TECHNOLOGICAL CAPABILITY OF SMALL-SCALE OIL PALM FRUIT PROCESSORS IN THE PRODUCTION OF SPECIAL PALM OIL IN NIGERIA

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ABSTRACT

This study assessed the technological capabilities of oil palm fruit processors in Akwa Ibom, Edo, Imo, Kogi, Ondo, and Osun States, Nigeria. This is with the view to ascertaining the availability of appropriate technologies for production of special palm oil (SPO). Relevant data were collected from 307 respondents, who were selected by multistage sampling procedure. Appropriate descriptive statistics (frequency of observations, percentages and statistical significance) were used to summarise the data and deduce inferences. Many of the respondents were between 50 and 59 years age group (27.0%) and between 40 and 49 years of age (25.4%), which indicates that a significant number of the processors were adults. Majority (87.4%) of the mills were owned by single private actors. Many of the respondents (63.93%) did not know about SPO production. The most and least available equipment were vertical digester and centrifuge which were found amongst 62.5 and 0.98% of the processors, respectively. Availability of stripper ($p < 0.05$), sterilizer ($p < 0.05$), digester-screw press ($p < 0.05$), centrifuge ($p < 0.05$), and decanter ($p < 0.05$) were associated with highest educational attainment of processors. The paper concluded that technological capability of SPO processors was very low; hence the need for interventions that would increase respondents' awareness about appropriate technologies for SPO production. This promises great boost in obtainable income and job generation for key actors in the oil palm value chain.

KEYWORDS: Capability, Oil palm fruit, Oil quality, Processing, Technology

1. INTRODUCTION

Palm oil is prime among vegetable oils in the Nigerian food system. It also has various valuable domestic and industrial applications in many other regions of the world (Tropical Agriculturalist, 1998; Owolarafe, 2007). It has been widely documented as a highly demanded raw material in the manufacture of soaps, detergent, ink, epoxy resins, animal feeds and confectioneries among others, thus attracting huge revenue by producing countries in global trade (Owolarafe, 2007).

Despite the potentials of palm oil in the food and agro-allied industries, local production has suffered serious decline in the past few decades; bringing Nigeria down from the first to fifth position in the global league of major producers (Owolarafe, 2015). Factors driving the decline in local production largely include lack of appropriate technologies for palm fruit processing and poor extension facilities. It therefore nauseates that in Nigeria presently, palm oil is imported in large quantities to augment local production (FAO, 2021). Owolarafe (2015) indicated the primacy of appropriate technologies for small and medium scale processors (i.e owners of processing centres or production plants) for special palm oil (SPO) in the attempts to reposition Nigeria on the global palm oil landscape. Typically, SPO is an industrial standard grade of palm oil which contains less than 3% and 1% of free fatty acid (FFA) and moisture, respectively. Research efforts to complement the high demand for SPO is driving a gradual shift of processors from labour-intensive traditional methods to improved methods with higher efficiency and better oil quality and yield (Owolarafe, 2015).

Generally, palm oil production from oil palm fruits involves some operations such as fruits sterilisation, fruits stripping, fruits digestion, oil extraction and oil clarification. The level of technology employed for each of these unit operations determine the quality of palm oil produced. For SPO, however, large scale plants wherein all the operations are mechanised are largely involved (Salako *et al*., 2014). There have been various interventions aimed at improving the efficiency of small and medium scale palm fruits processing; focusing on palm fruits handling, mechanisation of the process and appraisal of existing processing technologies for SPO production (Owolarafe *et al*., 2002; Owolarafe., 2007; Owolarafe and Oni, 2011; Morakinyo and Bamgboye, 2016; Badmus *et al*., 2019; 2021). Some milestones have been recorded with respect to improved processing methods, yield, and product quality and various machines have been developed to handle different unit operations. Some of these machines include palm fruit stripper, steriliser, digester (vertical or horizontal), press (hydraulic, or screw press) and clarifier. Recently, the inclusion of a digester-screw press to combine digestion and oil extraction as a unit operation has shown great improvement in the efficiencies of small and medium scale plants (Owolarafe *et al*., 2002; Owolarafe, 2015; Badmus *et al*., 2019). Additional accessories include oil dryer and decanter to ensure the oil is at the recommended moisture level and free of impurities. There are conveyance systems (such as bucket elevator, screw conveyor, to enhance the efficiency of the plants (by reducing processing time) and preserve the quality of the process materials from a unit operation to another and hence the quality of the oil (Owolarafe, 2015; Badmus *et al*., 2019). There are nut fibre separator and nut cracker developed to process palm nut as a byproduct of palm oil extraction and serve as raw material for palm kernel oil extraction (Olorunlagba *et al*., 2010). This also enables the recovery of palm kernel shell to serve as fuel material in oil palm fruit processing. Despite these achievements, the industry is rarely progressing at a pace that inspires hope because most of the technologies developed are either not adopted by many processors owing to high cost or due to addiction to cultural practice as observed by Owolarafe *et al.* (2007) on adoption of an aqueous oil extraction system developed and deployed to the field.

Technological capability involves machines possessed by processors in their centres, qualified personnel in terms of formal or informal education, utilisation and maintenance of the machines.

