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Fuel Used Analysis on Boiler Efficiency Variations and Water Intake Temperature Affected by Palm Oil Varieties

Zulham Effendi, Siti Aisyah♥, Rionaldo Hastyanda
Program Studi Teknologi Pengolahan Hasil Perkebunan, STIPER Agrobisnis Perkebunan, Medan
♥Corresponding author email: siti.aisyah@stipap.ac.id

Abstract. Several factors that affect the use of fuel in boilers are combustion efficiency, quality of feed water management, calorific value, and the potential for available fuel from oil palm varieties. The purpose of this research is to identify the use of fuel and its potential savings based on variations in boiler efficiency and water temperature that entered the boiler. The materials used in this research are FFB mass balance data and boiler fuel composition. Based on the analysis results, the lowest used fuel mass and the highest fuel savings are found in the DxPLangkat variety with an intake water temperature of 105° C and 80% boiler efficiency. The use of fuel is 4,231 kg/hour with shell savings of 967 kg/hour with a value of IDR 725,701. Fiber savings was 487 kg/hour with a value of IDR 121,751.The highest used fuel mass and the lowest fuel savings were found in the Yangambi derivative variety with an intake water temperature of 85° C and 60% boiler efficiency.The fuel consumption is 5,830 kg/hour with shell savings totalling -380 kg/hour. There is no fiber analysis because it is used up hence additional fuel is needed. Additional fuel can be done by asking for other palm oil mill units or buying. If they buy a shell with a requirement of 380 kg/hour, the funds required are IDR 284,939.
Keywords: fuel consumption, water temperature, Yangambi derivative variety

INTRODUCTION

A palm oil mill is a factory that processes FFB (Fresh Fruit Bunches) as raw material into palm oil (CPO/Crude Palm Oil) and palm kernel with various stages of processing starting from the receiving station for raw materials, boiling, shelling, pressing, oil and sludge separation, oil refining, core drying and stockpiling stations. There are also water treatment stations and power plants as support stations, in which one of the tools in the power plant is a boiler. A boiler (steam boiler) is a steam power plant in the form of a closed vessel in which the combustion heat is transferred to the water until hot water or steam is formed in the form of work energy (Pravitasari et al, 2017). Water is a useful and inexpensive medium for transferring heat to a process. Hot water or steam at a certain pressure and temperature has heat energy to a process (Winarto, 2012). If water is boiled to steam, its volume increases by about 1600 times, producing power similar to explosive gunpowder. Therefore the boiler system is equipment that must be managed and maintained very well so as not to experience damage (Kopf, 2015). In general, the boilers used in palm oil mills are boilers that produce superheated steam, in which this steam is used for the first time to spin the turbines as a power plant then the remaining steam from the plant is used for the processing process, namely, sterilizers (tools for boiling fresh fruit bunches) and the oil refining process or clarification (Rahmat, 2002).

The fuel used in the boiler is fiber, if the required steam is substantial, the factory will add a shell for boiler fuel hence the boiler pressure increases. Fiber and shells are sustainable by-products of palm oil mills hence the more fuel is needed, the more FFB is needed (Laila and Qodori, 2019). If the resulting pressure exceeds the desired steam demand, it can cause steam losses which result in losses and will increase the production value. This must be avoided considering that steam losses can no longer be used and used fuel will be wasted. Conversely, if the steam produced is in accordance with the desired steam requirement, less fuel will be used hence there will be a reduction in fuel use in the boiler and fuel savings will occur (Rahayu, 2016).

