

Research Article

Material-mass Balance of Smallholder Oil Palm Processing in the Niger Delta, Nigeria

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Abstract: This study evaluates the material-mass balance of smallholder oil palm processing in Niger Delta Nigeria. Ten smallholder oil palm processing mills were randomly sampled. Measuring scale was used to measure the weight of the Fresh Fruit Bunch (FFB) and all the processing intermediates/products including Threshed Fresh Fruit (TFF), Palm Pressed Fibre (PPF), Palm Kernel Shell (PKS), Empty Fruit Bunch (EFB), Crude Palm Oil (CPO), chaff and nut. During the study period (13-22 April 2012), 8 of the mills processed 90-400 bunches of Dura variety, while the remaining 2 mills processed 65-200 bunches of Tenera variety. During the batch processing of Dura variety, the proportion of the intermediate products computed in relation to the weight of the FFB (100%) are as follows; TFF (66.0-75.0%), mesocarp (44.8-51.1%), nuts (19.0-27.5%), kernel (5.7-7.2%), water in mesocarp (9.0-12.1%) and water in nut (2.4-3.4%), EFB (23.7-32.4%), chaff (0.8-2.4%), Palm Kernel Shell (PKS) (10.0-18.8%), Palm Press Fibre (PPF) (23.2-28.1%) and Crude Palm Oil (CPO) (9.4-12.8%). For the *Tenera* varieties, the compositions are as follows; TFF (70.9-72.9%), mesocarp (56.4-58.0%), nuts (14.5-14.9%), kernel (5.5-5.6%), water in mesocarp (10.1-10.4%) and water in the nut (1.9-2.1%), EFB (25.7-28.2%), chaff (0.9-1.4%), PKS (6.8-7.5%), (19.1-20.3%) and CPO (26.0-28.2%). This result shows that *Tenera* produces more oil and less wastes compared to the *Dura* variety. The solid wastes fractions are used as energy sources during the processing of oil palm and as filling materials for upgrading access roads to palm plantations. Except the huge volume of wastes (71.8-90.6%) generated by smallholder oil palm processors is effectively utilized, the process will be unsustainable.

Keywords: Material-mass balance, oil palm, solid wastes

INTRODUCTION

Oil palm is a perennial crop cultivated extensively in the humid tropical region (Yusoff, 2004) of West Africa where it was first cultivated (Poku, 2002). It is the most important species of the genus *Elaeis* belonging to the family Palmae (Rupani *et al.*, 2010). In Nigeria, oil palm trees were originally inter-planted in traditional agricultural production systems along with annual crops. It was said to have been domesticated some 5,000 years ago in Nigeria (Sridhar and AdeOluwa, 2009). But production during this time was for subsistence. *Elaeis guineensis* has been variously reported as the most productive oil crop in the world (Tagoe *et al.*, 2012; Akangbe *et al.*, 2011; Okechalu *et al.*, 2011; Ngando *et al.*, 2011; Dimelu and Anyaiwe, 2011; Rupani *et al.*, 2010; Sumathi *et al.*, 2008), with one hectare of oil palm producing 10-35 tonnes of Fresh Fruit Bunch (FFB) per year (Sridhar and AdeOluwa, 2009; Singh *et al.*, 2010; Singh *et al.*, 2011). According to Embrandiri *et al.* (2012), oil palm normally grows in the lowlands of the humid tropics within 15°N and 15°S where there is evenly distributed rainfall (1,800-5,000 mm/year). Oil palm adapts to soil

with a low pH, but sensitive to high pH (>7.5) and to stagnant water (Hartley, 1988). It requires a relative humidity of not less than 75% and a temperature range of 17-28°C (Poku, 2002).

In West African, two distinct varieties known as the *Dura* and *Pisifera* were dominant until a third variety was discovered from the hybrid of the *Dura* and *Pisifera* called *Tenera*, which produces the highest oil content of the three species. In Nigeria, about 80% of oil palm plantation is covered with *Dura* and *Pisifera* and are cultivated by smallholders, while *Tenera* covers approximately 20%. The *Tenera* has a thin-shelled fruit and improved partition of dry matter within it. It gives 30% increase in oil yield at the expense of shell, without changing the total dry matter production (Corley and Lee, 1992). Over 40% of an individual palm fruit and over 20% of a fruit bunch from a typical *Tenera* variety of oil palm can be extracted as palm oil (Sridhar and AdeOluwa, 2009).

