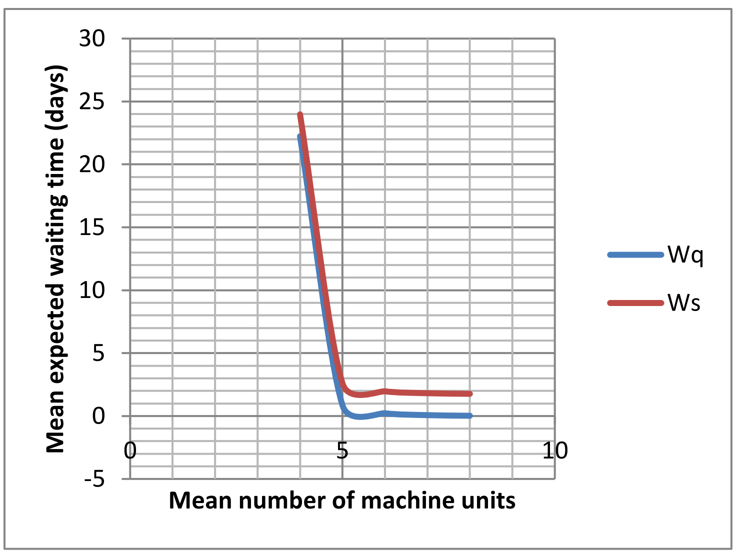

Figure 1a. Graphical display of variations of Wq and Ws with s in the industry

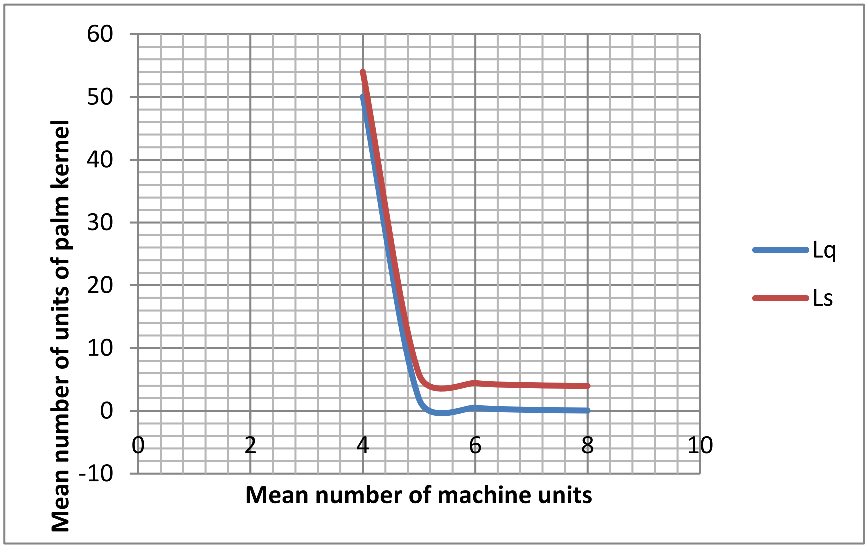

Figure 1b. Graphical display of variations of Ls and Lq with s in the industry.

4. DISCUSSIONS

From Table 14 and Figures 1a and 1b, as the number of processing machines (servers) increase from 0 to 3, the system is unstable, that is; $\frac{\lambda}{s\mu} \geq 1$. From 4 nos. machine units, stable state condition is met, i.e., $\frac{\lambda}{s\mu} < 1$; here the queue can be controlled.

It is generally noted that as the number of processing units increase, the queue length, number of palm kernel units in the system, waiting time in queue and in system decrease. This is as a result of decrease in the utilization factor. Significantly, when 4 processing machines are engaged, the queue length and waiting time in queue and in system are high (500.784 tonnes/day 22.237days and 23.79 days respectively), At 5 machines engagement, small queue length and waiting time become apparent. Furthermore, increase in number of processing machines beyond 5 yields no significant change in queue length or waiting time at this instance, the total time spent by the units of palm kernel in the system becomes dominated by the service time rather than the waiting time in queue.

5. CONCLUSION

This research is a case of vegetable oil industry in Imo state. As a consequence of the study, it is concluded that;

- Engagement of 1-3 processing machines has a consequence queue explosion.
- Engagement of 4 or more processing machines brings the queue system into stable state.
- Increment from 4 – 7 machines reduces the queue length and mass in the system by 99.7% and 92% respectively.
- At average installation of 7 processing machines, the queue length (Lq), mass in system (Ls), waiting time in queue (Wq) and in system (Ws) are; 1.589Tonnes/day, 40.819Tonnes/day, 0.071days and 1.813days respectively.
- Generally, performance characteristics of vegetable oil industry in Imo state, decrease with increase in the number of service (processing machines) units.

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