Previous studies have indicated that ownership of mill has effect on procurement of improved technology as most single and privately-owned processing centres lack the financial capability to acquire such facilities. Most of them prefer to have many units of the traditional or semi-modern technologies (Taiwo *et al*., 2000; Owolarafe, 2015). Also, age of processors, sex and marital status indicating capability to manage processing facilities as observed by Beveridge *et*

al. (2011) on Abia State palm oil value chain development project are other factors. In addition, available quantity of fruits for processing which depends on the size and ownership of plantations has been found to have effect of technological acquisition (Owolarafe and Arumughan, 2007a, 2007b; Beveridge *et al*., 2011)

Elekwachi *et al*. (2012) reported an annual demand gap of about 100 Mt of SPO in four industries (Honeywell, 1,680Mt; Indomie, 33,600Mt; Golden Oil, 27,900 Mt and Envoy Oil, 36,960 Mt) in Nigeria. It is estimated that about 388 small and medium scale processors would be required to fill the demand gap which is worth USD 91 million (Elekwachi *et al.*, 2012). There is therefore the need to assess the capability of processors with the view to ascertaining the availability of appropriate technologies for production of SPO in Nigeria.

2. METHODOLOGY

Six states (Akwa Ibom, Edo, Imo, Kogi, Ondo and Osun States, with latitudes and longitudes of 5.0000 N and 7.8333 E; 6.339185 N Nand 5.617447 E; 5.476310 N and 7.025853 E; 7.80232 N and 6.733343 E; 6.895929 N and 4.893563 E; and 7.629209 N and 4.187218 E; respectively) were purposefully selected among the palm oil producing states in Nigeria. The states were selected based on the intensity of their oil palm production and geographical zones of the country. Slovin formula (Equation 1) was used to calculate the sample size (Indarti *et al*., 2017).

$$n = \frac{N}{1+Ne^2} \quad (1)$$

where n = sample size, N = Population of respondents
e = margin error, usually taken as 0.05 (Indarti *et al*., 2017)

The estimated number of oil palm fruit processors or processing centres in Akwa Ibom, Edo, Kogi, Imo, Osun and Ondo States are 240, 270, 100, 250, 160 and 160, respectively based on the report of Market Development in the Niger Delta (2019) and data from the Ministries of Agriculture of the states. These make a total of 1180 processors or processing centres, Subjecting this to Sloving formula above a total of 298 processors were arrived at. The sample sizes per state using the total of the respective states as fraction of the total were, 60, 70, 25, 63, 40 and 40 for Akwa Ibom, Edo, Kogi, Imo, Osun and Ondo States. These give a total of 298 in all. Distribution of the sample size was carried out by purposefully selecting the respondents across the local government areas in each state based on intensity of palm oil production. However, a total of 307 respondents were eventually covered. The survey was carried out throughout January and February, 2021. The instrument used for data collection is a well-structured questionnaire supported by field observations. The questionnaire elicits information on the demographic characteristics, ownership of the mill, number of male and female dependents, mode of land acquisition for plantation, oil palm fruits processing machines available in the mill, maintenance of the machines, sales of products, and awareness about SPO, among others. Data analysis was carried out using Statistical Package for the Social Sciences (SPSS). Descriptive statistics such as mean and standard deviation were used to summarize the data while inferential such as cross-tabulation and Chi-Square were used to make deductions.

3. RESULTS AND DISCUSSION

3.1 Socio-demographic characteristics, education, and socio-economic status

The results (Table 1) show that the processors are largely between 50 and 59 years (27%) while 18.6% and 25.4% fall within the age of 30-39 years and 40-49 years, respectively. These age

groups seem to have more active processors (owners). The age distribution of machine operators at the mills were between 21 and 29 years, and they form 35.3% of the total respondents. In addition, majority (84%) of oil palm processors were married, 10.1% never married while 5.2% and 0.7% were widowed and separated, respectively. In the indigenous African family system, men marry more wives and bears more children to have more labour to support farm work and postharvest activities (Taiwo *et al*., 2000). Having more family members to engage in arduous work may enhance throughput of processing centres with traditional/semi-modern of intermediate technology and may blindfold the processors in considering modern technology with higher throughput (Beveridge *et al*., 2011). Sex distribution of respondents shows that 65.5% of the total processors were male while 34.5% were female. Women processors have been observed to be scared of acquiring machines and hence have slow adoption of technology (Taiwo *et al*., 2000). The distribution of respondents by occupation indicates that 54.4% of oil palm processors are full-timers; there are other actors in the industry who do not engage in the industry full-time.

Table 1: Percentage Distribution of the Respondents according to their Age

Age group (in 10 years)	Frequency	Percentage
20-29yrs	45	14.7
30-39yrs	57	18.6
40-49yrs	78	25.4
50-59yrs	83	27.0
60yrs+	44	14.3
Total	307	100

Source: Field Survey (2021)

Respondents within the latter category were either civil servants who own oil palm plantations or businessmen who engaged partly in oil palm production. Processors who take palm oil production as main occupation are likely to be more committed to the business and hence expand their business. Such processors are most likely to be positively disposed to injecting more resources in acquiring better technology and hiring of qualified hands. This is in line with the findings of Owolarafe *et al*. (2007a) on Indian palm oil mills.