During the processing of oil palm several by-products and residues with high economical potentials are formed. The oil palm processing waste streams include solid, liquid and gaseous emissions. The oil palm industry generates a large quantity of solid

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residues and wastes in the form of Empty Fruit Bunch (EFB), Palm Kernel Shell (PKS), Palm Pressed Fibre (PPF) and chaff. When palm oil is extracted and processed, it also produces effluents with high organic matter, suspended matter, oil and grease (Sridhar and AdeOluwa, 2009; Rupani *et al.*, 2010; Ma, 1999; Ma, 2000). Gaseous emissions are often unreported. These processing wastes if not adequately managed causes adverse environmental impacts including land and aquatic ecosystem contamination, loss of land and resources, negative impacts on soil micro flora and fauna and loss of biodiversity (Sridhar and AdeOluwa, 2009). Palm oil is a multipurpose raw material used by both food and non-food industries (Armstrong, 1998) for the manufacturing of margarine, soap, candle, base for lipstick, waxes and polish bases, confectionaries (Embrandiri *et al.*, 2012; Aghalino, 2000; Armstrong, 1998), pharmaceutical (Helleiner, 1966), tin plating, lubricant, fuel (biodiesel) (Pleanjai *et al.*, 2007; Armstrong, 1998).

Oil palm processing by-products can be further converted to useful products, for instance EFB and

PKC have been successfully converted into compost by enriching with goat manure or poultry manure and were useful in developing oil palm nurseries and other food crops as fertilizers (Sridhar and AdeOluwa, 2009; Er *et al.*, 2011). Also, composting of EFB has been carried out to improve soil quality (Prasertsan and Prasertsan, 1996). Palm oil mills in general, are self-sufficient in energy generation due to the large amount of solid fuel feedstock available. Currently, processors use solid wastes as boilers fuel and plantation-based mills return the solid by-products except PKS which is used as hardening material for the construction of roads to mills and plantations. The use of oil processing wastes as compost and mulch is a cost-saving measure as it aids in the reduction of fertilizer dependency by the plantation owners. PPF can be processed into various products to suit specific applications other than the once mentioned earlier such as mattress cushions, soil stabilization/compaction, landscaping and horticulture, ceramic and brick manufacturing (Ramli *et al.*, 2002). Other scarcely notable wastes are the chaff. It is

