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Model Formulation for Estimating Oil Extraction Rate to Measure Oil Extraction Efficiency in Palm Oil Mill

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Abstract. FFB that has high HQE and FCI will determine the OER that will be obtained at POM, so that OER can be estimated using HQE and FCI, ie by calculating the oil content in FFB and the potential for oil loss in loose fruit that is not collected in the plantation area. The purpose of this study was to formulate an OER estimation model to determine the processing efficiency of POM. This research is a qualitative and quantitative analysis research, which is a scientific study to formulate an OER estimation model based on HQE and FCI parameters which will be used as the dependent variable. Based on the results and discussion it can be concluded that OER, which is a parameter of oil palm processing performance at POM, can be estimated using a model formulation developed from HQE and FCI variables, where these variables are indicators of FFB harvesting performance in oil palm plantations

Keyword: OER, HQE, FCI, Parameter of Performance, Palm Oil Mill.

Abstrak. *TBS yang memiliki NSP dan IPB yang tinggi akan menentukan OER yang akan didapatkan di PKS, sehingga OER dapat diestimasi menggunakan NSP dan IPB, yaitu dengan menghitung kandungan minyak pada TBS dan potensi kehilangan minyak pada brondolan yang tidak terkutip. di area perkebunan. Tujuan dari penelitian ini adalah merumuskan model estimasi OER untuk menentukan efisiensi pengolahan PKS. Penelitian ini merupakan penelitian analisis kualitatif dan kuantitatif, yaitu penelitian ilmiah untuk merumuskan model estimasi OER berdasarkan parameter NSP dan IPB yang akan digunakan sebagai variabel dependen. Berdasarkan hasil dan pembahasan dapat disimpulkan bahwa OER yang merupakan parameter kinerja pengolahan kelapa sawit di PKS dapat diestimasi dengan menggunakan formulasi model yang dikembangkan dari variabel NSP dan IPB, dimana variabel tersebut merupakan indikator kinerja pemanenan TBS di perkebunan kelapa sawit.*

Kata Kunci: OER, NSP, IPB, Parameter Kinerja, Pabrik Kelapa Sawit.

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1. Introduction

The palm oil industry in Indonesia is experiencing very rapid development. In 2021, the plantation area will reach 16.83 million hectares and the harvested area will reach 14.62 million hectares or

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around 86.86%. Production of crude palm oil (CPO) reached 45.12 million tons, and 25.62 million tons, or 56.79% of which was exported [1]. Palm oil is currently Indonesia's main export commodity. In 2021, the export value of palm oil will reach USD 26.76 billion or 11.55% of the total national export value, while the oil and gas export value will only reach USD 12.25 billion or 5.29% of the total national export value [1] [2].

Palm oil is the main product of palm oil mills (POM). The oil is produced from the extraction process of oil palm fresh fruit bunches (FFB), which is the result of harvesting from oil palm plantations. The palm oil mill only extracts palm oil from the FFB [3] [4].

The quality of the production process at a POM depends on the performance of the process. The performance parameters of the extraction process at POM in extracting palm oil are throughput, oil extraction rate (OER), oil losses, and others. These parameters will be seen to assess whether the production process is going well according to the expected target [3] [4].

OER is a POM performance parameter. OER is the ratio between the quantity of palm oil obtained, and the quantity of FFB processed. This means that the OER will show how much palm oil is produced from the production process each day [3] [4].

OER will be measured daily, namely the next day after the production process, and will be reported in the daily POM production report. OER targets are determined in the POM production budget. This target will be updated and re-established at the beginning of the current fiscal year, based on OER realization in the previous year [5] [6].

In general, OER always deviates, or even far enough, from the target that has been set. This happens because, in reality, OER is very dependent on the oil content in FFB. The oil content will be analyzed periodically, according to seasonal conditions in Indonesia, i.e., the rainy and dry seasons [5] [6].

The oil content in FFB varies greatly. The oil content in FFB is highly dependent on FFB ripeness grade. The higher the ripeness, the higher the oil content. This happens because the water content in ripe FFB will be lower, so the oil composition in the FFB will be higher [3] [4] [5] [6].

