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Comparison of Traditional and Semi-mechanized Palm Oil Processing Approaches in Nigeria; Implications on Biodiesel Production

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Abstract

Oil palm processing is a source of livelihood to many rural families in the Niger Delta, Nigeria. About 80% palm oil processors are smallholders who basically employ manual equipment for processing. In this study, the processes of crude palm oil (CPO) production from fresh fruit bunch were compared between semi-mechanized and traditional processors in Niger Delta Nigeria. The study found that both approaches share the same processing steps like bunch reception, fermentation before threshing, sieving and digestion whereas steps like slicing, fermentation of PPF were typical of only traditional approach. Oil drying was peculiar to only semi-mechanized mill. Though, both methods of processing result to low quality CPO, but semi-mechanized quality is slightly better. The processing duration was shorter in semi-mechanized as compared to traditional approach. The quality of CPO produced by both approaches could be a challenge during transesterification process in biodiesel production.

Keywords: Biodiesel, Crude palm oil, Renewable energy

1 Introduction

Elaeis guineensis Jacq. is cultivated in the tropical and subtropical region of the World including Indonesia, Malaysia, Thailand, Columbia, Nigeria etc. Oil palm is believed to have originated from West Africa. Based on the scientific name, it's likely to have originated from guinea. However, several authors have cited Nigeria as the most probable place of origin **[1]**. Oil palm produces two type of oil namely crude palm oil (CPO) and palm kernel oil (PKO). CPO is the most utilized vegetable oils in most part of the world .CPO has dominated the global vegetable oil supply accounting for 33% of total edible oil in the world. Typically, an hectare of oil palm plantation have been variously reported to produce 10 – 30 tonnes/hectare/annum [2 – 7]. Oil palm has a life span of 200 years with economic life of 25 – 30 years [8]. Oil palm starts bearing fruit at 3 years reaching peak between 5 and 10 years [2 – 4, 8]. Like other cash crops such as cocoa and rubber, oil palm requires suitable climatic and soil conditions for optimum yield. These environmental conditions include relative humidity, temperature, rainfall and soil pH.

CPO is derived from the extraction processes of palm fruit. Basically, two species (Dura and Tenera) of oil palm is produced in Nigeria. The Tenera is a hybrid of Dura and Pisifera which have almost gone into extinction. The quantity of CPO produced from fresh fruit bunch (FFB) has been variously studied in different oil palm producing nations. Ohimain *et al.* [7] reported a yield of 9.4 – 12.8% and 26.0 – 28.0% for Dura and Tenera varieties respectively from smallholder processors in Nigeria. Prasertsan and Prasertsan [9] reported 25 – 28% and 11.5% from high and low quality FFB respectively in Thailand. Mahlia *et al.* [6] reported 23.52% in Indonesia/Malaysia. Hambali *et al.* [10] reported 23.5% in Indonesia. CPO is mostly utilized as ingredient for food, confectionaries and industrial applications including pharmaceutical, cosmetics, polish making, detergents, shampoo, lipstick, and biodiesel and lubricants. Also, every part of the oil palm including the processing wastes have been diversely utilized into different by-products.

CPO which is orange red to brownish or yellow-red in color, is extracted from the mesocarp of FFB oil palm [11, 12]. CPO is one of the major agricultural produce in the southern Nigeria where it's a source of livelihood to several families especially in the rural areas. Nwaugo et al. [13], Ohimain et al. [14] stated that most oil palm stands is found in southern Nigeria both in wild and plantations. The production of CPO is largely carried out by smallholder processors who uses manual equipment for processing and

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to a lesser extent by semi - mechanized processors [15]. It has been reported that the smallholder covers about 80% of the Nigeria oil palm sector [15 – 17]. The semi-mechanized processors account for about 16% of the industry while the industrialized processors are few [18]. Traditional approach of oil palm processing is grouped into fiber and press extraction processors [19]. According to Onwuka and Akaerue [19], there are two methods of traditional method i.e. the fiber method and press method. CPO is obtained in fiber method by mashing of boiled palm fruit in a mortar and further mashed with hot water [19]. Heat is applied to dry up the water. The press method is a kind of modern traditional oil palm processing involving harvesting, transportation, fermentation of FFB, stripping/threshing, sieving, boiling, digestion, oil extraction, re-fermentation, repressing and clarification (Fig. 1a) [7, 8, 16 – 18, 20 – 24]. This method is currently in practice by smallholder oil palm processors, in most communities in the Niger Delta region of Nigeria.