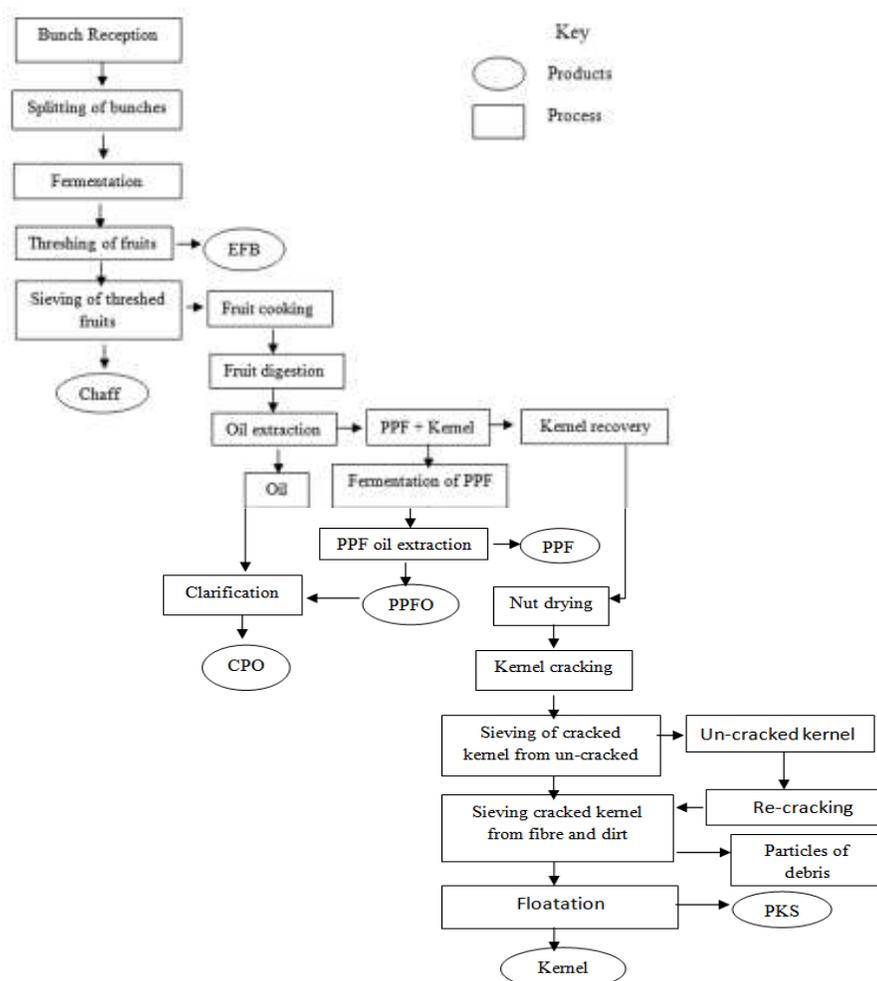


Fig. 1: A flow chart of small holder oil palm processing showing all the intermediaries in Niger Delta, Nigeria



Fig. 2: Processing intermediates from FFB of oil palm

produced during splitting of the FFB and sieving of threshed fruits. They are of lighter weight compared to all other solid wastes. The chaff can also be used as fuel and manure, though when used as fuel it burns quickly due to its light weight. In view of the abundance of oil palm by-products in Niger Delta, Nigeria and other parts of the world, sustainable management of these by-products is necessary for sustainable development. As wastes of biological origin, composting as well as vermi-composting can be a good option for sustainable management of these wastes (Rupani *et al.*, 2010; Singh

et al., 2011; Singh *et al.*, 2010; Embrandiri *et al.*, 2012).

Material mass balance analysis is very important in oil palm processing because it provides a means of quantifying the expected wastes from the process and making provisions for their utilization to avoid environmental impacts. During oil palm processing, about 20-24% of FFB are converted to oil (Poku, 2002), while the remaining 76-80% are essentially waste-products. Studies on material-mass balance have not been carried out on smallholders' oil palm processor in

Nigeria. Hence, this study investigates the material-mass balance of smallholder oil palm processing in Niger Delta Region of Nigeria.

MATERIALS AND METHODS

Field visit/data collection: Ten smallholder's oil palm processing sites were visited at Elele, River State, Niger Delta region of Nigeria from 13-22 April 2012. Oil palm is processed in batches at all the milling sites depending on the availability of FFB. The process of oil palm extraction at these sites is basically the same and is presented in Fig. 1. Measuring scale was used to measure the weight of the FFB and all the processing intermediates (PPF, PKS, EFB, CPO chaff and nut) which are presented in Fig. 2. From where the proportions (in %) of the intermediates to the FFB was computed.

RESULTS AND DISCUSSION

Table 1 presents the different fractions of the products derived during oil palm processing at the ten different mills. The mills processed FFB ranging from 90-400 and 65-200 bunches for *Dura* and *Tenera* respectively. In all the mills, oil palms are mostly processed in batches due to the small-scale nature of their operations and the limited availability of palm bunches.

The average weight of *Dura* and *Tenera* bunches ranged from 12.8-14.0 and 14.7-15.1%, respectively. This indicates that the *Tenera* variety have a bigger bunch size. The total weight of FFB processed is varied depending on the number of FFB available and the bunch size. TFF of *Dura* and *Tenera* varieties accounted for 66.1-75.0 and 70.9-72.9% of the FFB respectively. Chaff accounted for 0.8-2.4 and 0.9-1.4% of the FFB for *Dura* and *Tenera* varieties respectively, while EFB accounted for 25.7-28.2 and 25.7-32.4%,

respectively. Nut accounted for 19.0-27.5 and 14.5-14.9% of the FFB for *Dura* and *Tenera* varieties respectively, while the mesocarp accounted 44.8-51.1 and 56.4-58.0%, respectively. This shows that the *Dura* variety generates high quantity of nut and less mesocarp, while *Tenera* produces smaller nuts with larger mesocarp. This may be the reason why the *Dura* varieties produce less CPO when compared to *Tenera* varieties. The kernel from the nut consists of 5.7-7.2 and 5.5-5.6% of the FFB for *Dura* and *Tenera* varieties respectively. The PKS produced from the nut consists of 10.0-18.8 and 6.8-7.5% of the FFB for *Dura* and *Tenera* varieties respectively, while water in the nut consists of 2.4-3.4 and 1.9-2.1%, respectively. The result showed that there is a significant variation in PKS and water content of the nut. The CPO from the mesocarp of *Dura* and *Tenera* varieties ranged from 9.4-12.1 and 26.0-28.2%, respectively of the FFB. The significant variation is a true reflection of the different varieties. The *Tenera* varieties produce more CPO than *Dura* varieties. This may be attributed to the thickness and oil content of their mesocarp. The water from the mesocarpranged from 9.0-12.1 and 10.1-10.4% of the FFB for *Dura* and *Tenera* varieties respectively, while the PPF from the mesocarp ranged from 23.2-28.1 and 19.1-20.3%, respectively. The high PPF from the *Dura* varieties may be associated to the low CPO content, because the fibre occupies a significant proportion of the mesocarp along side with the nut.