Oil palm plants reproduce by seed and will germinate and then grow into plants. There are 4 type of superior oil palm seed varieties, namely ; 1) Sungai PancurDyP I Variety (Dumpy), this type is better known as Dumpy Variety which is an

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oil palm variety with specific advantages of slow-high growth rate (40-55 cm/year) and average high bunch weights. This variety has a slow growth character but can reach a production age of up to 30 years, longer than other varieties. In addition to its slow-growing, Dumpy also has a relatively large trunk structure making it suitable for planting in tidal areas to reduce the potential for toppling. Dumpy variety is the result of a cross between Dura Dumpy and Pisifera derived from SP540T, 2) The SP540T derived varieties, which are included in the SP540 group, are produced from pure SP540T Pisifera parents which are only owned by IOPRI which are crossed with the best Deli dura parents (Pahan, 2008). These varieties include DxP PPKS 540, DxPSimalungun, DxP AVROS, and DxP 540 NG. The superior characteristics of this group are quick starters and a relatively high percentage of mesocarp per fruit compared to other varieties as well as good productivity. With wide adaptation, this variety can be planted in various types of oil palm land, 3) A variety derived from Yangambi, is a population of palm oil from Africa to be precise from Congo. This population is widely used as Pisifera parent by top seed producers around the world.The IOPRI palm oil varieties produced from this population are DxPYangambi, DxP PPKS 239, and DxP PPKS 718. In general, this population has the advantage of a relatively large bunch weight. For example, the DxP PPKS 239 variety, in addition to having relatively large bunches it also has high potential for CPO and PKO production, making it suitable to be developed for the food and non-food industries, 4) The DxPLangkat variety was the first variety to be assembled by IOPRI from the results of the best parents' recombination of several Pisifera populations. The Pisifera elders from the recombination of Pisifera SP540T, Yangambi, and Marihat, were crossed with the best Dura Deli to produce varieties with superior characteristics with relatively short midrib (compact palm). Apart from being suitable for planting in wavy and hilly areas, this variety can also begin to bear fruit at the age of 22 months after planting (Rinaldi, 2012).

The above process attracted the authors to examine the use of fuel on boiler efficiency associated with superior oil palm seed varieties. Hence, the objectives of this study is to determine the use of fuel on water temperature which enter the boiler associated with superior oil palm seed varieties, and to determine the correlation of variations in water temperature which enter the boiler, and also the boiler efficiency variation on fuel use.

METHODS

Tools and Materials

The materials used in this research are FFB mass balance data and boiler fuel composition. The tools used in this research are:

Boiler

The boiler specifications used is Boiler schematic in figure 1 :

Type of Steam Kettle (Boiler): *Water Tube Boiler*

BoilerModel	: Takuma 600 SA
Max. Working Pressure	: 23 Kg/Cm²
Actual Steam Evaporation	: 20 t/h
Max. Steam Federation	: 20 Kg/Cm²
Fuel Consumption	: 5200 kg/h
Steam Temperature	: 260° C
Feed Water Temperature Max	: 90 ° - 95 ° C
Serial no	: 1696
Year built	: 1996

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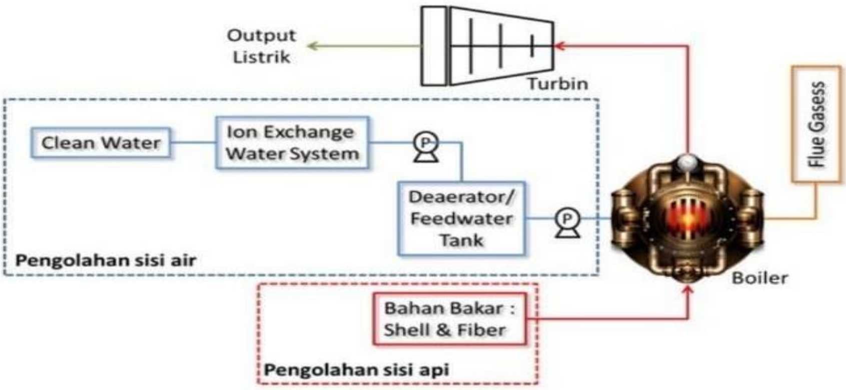

Figure 1. Boiler schematic

Research Stages

Data collection

The palm oil varieties used in this research were obtained from the Medan - Indonesian Oil Palm Research Institute (IOPRI) which consisted of 4 varieties, namely the DyP Sungai Pancur I (Dumphy) variety, SP540T derivative, Yangambi derivative and DxPLangkat. Then, the boiler used was obtained from one of the palm oil Mills in TebingTinggi with a capacity of 20 tons of steam/hour.