About 38.1, 31.3 and 13.4% of the respondents had high school certificate, first school leaving certificate, and no education at all, respectively. Education is very vital in the transfer and adoption of any new technology; it brings about the craving for new knowledge. Those with higher qualifications will have the opportunities of accessing information faster on available technologies, credit facilities (etc) and take advantage of such facilities. The study further shows that majority of the respondents 205 (76.5%) and 198 (73.6%) have 1-4 distribution of household sizes for both male and female, respectively. Household size therefore, is a factor in the production in terms of labor supply for most farming and postharvest operations. Household size may sometimes bring illusion of not needing improved machines for laborious and arduous operations because of availability of labour to run the drudgery-intensive traditional or manual technologies.

About 55% of respondents belonged to an industrial association from which information about the industry was obtained regularly. Being part of industrial association provides opportunity of getting awareness of information about the business, available technologies and credit facilities that may assist in acquiring improve technologies. Table 2 shows ownership status of the mills. About 87.6% of the respondents operates single-private ownership, while 8.8%, 2%,

1.3%, and 0.3% operate on Joint venture, cooperative society, government, and others, respectively. It may be inferred that the processing mills were largely owned by single-private owners. Single private owners may be limited in terms of resources to acquire new technology (finance), information sharing, loans facilities capacity etc and this may affect technological capability.

In terms of the educational qualification of the mill owners, 13.4% of the processors had no formal education, 31.3% had first school leaving certificate while 38.1% had high school certificate; others (17.3%) had diploma or higher qualification. This indicates that many of the processors had formal education. Processors with formal education are likely to be better enlightened and seize any available opportunity in terms of credit facilities, recruitment of qualified personnel and better managers particularly when combined with skill in processing operations. These findings are in consonance with the report of Owolarafe and Oni (2011) on palm industry in Abia State (which is another state with high intensity of palm oil production) of Nigeria.

Table 2: Frequency Distribution of Mill Ownership

Mill Ownership	Frequency	Percentage
Single-private	269	87.6
Cooperative society	6	2
Joint venture	27	8.8
Government	4	1.3
Others	1	0.3
Total	307	100

Source: Field Survey (2021)

3.2. Effect of demographic factors on capability of the processors

3.2.1 Effect of educational qualification of operators on the availability of equipment

Table 3 shows the relationship between the highest qualification obtained by machine operators and the available equipment within the various processing centres. The list of equipment associated with various unit operations include: stripper, sterilizer, horizontal digester, vertical digester, hydraulic press, screw press, digester-screw press, centrifuge, clarifier, crude palm oil tank, decanter, vacuum dryer, conveyor system, nut fibre separator, nutcracker, and diesel engine. Tables 3 shows that out of 85.7%, 263 of the respondents had no stripper while 14.3% respondents had stripper irrespective of the level of education except respondents with HND. The probability that a relationship exists between the level of education and having a stripper is 0.001 (Table 4). Fruit stripping was largely a manual unit operation in most small-scale processing centres in Nigeria until very recently (Taiwo *et al*., 2000). Sterilization of the FFB is very important because it influences the overall extraction efficiency and quality of the oil and kernels extracted (Owolarafe and Faborode, 2008).

Table 3: Effect of Education on Availability of Equipment

*Highest Qualification Obtained		None	FSLC	WAEC/NECO	ND	HND	First Degree	Masters	Ph.D.	**Total**
Stripper	NO	38	81	104	14	12	13	1	0	**263**
	YES	3	15	13	7	0	3	2	1	**44**
		41	96	117	21	12	16	3	1	**307**
Sterilizer	NO	38	75	97	13	8	13	1	0	**245**
	YES	3	21	20	8	4	3	2	1	**62**
		41	96	117	21	12	16	3	1	**307**
Horizontal digester	NO	35	80	90	16	7	13	1	1	**243**
	YES	6	16	27	5	5	3	2	0	**64**
		41	96	117	21	12	16	3	1	**307**
Vertical digester	NO	19	32	44	7	3	8	2	0	**115**
	YES	22	64	73	14	9	8	1	1	**192**
		41	96	117	21	12	16	3	1	**307**
Hydraulic press	NO	38	77	87	13	10	10	3	1	**239**
	YES	3	19	30	8	2	6	0	0	**68**
		41	96	117	21	12	16	3	1	**307**
Screw press	NO	31	56	75	11	7	7	1	0	**188**
	YES	10	40	42	10	5	9	2	1	**119**
		41	96	117	21	12	16	3	1	**307**
Digester-screw press	NO	37	84	86	14	7	10	2	1	**241**
	YES	4	12	31	7	5	6	1	0	**66**
		41	96	117	21	12	16	3	1	**307**
Centrifuge	NO	41	96	116	21	12	15	2	1	**304**
	YES	0	0	1	0	0	1	1	0	**3**
		41	96	117	21	12	16	3	1	**307**
Clarifier	NO	40	90	112	19	10	13	2	1	**287**
	YES	1	6	5	2	2	3	1	0	**20**