The FFB sent to the palm oil mills has various ripeness. The condition influences this so that the ripeness harvested in the oil palm plantation occurs in different ways for each tree. Harvesting is done in rotation according to the harvest rotation that has been determined by the company [5] [6].

Ripeness grade is indicated by the amount of loose fruit that is released from the fruit bunches. The loose fruit is a layer of fruit that is arranged on the outside of the fruit bunches. Loose fruit in this layer has the highest oil content, which is about 45% of the loose fruit weight [3] [4] [5] [6].

Loose fruit that is released from the fruit bunches will fall into the wide circle of trees and will be collected to be taken to POM along with the fruit bunches. The quantity of loose fruit that can be collected will also affect OER results, because the oil content is quite high [5] [6].

A good FFB harvesting process is a harvesting process that produces FFB with high ripeness grade and perfect loose fruit collected. The assessment of the overall ripeness grade is known as the harvested quality effectiveness (HQE), while the effectiveness of loose fruit collecting is known as the fruit collecting index (FCI). HQE and FCI are performance parameters for the FFB harvesting process in oil palm plantations [7].

FFB that has high HQE and FCI will determine the OER that will be obtained at POM, so that OER can be estimated using HQE and FCI, i.e., by calculating the oil content in FFB and the potential for oil loss in loose fruit that is not collected in the plantation area [7].

The estimated OER results will be a reference for determining the POM daily OER target. The actual OER will be compared with the estimate, so that the efficiency of the oil extraction process at the POM can be obtained. High efficiency will indicate a good quality production process at the POM.

POM is not a palm oil manufacturing factory. Still, it only extracts oil from FFB palm oil which is supplied from oil palm plantations, so the efficiency of the extraction process should be measured from the actual OER and estimated OER [3] [4] [5] [6]. How to estimate the OER and calculate the efficiency? The purpose of this study was to formulate an OER estimation model to determine the processing efficiency of POM.

2. Methodology

This research is a qualitative and quantitative analysis research, which is a scientific study to formulate an OER estimation model based on HQE and FCI parameters which will be used as the dependent variable.

The independent variables and data used in this study are FFB grade composition, oil content in each grade, oil content in loose fruit, actual loose fruit composition, and actual OER. The dependent variables used are harvested quality effectiveness, an equivalent factor of each grade to ripe grade, ideal loose fruit composition, fruit collection index, loose fruit lost in oil palm plantations, loose fruit composition of each grade, loose fruit lost in oil palm plantations, ideal OER, oil losses in loose fruit, estimated OER, and production process efficiency.

Data collection was carried out by means of literature studies and observation, i.e., conducting literature searches related to the object of research and observing the actual conditions that occur in the field, i.e., POM.

The discussion is carried out through descriptive analysis, i.e., explaining what OER, HQE, and FCI are and how to use them in estimating OER. The stages of the analysis are as follows:

1. Create a basic formulation concept for OER estimation.

This step is carried out by formulating the concept of efficiency and OER estimation based on HQE and FCI parameters. These two parameters will be multiplied by the oil content in FFB and loose fruit.

2. Develop an alternative model of the HQE variable.

This step is carried out using various existing HQE calculation models. The HQE models are formulated based on FFB grade.

3. Develop an alternative model of the FCI variable.

This step is carried out using various existing FCI calculation models. The FCI models are formulated based on FFB grade as well.

4. Testing alternative OER estimation models with various HQE and FCI variables using sample data.

Various alternative models will be obtained based on the second and third steps, combining the HQE and FCI models. Then testing of these alternatives will be carried out using data obtained from a POM.

5. Compare test results.

The test results will be compared by comparing the cumulative absolute error value and the average absolute error value. The absolute error value is the absolute value of the difference between the actual OER and the estimated OER.

6. Validation of the OER estimation model.

This is the last step., choosing the best alternative model. The best alternative is the one that produces the smallest cumulative absolute error value and the smallest average absolute error value. This alternative will later be used to estimate the OER.