Data processing

The data that has been obtained, then:

- The fuel used is calculated using different boiler efficiency variations (60%, 70%, and 80%) with variations in the water temperature which enter the different boilers (85° C, 90° C, 95° C, 100° C, and 105° C) and variations in types of superior palm oil seed varieties.

$$Mbb = \frac{Mux(H_{sup} - Hw)}{LHVx\eta boiler} \quad (1)$$

Description:

M_{bb} = mass of Fuel (kg)

Mu = steam Mass (kg of steam/hour)

H_{sup} =enthalpy superheater steam (kkal/kg)

H_w =enthalpy of water entering the kettle (kkal/kg)

LHV = low heating value/fuel calorific value (kkal/kg)

η_{boiler} = boiler efficiency variations (%)

- Analyze heat requirements to cover the required fuel requirements (if there is excess shell or fiber). To meet the need for less fuel, excess fuel is used by looking at the calorific value of the fuel.

Lack of shell (fiber) = n kg/hour

Lack of calor = n kg/hour x Calorific Value of Fuel (kcal/kg)

The addition of shells (fiber) can be calculated from the value of the calor deficiency divided by the calorific value of excess fuel.

Addition of shells (fiber) =

$$\frac{Calor\ Deficiency}{Excessive\ Fuel\ Calorific\ Value} \text{ (kg/hour)} \quad (2)$$

Then there will be a reduction in the potential for excess fuel savings hence the potential for initial savings is reduced and the total remaining fuel is the difference from the potential remaining initial fuel minus the addition of fuel.

PPBB = PSBB – PBB (3)

Description:

PPBB = Fuel Savings Potential (kg/hour)

PSBB = Remaining Fuel Potential (kg/hour)

PBB = Additional Fuel (kg/hour)

- Calculating the estimated value (money) that could result from fuel savings.

Money generated = BB_{value} x Price of Shells (750) (4)

Money generated = BB_{value} x Price of Fiber (250) (5)

(In this research, the calorific value of each palm oil variety is considered ideal or the

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same due to conditions that make it impossible to test fuel calorific value).

RESULT AND DISCUSSION

DyP Sungai Pancur I Varieties (Dumpy)