		41	96	117	21	12	16	3	1	**307**
Crude palm oil tank	NO	34	71	82	10	11	10	2	1	**221**
	YES	7	25	35	11	1	6	1	0	**86**
		41	96	117	21	12	16	3	1	**307**
Decanter	NO	41	96	114	21	12	15	2	1	**302**
	YES	0	0	3	0	0	1	1	0	**5**
		41	96	117	21	12	16	3	1	**307**
Vacuum dryer	NO	41	96	114	21	11	16	3	1	**303**
	YES	0	0	3	0	1	0	0	0	**4**
		41	96	117	21	12	16	3	1	**307**
Conveyance system	NO	40	94	113	20	12	15	2	1	**297**
	YES	1	2	4	1	0	1	1	0	**10**
		41	96	117	21	12	16	3	1	**307**
Nut fibre separator	NO	39	71	87	7	8	5	1	0	**218**
	YES	2	25	30	14	4	11	2	1	**89**
		41	96	117	21	12	16	3	1	**307**
Nut cracker	NO	26	55	68	7	7	8	0	0	**171**
	YES	15	41	49	14	5	8	3	1	**136**
		41	96	117	21	12	16	3	1	**307**
Diesel engine	NO	14	31	22	2	1	1	0	0	**71**
	YES	27	65	95	19	11	15	3	1	**236**
		41	96	117	21	12	16	3	1	**307**

Source: Field Survey (2021)

*FSLC – first school leaving certificate; WASC/NECO – West African School Certificate/National Examination Council
ND – National diploma; HND – Higher national diploma

Percentage possession and non-possession of processing machines/equipment are: stripper, 14,4 and 85.6 ; sterilizer, 20.2 and 79.8; horizontal digester, 20,8 and 79.2; vertical digester, 62.5 and 37.5; hydraulic press, 22.1 and 77.9; screw press, 38.8 and 61.2; digester screw press, 21.2 and 78.5; centrifuge, 0.98 and 99.02; clarifier, 6.5 and 93.5; crude palm oil tank, 28.0 and 72.0; decanter, 1.6 and 98.4; vacuum dryer, 1.3 and 98.7; conveyance system, 3.3 and 96.7; nut fibre separator, 29.0 and 71.0; nut cracker, 55.7 and 44.3 and diesel engine, 76.9 and 23.1, respectively

Table 4: Statistical Significance of the Education on Availability of Equipment

Equipment	Statistical Significance of education on its possession Pearson chi2 (6)	Probability
Stripper	23.8692	0.001
Sterilizer	18.5376	0.010
Horizontal digester	9.7952	0.205
Vertical digester	5.7926	0.564
Hydraulic press	12.9978	0.072
Screw press	9.6754	0.208
Digester screw press	17.2724	0.016
Centrifuge	38.7604	0.000
Clarifier	11.9827	0.101
Crude palm oil tank	12.4617	0.086
Decanter	24.4250	0.001
Vacuum dryer	8.4092	0.298
Conveyance system	10.1715	0.179
Nut fibre separator	44.0179	0.000
Nut cracker	10.8964	0.143
Diesel engine	15.9956	0.025

Source: Field Survey (2021)

About 20.2% of the respondents, had sterilizer, and the probability that there was relationship between the respondents' educational status and procuring a sterilizer was 0.01. This implies majority of the respondents knew the importance of the equipment but could not afford it probably due to the fact that they felt it is expensive. About 20.85% of the respondent had horizontal digester while 79.15% did not have. While majority of the respondents (62.54%) had vertical digester, 37.46% of the respondents did not have. The effect of educational status on possession of horizontal or vertical digester was not significant. This may be attributed to the fact that digestion is perhaps an operation that has been successfully mechanized long ago and has been modified to be easily operated (Babatunde *et al*., 1988; Taiwo *et al*., 2000).

A high percentage of the processors (77.9 %) did not have hydraulic press. This may be due to the fact that, though hydraulic is considerably efficient, its frequent breakdown has caused many processors to abandon its use (Owolarafe and Oni, 2011). It will require extra skill to maintain it and this explain why educational status has significant effect on its possession as indicated in Table 4. Furthermore, a good percentage (61.2%) of the respondents did not have either the manual threaded vertical press or the motorized horizontal press. This implies that many of the processors still adopt aqueous extraction system when compared with the percentage of those not having hydraulic press; although, aqueous extraction system is not as efficient as the use of press (Owolarafe *et al*., 2007). Majority of the respondents did not have digester screw press and this may be due to the fact that the machine is a bit expensive and also require some technical knowledge when compared with the ordinary press. This may explain the reason why the effect of educational status on its possession is significant (Table 4).

Table 3 also shows that 99.02% and 98.37% of respondents did not have or process with centrifuge and decanter, respectively while only 0.98% and 1.63% of the first degree and master's respondents process with the duo. The use of screw press in oil separation and the recapturing of oil by a sludge centrifuge for further clarification enables over 90% of the oil to

be extracted (Hartley, 1988). There is significant effect of educational status on availability of centrifuge and decanter. Low percentage of possession of the machine implies low technology since the machines/equipment are important in the production of special palm oil**.** The result of availability of clarifiers shows that 93.49% of respondents did not have or process with clarifier while only 6.51% of the respondents processed with clarifier. In the same vein with centrifuge and decanter, low percentage of possession of clarifier (which is an important device in purifying extracted crude palm oil) is an indication of negative influence on technological capability. This implies that most of the processors captured in the study area use ordinary drum for cooking the extracted crude oil. There is, however, no effect of educational status on the use of clarifier by the respondents. This is because whether not educated, fairly educated or well educated, the device wasn't popular in the palm oil industry in the study area.