The CPO produced by smallholders is of low quality. Though, the CPO consumed as food are hardly subjected to strict quality analysis in Nigeria. The industrial application of CPO such as biodiesel production is challenged by poor quality. CPO with free fatty acid >1% often pose a challenge during transesterification. Thereby increasing the overall production cost due to refining. Apart from FFA, moisture content, impurity level, peroxide value and saponification value could be a challenge to biodiesel production from oil palm feedstock. Nigeria have opted to diversify from the highly favor petroleum product to agricultural produce for the production of biofuels such as biodiesel from oil palm feedstock. Therefore, this study aimed at [a] visiting the modern-traditional and semi-mechanized oil palm mills in the Niger Delta region of Nigeria and observing the various processing activities, [b] comparison of the processing components of both mill, and [c] analyzing their influence on biodiesel industry.

2 Materials and Methods

Ten traditional oil palm processing mills were visited at Elele, River State, Niger Delta region of Nigeria from 13th – 22nd April 2012. The process of palm oil extraction from FFB at these mills is basically the same and is presented in Fig. 1a. A semi-mechanized palm oil mill was visited at Elebele, Bayelsa State, Niger Delta of Nigeria from 03rd to 07th June, 2013. The process of palm oil extraction is presented in Fig. 1b. The activities leading to palm oil production in each of the two groups of mills were compared with main focus on biodiesel production.

3 Results and Discussion

The various processing steps employed in the production of CPO by traditional and semi-mechanized processors in the Niger Delta Nigeria are presented in Figure 1 and Table 1. The harvested fruit is loaded in a tractor, which then conveys it to the processing mill. The tractors that are used can contain 360-400 fresh FFB, depending on the size of the bunch. Bruises that may occur during harvesting and transportation create avenue for microbial attack. Acid formers and hydrocarbon degraders are capable of flourishing in oil environment could inhabit and proliferate in the fruit via the exposure due to bruises. In traditional method, FFB is sliced manually into six or more pieces; they are left for 2-4 days to ferment to ease stripping. This is mostly done with cutlass in traditional methods whereas the semi-mechanized processor do not slice the FFB. Both approaches employ fermentation to aid in loosening of fruit from the spiklets. Bruises from slicing, and fermentation promotes microbial infestation which may ultimately increase the FFA content of the CPO [19].

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Table 1: Comparisons of traditional and semi-mechanized palm oil production

Processing activities	Traditional	Semi-mechanized	Implications
Bunch/ transportation reception	Tractor	Tractor also used	Bruise that may occur during transportation may promote microbial infestation
Bunch slicing	FFB is sliced using cutlass	FFB is not sliced	It promotes microbial attack
Fermentation	2 – 4 days	2 – 3 days	The fermentation of FFB promotes proliferation of lypolytic microorganisms that have invaded the fruit due to bruises and subsequently increases the FFA
Threshing	Stick	Motorized	Increases bruises, thereby increasing chances of microbial infestation
Sieving	Makeshift sieve made from raffia and oil palm fronds	Metallic mesh	Sieving enhances quality oil through reduction in impurity
Boiling/ sterilization	Drum or barrels is used for boiling	Boiler is employed	Boiling aid in the destruction of hydrolytic enzymes
Digestion	Mechanical engine connected to rotary drum	Same as traditional method	Facilitate oil extraction
Pressing/oil extraction	Screw press is mostly used	Hydraulic press is mostly utilized for oil extraction	The extracts (mixture of oil and POME) is removed from the fiber and nut
Fiber separation	Separating knife is used	Rotary drum connected to electricity	The nut is separated from the PPF
Fermentation of PPF	2 – 4 days to produce second grade oil called PPFO	The PPF is not fermented	PPFO produced is of low quality with regard to physico-chemistry
Clarification	Manual clarification tank	Motorized clarification tank	The CPO is fully recovered separating POME from it
CPO drying	Do not dry CPO produced	Heat is applied gently	The residual moisture are removed while the FFA are enhanced
Storage/ packaging	Transparent gallons mostly from consumed vegetable oil are used for storage	Opaque storage tank are used	Empty vegetable oil gallons are transparent hence it promotes rancidity of the CPO