The material-mass balance of different fractions of FFB produced during the processing of oil palm by smallholder is summarized in the Fig. 3. The total FFB were taken to be 100% for both *Dura* and *Tenera*. Hence, the composition of the products/intermediates produced during the processing of *Dura* variety are as follows; TFF (66.0-75.0%), mesocarp (44.8-51.1%), nuts (19.0-27.5%), kernel (5.7-7.2%), water in mesocarp (9.0-12.1%) and water in nut (2.4-3.4%), EFB (23.7-32.4%), chaff (0.8-2.4%), PKS (10.0-

Table 1: Different fractions of the product derived during oil palm processing

Site #	No. of FFB	Average weight of FFB (Kg)	Total weight of FFB (Kg)	TFF (%)	EFB (%)	Chaff (%)	Nut (%)
A*	90	14.0	1,260	68.0	30.6	1.4	19.0
B*	260	12.8	3,328	66.4	32.0	1.6	21.2
C*	260	13.5	3,510	70.4	28.3	1.3	25.2
D*	200	13.0	2,600	67.7	31.5	0.8	22.9
E*	400	12.4	4,960	72.6	25.0	2.4	21.5
F**	65	15.1	981.5	70.9	28.2	0.9	14.5
G*	300	12.9	3,870	68.1	30.3	1.6	19.0
H**	200	14.7	2,940	72.9	25.7	1.4	14.9
I*	200	12.8	2,560	75.0	23.7	1.3	27.5
J*	200	12.7	2,540	66.1	32.4	1.4	21.0
Site #	Kernel (%)	PKS (%)	Water in nut (%)	Mesocarp (%)	PPF (%)	CPO (%)	Water in mesocarp (%)
A*	6.3	10.0	2.7	49.0	28.1	10.9	10.0
B*	6.5	11.6	3.1	45.2	25.6	10.1	9.5
C*	7.2	14.6	3.4	45.2	23.7	9.7	11.8
D*	6.0	14.5	2.4	44.8	23.2	10.5	11.1
E*	5.7	13.3	2.5	51.1	26.2	12.8	12.1
F**	5.6	6.8	2.1	56.4	20.3	26.0	10.1
G*	5.8	10.0	3.2	46.1	26.4	10.2	9.5
H**	5.5	7.5	1.9	58.0	19.4	28.7	10.4
I*	5.8	18.8	2.9	47.5	25.0	11.0	11.5
J*	6.5	11.5	3.0	45.1	25.4	10.7	9.0

FFB: Fresh fruit bunch; TFF: Threshed fresh fruit; EFB: Empty fruit bunch; PKS: Palm kernel shell; PPF: Palm press fibre; CPO: Crude palm oil; *: *Dura* variety; **: *Tenera* variety