3. Result and Discussion

It is necessary to formulate an OER estimation model to serve as a basis for determining the daily targets get that must be achieved by POM in the oil extraction process from palm oil FFB, so that the production supervisor can control the ongoing process. OER is a parameter POM must achieve because this achievement is a parameter of POM performance and determines whether POM can operate economically or not [8].

So far, OER has only been a target that must be achieved, but there is no basis that serves as a reference for achieving it. The company only uses historical data and general descriptions of FFB conditions received at POM as assumptions, so OER estimates become unrealistic and often greatly deviate from the actresultssult. After that, if the actual OER does not reach the target, the manager will only look for the causes of the unachieved OER target, so the problem will never be resolved because the real root cause of the problem has never been found and resolved [7] [9] [10].

3.1. Basic Formulation Concept for OER Estimation

The model formulation starts with formulating the efficiency variable, i.e., the comparison between the actual OER and the estimated OER. The formula is as follows:

$$\eta_{OER}=\frac{OER_A}{OER_E}\times 100\% \qquad (1)$$

Where η_{OER} is define as the production process efficiency (%); OER_A is define as the actual OER (%); and OER_E is define as the estimated OER (%).

The actual OER variable is the OER value obtained from calculating the ratio of the quantity of oil recovered to the quantity of FFB processed during a day. The estimated OER variable is the OER value obtained from the following formula:

$$OER_I=HQE\times ROC \qquad (2)$$

$$OL_{LF}=L_{LF}\times LFOC \qquad (3)$$

$$OER_E=OER_I-OL_{LF} \qquad (4)$$

Where OER_I is define as the ideal OER (%); HQE is define as the harvested quality effectiveness (%); ROC is define as the oil content in ripe grade (%); OL_{LF} is define as the oil losses in loose fruit (%); L_{LF} is define as the loose fruit lost in oil palm plantations (%); LFOC is define as the oil content in loose fruit (%); and OER_E is define as the estimated OER (%).

3.2. Alternative Models of the HQE Variable

HQE is a parameter used to assess the quality of FFB harvested in oil palm plantations [3] [4]. The HQE value indicates that the quality of the harvested FFB has such a level of ripeness. There are three models for calculating the HQE variable as follows:

1. Based on fruit bunch ripeness fraction system

This system is the first system used. The basis for the calculation is the ripeness fraction of fruit bunches, i.e., there are seven fractions ($Fr.00 – 5$). The HQE model based on this system is as follows [3] [5]:

$$HQE = -5(Fr.00) - 1(Fr.0) + 1(Fr.1+2+3) + \tfrac{1}{2}(Fr.4) - \tfrac{1}{3}(Fr.5) \qquad (5)$$

Where HQE is define as the harvested quality effectiveness (%); and $Fr._{00\text{-}5}$ is define as the composition of FFB fraction (%).

2. Based on a penalty system for unripe and overripe fruit bunches

This system was developed based on the Regulation of the Minister of Agriculture of the Republic of Indonesia No. 01/2018, i.e., by implementing a penalty system for unripe and overripe fruit bunches received at POM [11]. The HQE model based on this system is as follows [7]:

$$HQE = FB_N - 50\%(FB_{UN}) - 25\%\ (FB_{OR} - 5\%) \qquad (6)$$

Where HQE is define as the harvested quality effectiveness (%); FB_N is define as the normal FFB composition (%); FB_{UN} is define as the unripe grade composition (%); and FB_{OR} is define as the overripe grade composition (%).