Conveyance system is designed to move material from one facility or operation to another on the same site. Table 3 shows that 96.74% of respondents did not have or process with conveyance system while only 3.26% of the respondents processed with conveyance system. The low percentage as 3.26% of this equipment is an indication of technological capability to support the production of special palm oil. Conveyance system reduces operating time and minimizes contamination due to handling and hence improve oil quality (Owolarafe, 2015). The probability is 0.179 shows that there is no relationship between the level of education and having a conveyance system, because level of education did not influence the procurement and utilization of the equipment in special palm oil production technology profile. (Majority of the respondents did not have nut fibre separator and nutcracker because the operation requires some level of experience and education. On this note, the analysis shows that there is a great significance in pursuing some level of education and having some of the sets of equipment and hence level of technological capability to support production of special palm oil. Analysis of the data shows that there is significant influence of the level of education on availability of diesel engines while the influence of education on possession of vacuum dryers is significant and no significant, respectively, with the level of education, though majority (76.87%) of the respondents use diesel engines. Diesel engine is an important device in processing activities in the rural area because of its ruggedness and most processors usually procure it.

3.2.2 Effect of mill ownership on availability of equipment

Table 5 shows the relationship between the scale of operation and the available equipment. Table 6 establishes the probability of this relationship. Table 5 further shows that majority of the processors that own the mill acquire it based on single-private ownership. Few out of the total processors operates based on cooperative society, joint venture and government. It can be deduced from Table 5 that few of single-private ownership (less than 20%) were processing with the stripper, sterilizer, horizontal digester, hydraulic press, digester- screw- press, centrifuge, clarifier, crude palm oil, decanter, vacuum dryer, and conveyance system; whereas for vertical digester, screw press, nut cracker and diesel engine, higher percentages of 62.96, 40.74, 43.7 and 91.23%, respectively; others were in the minority. This may be attributed to the fact that most of the processors operate on small scale who may not likely acquire such facilities geared towards production of high quality oil because they are expensive. Table 6 shows that there is no relationship in the mill ownership and the equipment available in the processing centre. This trend may be attributed to the fact that vertical digester and screw press (particularly the vertical shaft and plunger type) have been mastered over the years by many processors and thus require lower initial and maintenance costs (Taiwo *et al*., 2000; Owolarafe, 2007). Furthermore, diesel engine has been found to be suitable for the small-scale processors because of its ruggedness and adaptability to the rough conditions where the processors are concentrated (Taiwo *et al*., 2000).

Table 5: Effect of Mill Ownership on Availability of Equipment

Description of Mill Ownership/ Availability of		Single-Private (%)	Cooperative / (%)	Joint V / (%)	Government / (%)	Total
Stripper	NO	229 (84.44)	5 (83.33)	26 (100.00)	4 (100.00)	**264**
	YES	42 (15.56)	1 (16.67)	0 (0.00)	0 (0.00)	**43**
		271 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**
Sterilizer	NO	210 (77.41)	6 (100.00)	25 (96.15)	4 (100.00)	**245**
	YES	61 (22.59)	0 (0.00)	1 (3.85)	0 (0.00)	**62**
		271 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**
Horizontal digester	NO	213 (78.52)	5 (83.33)	21 (80.77)	4 (100.00)	**243**
	YES	58 (21.48)	1 (16.67)	5 (19.33)	0 (0.00)	**64**
		271 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**
Vertical digester	NO	100 (37.04)	4 (66.67)	10 (38.46)	1 (25.00)	**115**
	YES	171 (62.96)	2 (33.33)	16 (61.54)	3 (75.00)	**192**
		271 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**
Hydraulic press	NO	206 (75.93)	5 (83.33)	24 (92.31)	4 (100.00)	**239**
	YES	65 (24.07)	1 (16.67)	2 (7.69)	0 (0.00)	**68**
		271 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**
Screw press	NO	161 (59.26)	5 (83.33)	19 (73.08)	3 (75.00)	**188**
	YES	110 (40.74)	1 (16.67)	7 (26.92)	1 (25.00)	**119**
		271 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**
Digester screw press	NO	208 (76.67)	6 (100.00)	23 (88.46)	4 (100.00)	**241**
	YES	63 (23.33)	0 (0.00)	3 (11.54)	0 (0.00)	**66**
		271 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**
centrifuge	NO	268 (98.89)	6 (100.00)	26 (100.00)	4 (100.00)	**304**
	YES	3 (1.11)	0 (0.00)	0 (0.00)	0 (0.00)	**3**
		271 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**
Clarifier	NO	251 (92.59)	6 (100.00)	26 (100.00)	4 (100.00)	**287**

	YES	20 (7.41)	0 (0.00)	0 (0.00)	0 (0.00)	**20**
		270 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**306**
Crude palm oil tank	NO	193 (71.11)	5 (83.33)	21 (80.77)	3 (75.00)	**222**
	YES	78 (28.89)	1 (16.67)	5 (19.33)	1 (25.00)	**85**
		271 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**
Decanter	NO	266 (98.15)	6 (100.00)	26 (100.00)	4 (100.00)	**302**
	YES	5 (1.85)	0 (0.00)	0 (0.00)	0 (0.00)	**5**
		271 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**
Vacuum dryer	NO	267 (98.52)	6 (100.00)	26 (100.00)	4 (100.00)	**303**
	YES	4 (1.48)	0 (0.00)	0 (0.00)	0 (0.00)	**4**
		271 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**
Conveyance system	NO	262 (96.67)	6 (100.00)	26 (100.00)	4 (100.00)	**298**
	YES	9 (3.33)	0 (0.00)	0 (0.00)	0 (0.00)	**9**
		271 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**
Nut fiber separator	NO	189 (69.63)	5 (83.33)	21 (80.77)	3 (75.00)	**218**
	YES	82 (30.37)	1 (16.67)	5 (19.33)	1 (25.00)	**89**
		271 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**
Nut cracker	NO	153 (56.30)	3 (50.00)	14 (53.85)	2 (50.00)	**172**
	YES	118 (43.70)	3 (50.00)	12 (46.15)	2 (50.00)	**135**
		2710 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**
Diesel engine	NO	62 (8.77)	2 (33.33)	6 (23.08)	1 (25.00)	**71**
	YES	209 (91.23)	4 (66.67)	20 (26.92)	3 (75.00)	**236**
		271 (100.00)	6 (100.00)	26 (100.00)	4 (100.00)	**307**