Traditional oil palm processors separate the fruit from the sliced fruit via shaking whereas semi-mechanized processor uses mechanized rotary drum. The approach used by traditional processors is time consuming and high human energy consumption whereas the semi-mechanized approach is relatively faster with little human energy applied. Onwuka and Akaerue [19] stated that traditional method of oil palm extraction is tedious and inefficient. Like transportation, slicing and fermentation processes, threshing/stripping by traditional processors expose the fruit to microbial infestation. Both approaches carry out this activity using similar technology. But unlike traditional method that uses sieve from raffia and oil palm fronds, semi-mechanized processors uses sieve that is made with metallic mesh

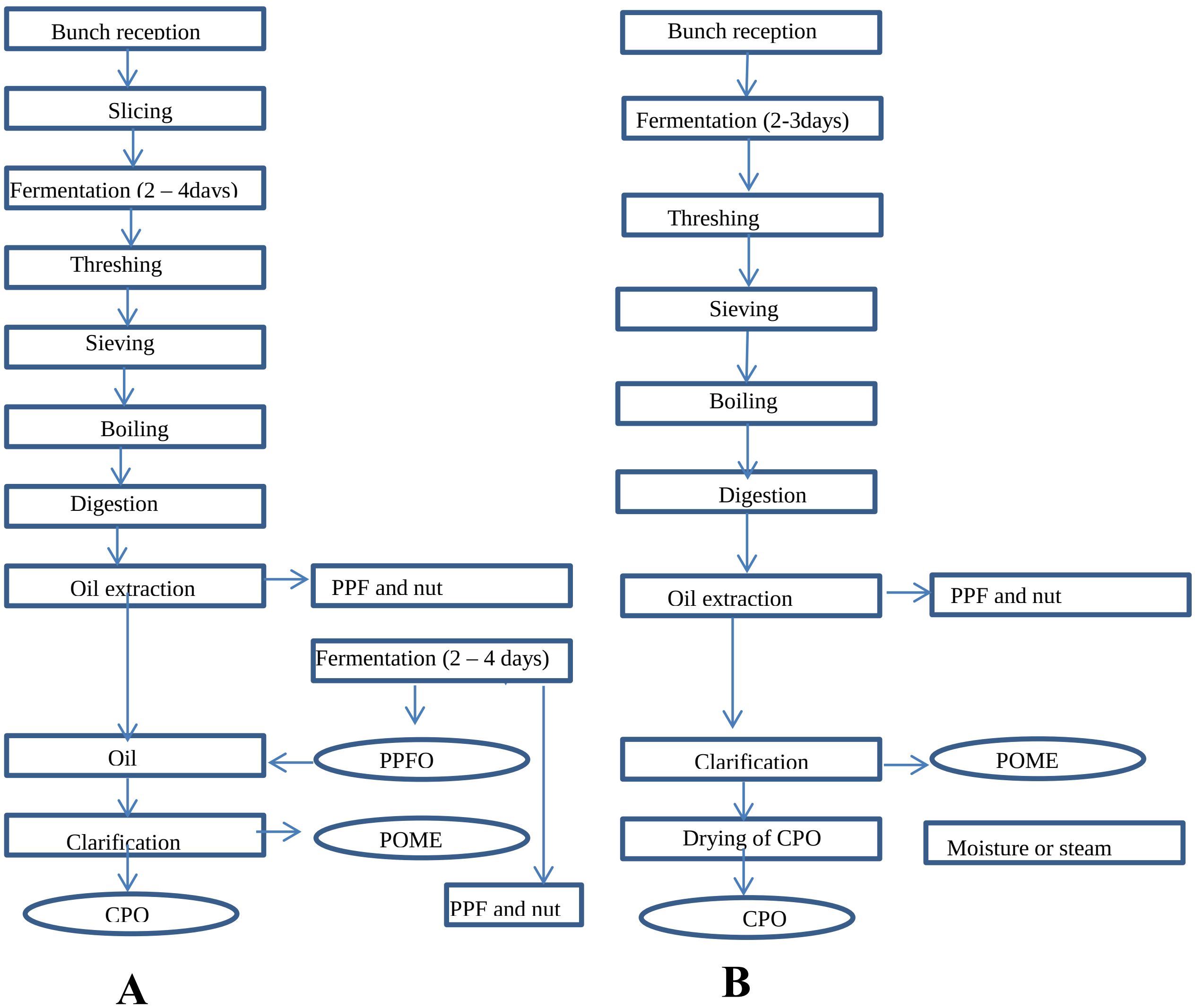

Fig. 1: Flow chart of oil palm processing in Niger Delta, Nigeria [A] Traditional [B] Semi-mechanical/Industrial approach (PPFO = palm press fiber oil; PPF = palm press fiber CPO = crude palm oil; POME = palm oil mill effluents)

Boiling/sterilization aids in the destruction of splitting enzymes and stop of hydrolysis and autoxidation. Boiling declines the pulps structure, thereby enhancing the detachment of fiber from the nut in subsequent activities. The water absorbed by the fruit during boiling also aid in the digestion activity. During boiling, the nut of palm fruit expands due to heat and pressure. The crushing of boiled fruit aid in the release of oil during pressing in a digester is carried out using a cylindrical vessel that is fitted with central rotating shaft carrying a series of beater (impeller) [25]. In both approaches, the technique are the same. Crushing is carried out at high temperature to decrease viscosity of the oil, destroys the fruits outer covering and loosening the mesocarp from the nut. The extraction of CPO from the crushed fruit is carried out by traditional processors using screw press and hydraulic press by semi-mechanized processor. The screw press is operated by 2-4 persons whereas the hydraulic press can be operated by one person. According to Orewa *et al.