3. Based on fruit bunch ripeness equivalence system

This system was developed based on the grading of fruit bunches most likely by many companies today, in which the grading of fruit bunches consists of four grades, i.e., unripe, underripe, ripe and overripe fruit bunches. The HQE model based on this system is as follows [7]:

$$EF_{FB}=\frac{GOC}{ROC}\times 100\% \qquad (7)$$

$$HQE = EF_{UN}(FB_{UN}) + EF_{UD}(FB_{UD}) + EF_R(FB_R) + EF_{OR}(FB_{OR}) \qquad (8)$$

Where $EF_{UN\text{-}OR}$ is define as the equivalent factor of each grade to ripe grade (%); GOC is define as the oil content in each grade (unripe, underripe, ripe and overripe) (%); ROC is define as the oil content in ripe grade (%); HQE is define as the harvested quality effectiveness (%); and $FB_{UN\text{-}OR}$ is define as the FFB composition of each grade (%).

3.3. Alternative Models of the FCI Variable

FCI is a parameter used to assess the effectiveness of collecting loose fruit from harvesting FFB in oil palm plantations. The FCI value indicates the quantity of loose fruit that can be collected from the harvested FFB. Uncollected loose fruit will cause oil losses and is a loss for the company. There are two models for calculating the FCI variable as follows:

1. Based on the fruit bunch ripeness fraction system

Loose fruit that is counted in this system is only loose fruit that comes from ripe fruit bunches, i.e., 4^{th} to 5^{th} fractions (Fr.2 and Fr.3), while other fractions are not counted. The FCI model based on this system is as follows [3] [5]:

$$LF_I=\frac{Fr.4 + Fr.5}{2}+7\% \qquad (9)$$

$$FCI=\frac{LF_A}{LF_I}\times 100\% \qquad (10)$$

$$L_{LF}=100\%\text{-}FCI \qquad (11)$$

Where LF_I is defined the ideal loose fruit composition (%); Fr.4 is defined the fruit bunch fraction 4 composition (%); Fr.5 is define as the fruit bunch fraction 5 composition (%); LF_A actual loose fruit composition (%); FCI is define as the fruit collection index (%); and L_{LF} is define as the loose fruit lost in oil palm plantations (%).

2. Based on fruit bunch ripeness equivalence system

Loose fruit that is counted in this system are loose fruit that comes from three grades, ie underripe, ripe and overripe fruit bunches. The FCI model based on this system is as follows [7]:

$$LF_I = LF_{UD}(FB_{UD}) + LF_R(FB_R) + LF_{OR}(FB_{OR}) \quad (12)$$

$$FCI = \frac{LF_A}{LF_I} \times 100\% \quad (13)$$

$$L_{LF} = 100\% - FCI \quad (14)$$

Where LF_I is define as the ideal loose fruit composition (%); $LF_{UD\text{-}OR}$ defines the loose fruit composition of each grade (underripe, ripe and overripe) (%); $FB_{UD\text{-}OR}$ is define as the FFB composition of each grade (underripe, ripe and overripe) (%); LF_A is defined the actual loose fruit composition (%); FCI is define as the fruit collection index (%); and L_{LF} is define as the loose fruit lost in oil palm plantations (%)

3.4. Test of Alternative OER Estimation Models

Model testing is carried out to see how the level of accuracy of the models developed so that the most appropriate model can be determined to be used as an OER estimator. This test is carried out by combining the HQE and FCI variables. The combination of these models can be seen in Table 1.

Table 1 Combination of Variables to Test of Alternative OER Estimation Models

No.	Combination of Variables	
	HQE	FCI
1	1	1
2	1	2
3	2	1
4	2	2
5	3	1
6	3	2

Testing alternative models is carried out using the following data:

1. Data from the analysis of oil content in each grade of fruit ripeness (performed periodically).
2. Data on the results of the analysis of the oil content in the outer layer of loose fruit (performed periodically).
3. Data on FFB grading results (performed daily).
4. Data on loose fruit composition for each grade of fruit ripeness (performed periodically).
5. Daily OER and oil loss data.
6. The test was carried out using daily data for January 2022 from a POM, the results can be seen in Table 2.