Source: Field Survey (2021)

Table 6: Statistical Significance of the Effect Mill Ownership on Equipment Availability

Description of Mill Ownership/Availability of Equipment	Pearson chi2(6)	Probability
Stripper	5.4441	0.142
Sterilizer	7.7856	0.051
Horizontal digester	1.2203	0.748
Vertical digester	2.4764	0.48
Hydraulic press	4.9615	0.175
Screw press	3.5275	0.317
Digester screw press	4.7933	0.188
Centrifuge	0.0713	0.965
Clarifier	0.404	0.939
Crude Palm Oil tank	2.8531	0.415
Decanter	1.4975	0.683
Vacuum dryer	0.5404	0.91
Conveyance system	1.2364	0.744
Nut fiber separator	1.9213	0.589
Nut cracker	0.2028	0.977
Diesel engine	0.3618	0.948

Source: Field Survey (2021)

Nut cracker is an additional facility but useful in recovering shells as fuel for firing steriliser and clarifier. It was observed that cooperative society, joint venture and government mill ownership are very few in the study area probably due to the fact palm oil production is an agelong occupation with most families in the area and so everybody may feel comfortable being independent. There is no relationship between the ownership of mill and having a diesel engine ($p = 0.948$), i.e., anybody can have diesel engine because diesel engine is considered necessary by all processors as suitable prime mover for all conditions (Taiwo *et al*., 2000)
Generally, the effect of mill ownership did not affect technological capability in terms of availability of machines/equipment (except for sterilizer) required for production of special palm oil based on the result of the statistical analysis. This implies that, whether single-privately- owned, jointly- owned, cooperatively-owned or government-owned, processors may decide to own or not own a particular set of equipment.

3.2.3 Effect of size of mill on tonnage of palm fruits processed per day.

Table 7 shows the relationship between the size of mill and tons of palm fruit that can be processed per day (generally, mills with throughputs 1- 10, 11 to 20 tons and > 20 tons/hr are classified as small, medium and large scales, respectively). The table shows that 82.03%, 11.44%, 3.59%, and 2.94% of the respondents processed their palm fruits in the range of 1-3, 4-6, 7-10, and 11+ tons/day, respectively. This implies that majority of the respondents processed 1-3 tons/day irrespective of the size of the mill. This implies that, though processors with higher scale of operation have the opportunity to process more fruits per day, they are likely to be limited by the available fruits to be processed. Field observations indicate that processors on higher capacity usually buy fruits from plantations and many plantations' owners prefer to process their fruits themselves and may not want to sell their fruits.

Table 7: Effect of Size of Mill on Tonnage of Palm Fruits Processed/Day

Scale of Operation	Tonnes of Palm Fruits Processed per Day				
	1-3	4-6	7-10	11+	Total
Small	164 (90.61)*	7 (3.87)	5 (2.76)	5 (2.76)	181
Medium	80 (70.18)	25 (21.93)	6 (5.26)	3 (2.63)	114
Large	7 (63.64)	3 (27.27	0 (0.00)	1 (9.09)	11
Total	251 (82.03)	35 (11.44)	11 (3.59)	9 (2.94)	306

Source: Field Survey (2021). Pearson chi^2 (6) = 29.5810 Probability = 0.000
*Figures in brackets represent percentage of each range of tonnes of oil palm fruit in each scale of operation.

This may explain why medium and large scales mills are underutilized in the study area. This is in agreement with the findings of Owolarafe and Arumughan (2007a; 2007b) on assessment of Indian plantations and palm oil mills. Statistical analysis indicates that a significant relationship exists between the size of the mill and tons of palm fruit processed per day. Lending credence to the work of Poku (2002) that small-scale oil palm fruit processors operating in the rural informal economy are those who process no more than 2 tons of oil palm fruit per hour. The small-scale processors account for about 80% of the total palm oil production sector's output in Nigeria being largely responsible for majority of the oil palm trees growing wild and on abandoned farm in the country (Carrere, 2010).

3.2.5 Size of mill versus number of plantations

Table 8 shows the relationship between the size of the mill and the number of plantations owned by each respondent. It shows that 79.74% of the respondents have number of plantations where they sourced fruits in the range of 1-10, while about 8.82, 2.67, 2.67 and 6.21%, have within the range of 11-20, 21-30, 31-40, and >40 number of plantations , respectively. The average size of these plantation is between 1 to 5 ha. The structure of the plantations and number patronised are similar to the findings of Owolarafe and Oni (2011) and Owolarafe (2012) on Abia palm oil industry. The probability of 0.250 shows that there is no strong relationship between the size of the mill and the number of plantations owned.