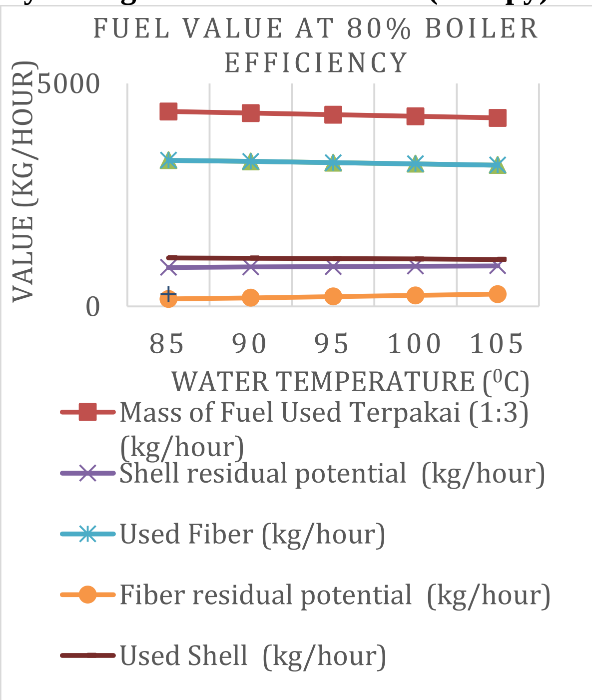

Figure 2. Graph of remaining fuel

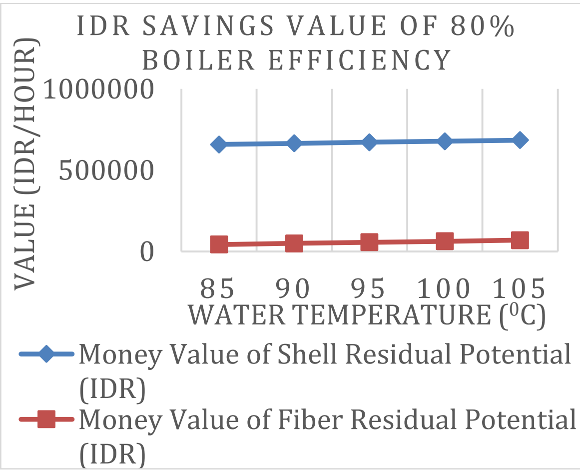

Figure 3. IDR/money value at 80%

In Figure 2 and 3, it can be seen that fuel savings and IDR value are based on variations in the intake water temperature, and the lowest 80% boiler efficiency was at a temperature variation of 105^{o} C with a value of 4,231 kg/hour with a fuel composition of 1 : 3 (shell : fiber). Shells potential for fuel savings is 913 kg/hour with a value of IDR 685,001. Fiber potential for fuel savings is 277 kg/hour with IDR 69,251 hence the ideal fuel ratio is 25% : 75% (shell : fiber). The highest use of fuel is at a temperature variation of 85^{o} C with a value of 4,373 kg/hour and fuel composition of 1 : 3 (shell : fiber). Shells potential for fuel savings is 878 kg/hour with an IDR value of IDR 658,337, while for fiber, it can save 170 kg/hour with an IDR value of IDR 42,587 hence the ideal fuel ratio is 25% : 75%. (shell : fiber). These savings are in line with the factory's expectations but do not reduce the quality of the product and work of the boiler (Batubara, 2014).

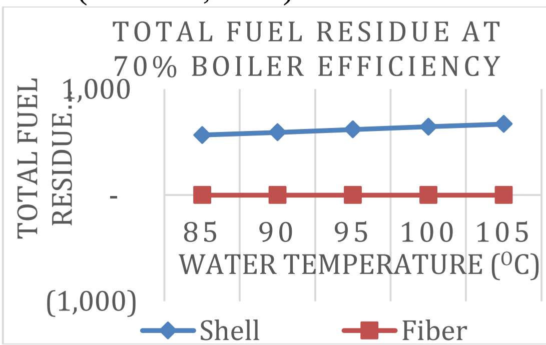

Figure 4. Graph of remaining fuel

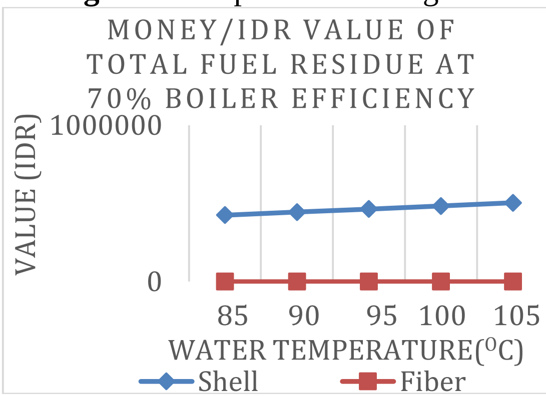

Figure 5. IDR/money value at 70%

In Figure 4 and 5, you can see the calculation results of potential fuel savings and the value of the IDR based on variations in the intake water temperature and 70% boiler efficiency of the palm oil mill, the lowest is at a temperature variation of 105^{o} C with a value of 4,835 kg/hour with a fuel composition of 1 : 3 (shell : fiber). Shell potential for fuel savings is 762 kg/hour. Fiber potential for savings is not mentioned

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because the available fiber is not sufficient to meet the required fuel requirements (-176 kg/hour). The highest fuel-used is at a temperature variation of 85° C with a value of 4,998 kg/hour : fuel composition of 1 : 3 (shell : fiber). Shell potential for fuel savings is 722 kg/hour. Fiber saving is not mentioned due to insufficient fiber to meet the required fuel requirements (-298 kg/hour), to cover the insufficient fuel, excess fuel (shell) can be used. According to Laila and Qodori (2019), if there is a shortage of fuel to improve boiler performance, the fuel can be obtained from other fuels such as shells.