Table 2 OER Estimated from the Alternative OER Estimation Models

No.	Alternative Models						Actual OER	Oil Losses
	1	2	3	4	5	6		
1	24,38	20,17	30,34	26,13	29,94	25,74	24,52	1,50
2	23,89	21,77	28,93	26,81	28,83	26,71	24,25	1,70
3	25,29	24,78	28,67	28,17	28,82	28,31	24,76	1,80
4	23,65	20,84	28,76	25,95	28,66	25,85	24,96	1,33
5	25,25	22,79	29,46	27,00	29,34	26,87	24,86	1,75
6	24,64	22,54	28,61	26,51	28,54	26,44	24,66	1,72
3	26,72	22,88	30,77	26,93	30,54	26,70	24,80	1,89
4	24,71	21,59	28,94	25,81	28,78	25,66	24,82	1,22
5	25,73	21,66	29,97	25,90	29,66	25,59	24,84	1,29
6	27,84	23,56	30,92	26,63	30,70	26,42	24,81	1,75
7	26,48	22,06	30,10	25,68	29,80	25,38	24,87	1,23
8	26,12	22,35	29,47	25,69	29,26	25,49	24,90	1,26
9	24,17	21,22	28,53	25,58	28,34	25,39	24,93	1,27
10	27,80	22,47	30,97	25,64	30,64	25,31	24,92	1,26
11	26,56	22,38	29,93	25,76	29,69	25,51	24,93	1,24
12	29,31	24,33	32,07	27,09	31,80	26,82	24,95	1,76
13	26,16	21,52	30,55	25,91	30,20	25,56	24,97	1,23
14	25,69	21,57	29,59	25,47	29,35	25,24	24,98	1,29
15	26,22	21,86	30,12	25,76	29,83	25,47	24,97	1,28
16	24,96	21,92	28,47	25,43	28,38	25,35	24,95	1,22
17	27,10	22,04	31,20	26,13	30,81	25,75	24,97	1,25
18	26,68	23,02	30,14	26,48	29,96	26,30	24,98	1,70
19	24,68	21,20	29,16	25,67	28,91	25,43	24,95	1,25
20	24,04	21,20	28,46	25,62	28,27	25,43	24,96	1,24
21	25,31	21,88	28,93	25,51	28,77	25,34	24,99	1,22
22	24,38	20,17	30,34	26,13	29,94	25,74	24,52	1,50
23	23,89	21,77	28,93	26,81	28,83	26,71	24,25	1,70
24	25,29	24,78	28,67	28,17	28,82	28,31	24,76	1,80
25	23,65	20,84	28,76	25,95	28,66	25,85	24,96	1,33

3.5. Comparison of Test Results

The accuracy of the test results for the alternative models can be measured by accumulating the error between the estimated OER and the actual OER, as well as oil losses in the processing at POM. The results of this comparison can be seen in Table 3.

Table 3 Comparison of the Accuracy of Alternative OER Estimation Models

Description	Alternative Models					
	1	2	3	4	5	6
Cumulative Absolute Error	27,25	82,21	110,51	20,75	98,30	10,59
Average Absolute Error	1,09	3,29	4,42	0,83	3,93	0,42

3.6. Validation of OER Estimated Mode

Based on the comparison of the accuracy of the test results against the alternative models shown in Table 3, it can be seen that the most accurate model is the model in the sixth alternative because it has the smallest cumulative absolute error value, i.e., 1059, and the smallest average absolute error value, i.e., 0.42. Thus, the sixth alternative, an alternative with a combination of the third HQE model and the second FCI model, is declared a valid model and can be used to estimate OER at POM. This model also shows that the average efficiency in processing palm oil in January 2022 is 93.43%.

The efficiency of 93.43% indicates that there is 6.57% of the oil potential that has yet to be tapped in palm oil processing at POM, i.e., in the form of measurable and unmeasured oil losses.

4. Conclusion and Future Research

Based on the results and discussion it can be concluded that OER, which is a parameter of oil palm processing performance at POM, can be estimated using a model formulation developed from HQE and FCI variables, where these variables are indicators of FFB harvesting performance in oil palm plantations.

Based on the data used in the model test, it appears that the efficiency of processing palm oil at POM is still quite low. Therefore, it is necessary to conduct research to see the level of oil losses, both measured and unmeasured.

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