Table 8: Effect of Size of Mill on Number of Plantations

Scale of Operation	Number of Plantation					
	1 - 10	11 - 20	21 - 30	31 - 40	40+	Total
Small	150(82.87)*	11(6.08)	4(2.21)	7(3.87)	9(4.97)	181
Medium	86(75.44)	15(13.16)	3(2.63)	1(0.88)	9(7.89)	114
Large	8(72.73)	1(9.09)	1(9.09)	0(0.00)	1(9.09)	11
Total	244(79.74)	27(8.82)	8(2.67)	8(2.67)	19(6.21)	306

Source: Field Survey, 2021. Pearson chi^2(6) = 10.2137 Probability = 0.250
*figures in brackets represent percentage of each range of number of oil palm plantation patronized by each scale of operation

3.2.6 Effect of mill size (on end users

Table 9 shows the relationship between the size of the mill (scale of operation) and the buyers of the product, which includes the consumers, industries, and both the consumers and industries. It shows that majority of respondents 71.90% sell their products to consumer

irrespective of the scale of operation while only few 24.84% sell to both consumer and industries. Based on field observations, the oil produced by nearly oil the small-scale processors is usually of low quality and usually purchased by customers for domestic applications. Inability to produce high quality oil is an indication of low technology employed by the small-scale processors who occupy a major position among the respondents.

Very few large-scale plants are able to place their products in industries. The probability of 0.025 shows that there is a strong relationship between the scale of operation and the buyers of products because of the concept of demand and supply and the quality expected. (It has been reported by Beveridge *et al*. (2011) and Partnership Initiatives in the Niger Delta-PIND (2011) that most food processing industries in Nigeria source their palm oil especially special palm oil outside the country.

3.2.7: Effect of size of mill on level of awareness about SPO

Table 10 shows the relationship between the scale of operation and the level of awareness about SPO. The table shows that majority of respondents (64.17%) were not aware of SPO production process irrespective of the size of the mill. The probability of 0.124 however shows that there is no close relationship between the level of awareness about SPO and the size of the mill.

Table 9: Size of Mill and End Buyers

Scale of Operation	Buyers of Products			
	Consumers	Industries	Both	Total
Small	142(78.45*)	3(1.66)	36(19.89)	181
Medium	72(63.16)	6(5.26)	36(31.58)	114
Large	6(54.55)	1(9.09)	4(36.36)	11
Total	220(71.90)	10(3.27)	76(24.84)	306

Source: Field Survey (2021). Pearson chi2(4) = 11.1789 Probability = 0.02

* The figures in bracket represent the percentage of each buyer among of the total for each scale of operation

Table 10: Effect of Scale of Operation on Level of Awareness SPO

Scale of Operation	Level of Awareness about SPO				
	Not at all	Heard it	Seen it	Used it	Total
Small	122(66.67*)	54(29.51)	2(1.10)	1(2.70)	183
Medium	67(59.30)	41(36.28)	1(0.88)	4(3.54)	113
Large	8(72.73)	1(9.09)	1(9.09)	1(9.09)	11
Total	197(64.17)	96(31.27)	4(1.30)	10(3.26)	307

Source: Field Survey (2021). Pearson chi2(6) = 10.0037 Pr = 0.124

* Figures in bracket represent the percentage of each level of awareness among the the toal for each scale of operation

CONCLUSIONS

An assessment of local processors' technological capacity, in terms of knowledge, skill acquisition and type of equipment required for the production of SPO was carried out in this study. Majority of the respondents did not know about SPO; let alone possessed the knowledge and skill necessary for its production. It was established that increasing the level of awareness about SPO among the processors will motivate an increase in the size of existing oil mill. Education qualification was associated with the availability of some pieces of critical

equipment for the production of SPO. The study recommended that technological interventions that would increase respondents' awareness of how to produce SPO will bring valuable boost to the industry. Such interventions may include the training of the processors and granting them incentives to increase production. This will hence be a right step in addressing the shortage of SPO for the use local industries, reduce the dependency of the industries on importation of the oil and will also enhance employment.

ACKNOWLEDGEMENTS

Authors are grateful to:

i. Tertiary Education Trust Fund (TetFund), Nigeria, for providing the financial support for the study, and
ii. Staff of Nigerian Institute for Oil Palm Research, Benin , Edo State; Okomu Oil Palm Industries, Edo State; Okitipupa Oil Palm Factory, Okitipupa, Ondo State, JB Farms, Odogbolu, Ogun State and Royal Farms, Osu, Osun State.

FUNDING

The study was carried out under the Tetfund National Research Fund (NRF) project titled "Development of Appropriate Agro-processing Technologies for Production of Special Palm Oil for Industrial Applications in Nigeria" with Grant Code: Tetfund/DR&D/CE/NRF/CC/10/VOL.1

REFERENCES

Babatunde, O. O., Ajibola, O. O., Ige, M. T. (1988). A modified process for low-cost palm oil extraction. *Journal of Food Science and Technology*, 25(2):67–71.