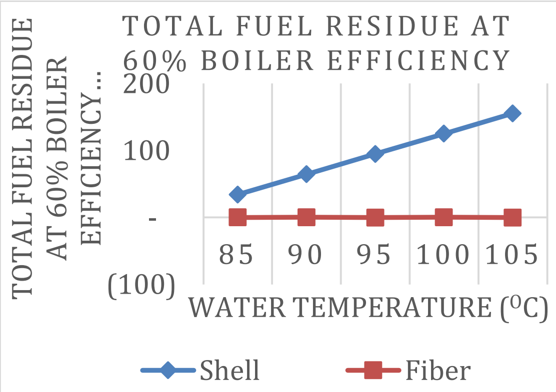

Figure 6. Graph of remaining fuel

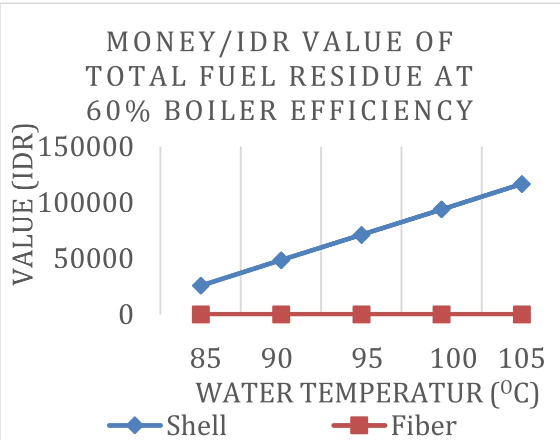

Figure 7. IDR/money value at 60%

In Figure 6 and 7 above, presented the calculation results of potential fuel savings and IDR value based on variations in the intake water temperature, and the lowest of 60% boiler efficiency was at a temperature variation of 105° C with a value of 5.461 kg/hour and fuel composition of 1 : 3 (shell : fiber). Shells potential for fuel savings is 561 kg/hour and for fiber saving is not mentioned due to insufficient fiber available to meet the required fuel requirements (-781 kg/hour). The highest fuel-used is at a temperature variation of 85° C with a value of 5,830 kg/hour and fuel composition of 1 : 3 (shell : fiber). Shell fuel saving is 513 kg/hour. Fiber saving is not mentioned because the available fiber is not sufficient for the required fuel (-923 kg/hour), to cover the insufficient fuel, excess fuel (shell) is used. According to Laila and Qodori (2019), if there is a shortage of fuel to improve boiler performance, the fuel can be obtained from other fuels such as shells.