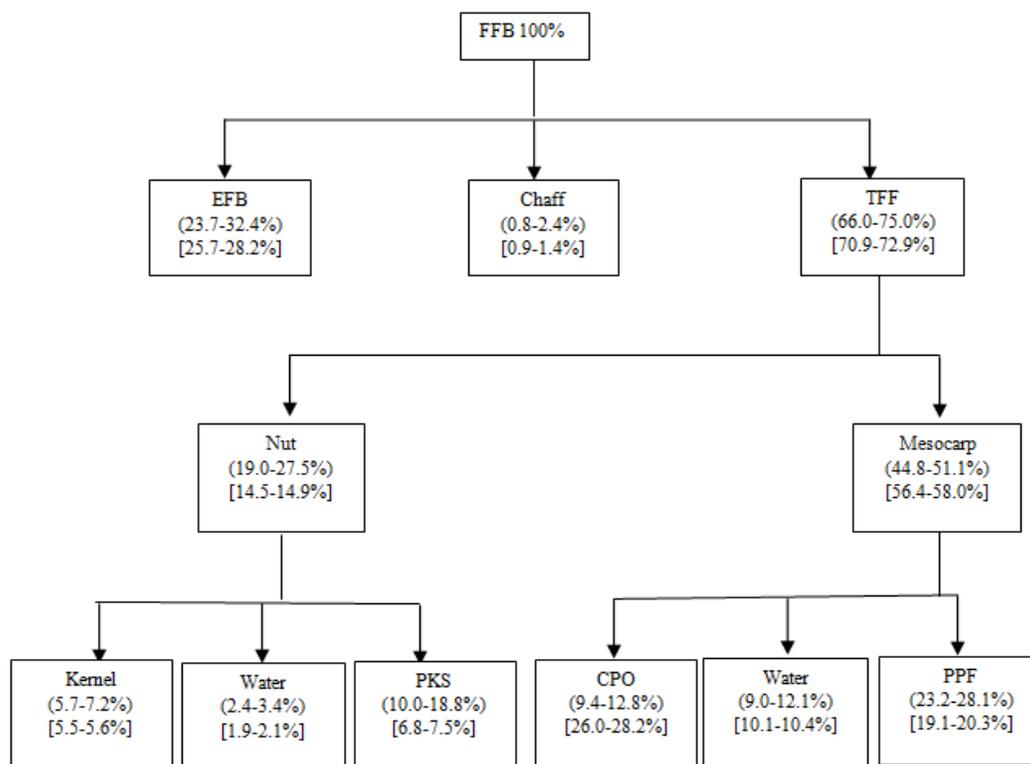


Fig. 3: Material-mass balance of FFB processed by small holders in Nigeria

Figures in bracket are the percentage of the different fraction of FFB: () = *Dura* variety, [] = *Tenera* variety

18.8%), PPF (23.2-28.1%) and CPO (9.4-12.8%). While that of *Tenera* are as follows; TFF (70.9-72.9%), mesocarp (56.4-58.0%), nuts (14.5-14.9%), kernel (5.5-5.6%), water in mesocarp (10.1-10.4%) and water in nut (1.9-2.1%), EFB (25.7-28.2%), chaff (0.9-1.4%), PKS (6.8-7.5%), PPF (19.1-20.3%) and CPO (26.0-28.2%). Prasertsan and Prasertsan (1996), recorded the composition of palm bunch as follows: FFB (100%), EFB (20-30%), fruits (70-74%), dry EFB (14-16%), pericarp (51-55%), nut (18.9-19.2%), kernel (8.4-8.5%), PKS (6.8-7.4%), moisture (3.3-3.4%), PPF (12-13%), CPO (25-28%) and moisture (13-14%). Also, Hambali *et al.* (2010) presented mass balance of palm oil processing as follows: FFB (100%), EFB (21.0%), fruits (64.5%), nuts (11.9%), mesocarp (53.4%), kernel (4.9%), shell (6.4%), CPO (23.5%) and fibre (14.4%). The result of this study is similar to what was reported by Prasertsan and Prasertsan (1996) and Hambali *et al.* (2010) for EFB, FF, mesocarp and PKS. However, the proportion of nut, water in mesocarp and CPO to the FFB for *Tenera* variety is close to the findings of Prasertsan and Prasertsan (1996), whereas there is disparity in the percentage of kernel and PPF produced. Also, Mahalia *et al.* (2001) reported the CPO, PKS, kernel FF (fruitlet), nut and PPF as 23.52, 5.2, 5.2, 67.43, 11.8 and 10.62%, respectively. Chavalparit *et al.* (2006) reported EFB, shell and PPF to be 24, 6 and 14%, respectively. None of these studies mention chaff

as a component of the FFB, whereas in this study chaff is a major constituent of the FFB.

CONCLUSION

This study investigated the material-mass balance of smallholder's oil palm processing in Elele, Rivers State, Nigeria. It was found that CPO and kernel which are the major products of FFB accounting for 9.4-12.8 and 26.0-28.2% for *Dura* and *Tenera* varieties respectively. The differences in the quantity of CPO produced may be associated to the superiority of the *Tenera* variety over the *Dura*. Thus, since *Dura* varieties of oil palm covers about 80% of the oil palm plantation in Niger Delta region, it has contributed significantly to the low yield of CPO in the mills. Kernel accounted for 5.7-7.2 and 5.5-5.6% of the FFB for *Dura* and *Tenera* varieties respectively. Because of the low yield of oil, large volume of processing wastes are generated in the form of PPF, PKS, EFB, chaff and water. The wastes are used in the mills mostly as energy source for boilers; PKS is used to upgrade access roads to mills and plantation, while chaff and EFB are commonly used as mulch and compost.

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