Badmus, G.A., Owolarafe, O. K., Osunleke, A.S. Ajadi, S.O and Ajayi, O.A (2019). Mathematical modelling of digester-screw press process for expression of oil from oil palm fruit. *Ife Journal of Science*, 21(3):193-211

Badmus, G. A., Owolarafe, O. K., Osunleke, A. S. and Ajayi, O. A. (2021) Effect of design parameters on oil yield, extraction efficiency and volumetric flow of digester-screw press. *Journal of the Nigerian Academy of Engineering*, 3 (1): 68 -83

Beveridge , A**. ;**. Owolarafe, O.K., Usman, Z.; Odoemena, B.; Barkees, C; Dry, B. and Lockwood, R (2011): Abia State Palm Oil Industry Supply Chain Development Programme Quarterly Report submitted to the National Investment Promotion Commission.

Carrere, R. (2010), 'Oil Palm in Africa: Past, Present and Future Scenarios', World Rainforest Movement Series on Tree Plantations No. 15, Montevideo, www.wrm.org.uy/publications/oil-palm-africa-past-present-and-future-scenarios-2013-update. Retrieved 11/07/2022

Elekwachi, J.; Owolarafe, O.K.; Fadare, S.O. and Adu, A (2012). Palm Oil Scoping Study. A report submitted to the Partnership Initiatives in the Niger Delta.

F.A.O. (2021). FAO Statistical Yearbook, World Food and Agriculture. www.fao.org/3/cb4477en/online/cb4477en.html#Front_matter. Retrieved 11/07/2022

Foundation for Partnership Initiatives in the Niger Delta (PIND). (2011). 'A report on palm oil value chain analysis in the Niger Delta'. 167 Ademola Adetokunbo Crescent, Wuse II, Abuja,Nigeria.

Hartley C.W.S. (1988) *The Oil Palm*, UK, 3rd Edition Longman Group Publisher, Chapter 14.

Indarti, S., Fernandes, A. A. R., and Hakim, W. (2017). The effect of OCB in relationship between personality, organizational commitment and job satisfaction on performance. *Journal of Management Development,* 36 (10): 1283-1293

Market Development in the Niger Delta (2019): Mapping of oil palm clusters in Niger Delta, Nigeria, Monograph series no. 22.

Morakinyo, T. A and Bamgboye, A. I. (2016). Performance characterization and optimization of a synchronized medium-scale of oil palm fruits processing mill. *Journal of Food Processing Engineering*, 40(5):1223.

Ologunagba, F.O. Olutayo L.A. and Ale, M.O. (2010). Development of a palm nut and fibre separator. *Journal of Engineering and Applied Sciences*, 5(12):10-15

Owolarafe, O.K., Faborode, M.O., and Ajibola, O.O. (2002). Comparative evaluation of the digester-screw press and hand-operated hydraulic press for oil palm fruit processing. *Journal of Food Engineering*, 52: 249–55.

Owolarafe, O.K. (2007). The mechanics of palm oil extraction. Unpublished Ph.D Thesis of the Department of Agricultural Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria.

Owolarafe, O. K**.** and Arumughan, C. (2007a): A Review of Oil Palm Fruits Plantations and Production under the Contract-Growers Scheme in Andhra Pradesh and Tamil Nadu States in India. Agricultural Engineering International, CIGR Ejournal, USA., Vol IX (March), invited overview article no 4.

Owolarafe, O. K**.** and Arumughan, C.(2007b): Technological Capability of Palm Oil Mills under The Contract-Growers Scheme in India. Agricultural Engineering International,. CIGR Ejournal USA,. Vol. IX. (November), article no 72.

Owolarafe, O. K.; Sanni, L. A.; Olosunde, W.O.; Fadeyi, O. O. and Ajibola, O.O. (2007): Development of an aqueous palm oil extraction system. *Agricultural Mechanisation in Asia, Africa and Latin America,* 38(4):61-66,

Owolarafe, O. K. and Faborode, M.O. (2008): Micro-structural characterisation of palm fruit at stages of sterilisation and digestion in relation to oil expression. *Journal of Food Engineering,* 85(4): 598-605.

Owolarafe, O.K. and Oni, O.A. (2011): Modern mill technology and centralised processing system, an alternative for improving performance of palm oil mills in Abia State, Nigeria-*Technology in Society*, 33: 12–22.

Owolarafe, O.K. (2012): Oil Palm Plantation Development and Management in Nigeria- a Case Study of Abia State. Ife Journal of Agriculture, 25 (2): 65- 82.

Owolarafe, O. K. (2015). "Building a Paradise in Nigeria-The R & D Option for Small and Medium Scale Agro-Allied Industries", the 282nd Inaugural Lecture Series of Obafemi Awolowo University, Ile-Ife, presented on 22nd December, 2015, Obafemi Awolwo University Press Ltd.

Poku, K. (2002). Origin of Oil Palm: Small-Scale Palm Oil Processing in Africa. FAO Agricultural Services Bulletin 148. Food and Agriculture Organization. ISBN 92-5-104859-2.

Salako, Y.A. Owolarafe, O.K. and Anozie, A.N (2014). Performance evaluation of a small-scale palm fruit biomass fired boiler, *Agricultural Engineering International, CIGR Journal*, 16(4): 51-55

Taiwo, K.A.; Owolarafe, O.K.; Sanni, L.A.; Jeje, J.O.; Adeloye, K. and Ajibola, O.O. (2000). Technological assessment of palm oil production in Osun and Ondo States of Nigeria, *Technovation*, 20(4): 215 – 223

Tropical Agriculturalist. (1998). *The Oil Palm.* Macmillan Educational Publisher Ltd. London and Basingstoke. 1st Edition, p 19-20.