Derivative Varieties of SP540T

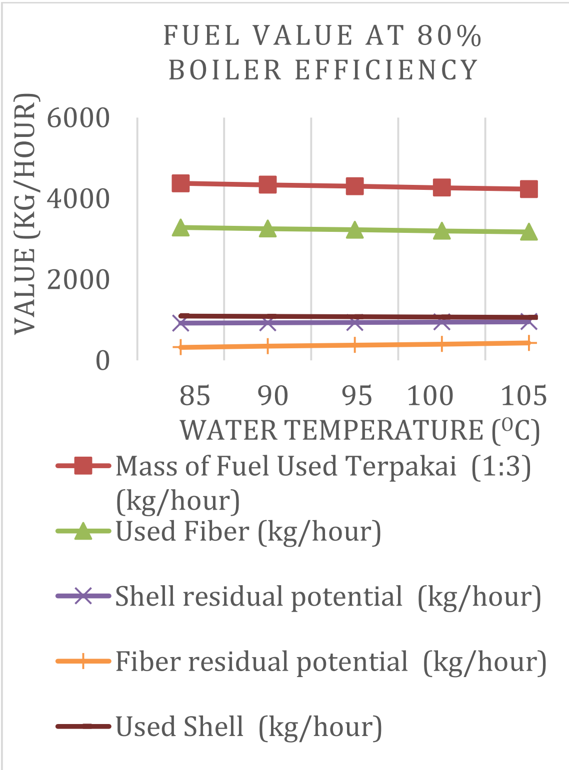

Figure 8. Graph of remaining fuel

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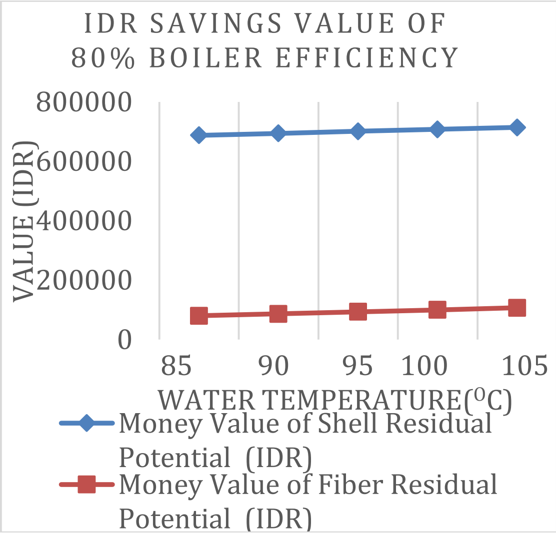

Figure 9. IDR/money value at 80%

In Figure 8 and 9, it can be seen that the calculation results of potential fuel savings and the IDR value based on variations in the intake water temperature and the lowest of 80% boiler efficiency of the palm oil mill are at a temperature variation of 105^o C with a value of 4,231 kg/hour and fuel composition of 1 : 3 (shell : fiber).Shell savings are 952 kg/hour with a value of IDR 714,251 per hour, while for fiber are 427 kg/hour with IDR 106,751 per hour in which the ideal fuel ratio is 25% : 75% (shell : fiber).The highest fuel-used is at a temperature of 85^o C with a value of 4,373 kg/hour with a ratio of 1 : 3 (shell : fiber). Shells savings are 917 kg/hour or IDR 687,587 per hour, while fiber is 320 kg/hour or IDR 80,087 per hour with an ideal fuel ratio of 25% : 75% (shell : fiber). This savings is in accordance with what the factory expects, but it is also hoped that it does not reduce the product quality and work of the boiler (Batubara, 2014).

In Figure 10 and 11, it can be seen the fuel savings and IDR value based on variations in intake water temperature and the lowest 70% boiler efficiency of palm oil mill was at 105^o C temperature with a value of 4,835 kg/hour with a fuel composition of 1 : 3 (shell : fiber). Shells saving are 801 kg/hour and fiber saving is not mentioned because the available fiber is not sufficient for the fuel needs in the palm oil mill (-26 kg/hour). The highest fuel-used is at a temperature of 85^o C with a value of 4,998 kg/hour and fuel composition of 1 : 3 (shell : fiber). Shells can save 761 kg/hour of fuel and fiber saving is not mentioned because fiber does not meet the fuel needs of the palm oil mill (-148 kg/hour), to cover the insufficient fuel, excess fuel (shell) is used by looking at the calorific value of the fuel. According to Laila and Qodori (2019), if there is a shortage of fuel to improve boiler performance, the fuel can be obtained from other fuels such as shells.