* [26] and Ekine and Onu [27], the traditional approach usually lead to loss of CPO to the processing wastes such as palm press fiber and this method is arduous and time consuming.

CPO is separated from the POME via pumping of oil to the dryer for semi-mechanized whereas in traditional method, the processors carefully skim the CPO leaving the POME at the clarification tank/drum. In traditional approach, clarification is carried out when the mixture is still hot. Poor clarification and filtration enhances the impurities level [19]. Whereas in semi-mechanized mills, the mixture is pumped to the dryer where light heat is applied to create a barrier causing the heavy solids to fall to the bottom of the container while the lighter droplet flows through the watery mixture to the top [25].

The mixture of palm press fiber and nut are separated using separating knife by traditional method whereas the semi-mechanized processor uses mechanized rotary drum for the separation. Unlike the semi-mechanized processors, the palm press fiber recovered in traditional mill is fermented anaerobically after adding POME. The fermentation leads to the production of more oil via the exothermic reactions for 2-4 days. The repressing of the PPF produces oil called palm press fiber oil (PPFO) with high moisture, FFA and impurity level [28]. In semi-mechanized systems PPFO is called technical palm oil (TPO).

Unlike the traditional method, semi-mechanized method involves reheating the clarified oil to remove engrained dirt and residual moisture content of the oil. The dried CPO is store at temperature at about 50ºC to prevent fractionation, solidification and oxidation [25]. But traditional palm oil mills do not dry oil rather they package and store clarified CPO in transparent containers. Okonkwo [29] reported that transparent packaging container could influence the quality of CPO.

The extraction duration, environment, energy requirement and volume and quality of CPO are presented in Table 2. The duration of CPO processing by traditional method is 6 – 10 days and semi-mechanized methods 2 – 4 days. The increased time of processing and storage could enhance the FFA content of the oil [30]. The traditional oil palm mills process the FFB into CPO in batches which often result to longer period of processing as compared to semi-mechanized mills. The traditional mills are untidy and unhygienic while the semi-mechanized mill appears neater. Dirty environment especially from palm oil mill promotes the proliferation of microorganisms capable of flourishing in oily habitats [20, 24]. Ohimain *et al.* [14, 17] reported the physico-chemical properties of CPO produced by traditional method in Niger Delta, Nigeria in the range of 8.44 – 10.30% (FFA), 13.70 – 18.21% (moisture content), 5.48 – 12.52% (impurity level) and 1.20 – 1.90 $MeqO_2$/kg (peroxide value). Onwuka and Akaerue [19] attributed the impurity level to unhygienic handling and further asserted that traditional method of processing expose CPO to rapid spoilage. Poor heat treatment during processes enhances the FFA level [19].

Traditional processing mills utilize oil palm solid wastes (EFB, PKS, PPF and chaff as boilers fuel whereas semi-mechanized mill uses only EFB as boiler fuel. Both approaches generate solid biomass, POME and gaseous emissions as the waste streams. Like traditional processing mills, semi-mechanized processors burn off excess wastes to the atmosphere where they cause air pollution.

Table 2: Comparative features of traditional and semi-mechanized oil palm processing

Determinants	Traditional	Semi-mechanized
Operation	Small and in batches	Large and in batches
Duration	6 – 10 days	2 – 4 days
Quality of CPO produced	Poor in physico-chemical properties	Poor in physico-chemical properties, though slightly better than that of traditional approach.
Energy utilization	Digestion utilizes fossil fuel, boiling uses oil palm processing biomass (EFB, PPF, PKS and chaff) as fuel	Threshing, digestion utilizes fossil fuel while EFB are mostly used as boilers fuel
Wastes generations	Solid biomass, POME and air emissions	Solid biomass, POME and air emissions

The Nigerian biofuel policy has mandated a blend of 20% (B20) for diesel creating an immediate demand of 480 million liter/annum [31]. The Nigeria biodiesel industry has listed oil palm as one of the potential crop for the emerging biodiesel industry. Ohimain *et al.* [16] stated that Nigeria is in the process of installing two large-scale oil palm based biodiesel refineries in Cross River State. One of the plants having a 15,000 hectare plantation is expected to produce 55,000 tonnes of CPO per year which produce 34 million liters of biodiesel/year. While the second plant having10,000 hectare estate could produce of 29,000 tonnes of CPO per year which could be used to the produce 18 million liters of biodiesel. These volume of biodiesel that is supposed to be produced from the two bio-refineries will not be able to replace the fossil diesel completely if all condition being favorable. This is because diesel consumption in Nigeria is high compare to the volume of biodiesel that will be produced annually from oil palm feedstock. For the period (2008 – 2012) Nigeria oil palm industry have been stagnated producing only 850,000 metric tonnes of CPO. But due to diversification attempt the CPO produced in Nigeria is 930,000 metric tonnes for the period 2013 - 2014. Also, poor physico-chemical reported in both approaches of CPO production could pose a challenge during biodiesel transesterification and increases the production cost [31]. This could also lead to low biodiesel yield. The poor quality is mostly associated with traditional method of processing, which unfortunately dominated the Nigeria oil palm industry.

4 Conclusion

The processing activities of CPO production by traditional and semi-mechanized processors in the Niger Delta Nigeria were compared. The processes of both approaches were found to share some characteristics. Semi-mechanized method was found to be more efficient with processing time and the quality is slightly higher than the traditional processing. Generally, the low quality of CPO from both approaches could be a challenge during biodiesel production. Due to extreme low quality by traditional processors, we hereby recommend that fermentation before threshing should be avoided and care should be taken when processing CPO to prevent deterioration of quality.

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