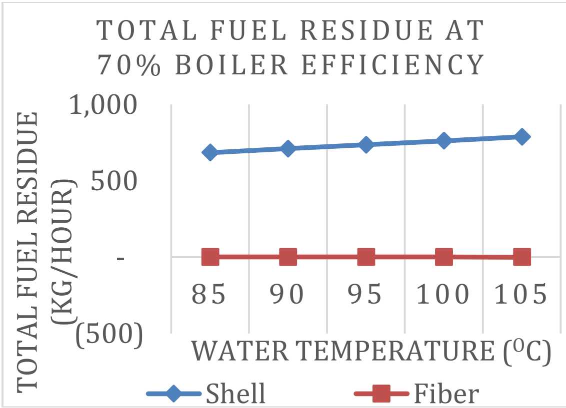

Figure 10. Graph of remaining fuel

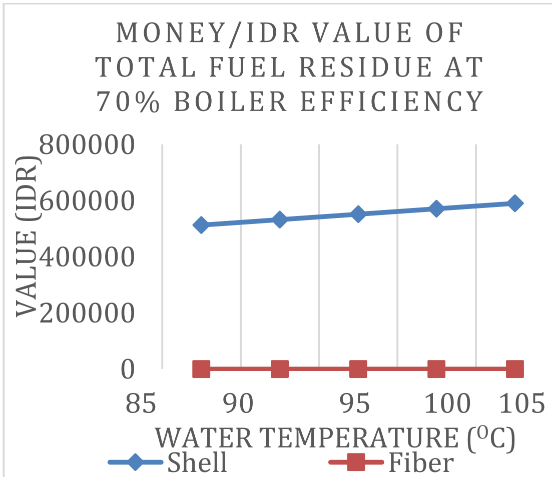

Figure 11. IDR/money value at 70%

In Figure 12 and 13, presented the calculation results of the total remaining fuel savings and IDR value based on variations in the water intake temperature, and the highest of 60% boiler efficiency of the palm

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oil mill are at a temperature of 105° C, with shells saving of 272 kg/hour or IDR 204,218 per hour. Fiber saving is not mentioned because fiber has been used up with the ideal fuel ratio value is 29.1% : 70.9% (shell : fiber). The lowest total remaining fuel is at a temperature of 85° C in which the shells are 151 kg/hour or IDR 113,282 per hour. There are no fuel savings in fiber because it has been used up with the ideal fuel ratio of 29.8% : 70.2% (shell : fiber). An unbalanced savings ratio can reduce boiler activity that requires too much fuel in the production process. This savings is in accordance with what the factory expects, but it is also hoped that it does not reduce the product quality and work of the boiler (Batubara, 2014).

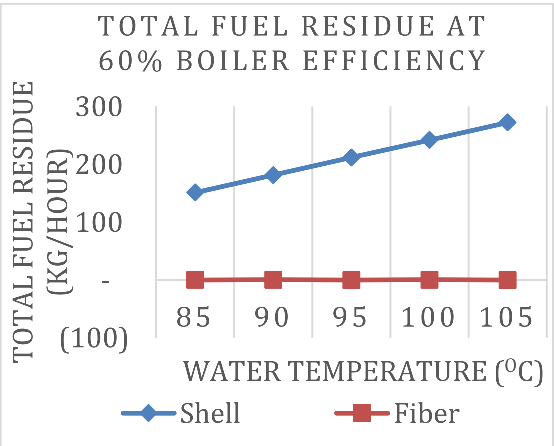

Figure 12. Graph of remaining fuel

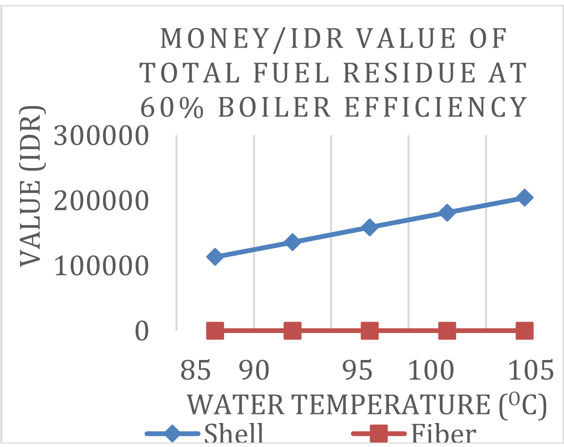

Figure 13. IDR/money value at 60%

Yangambi Derivative Varieties

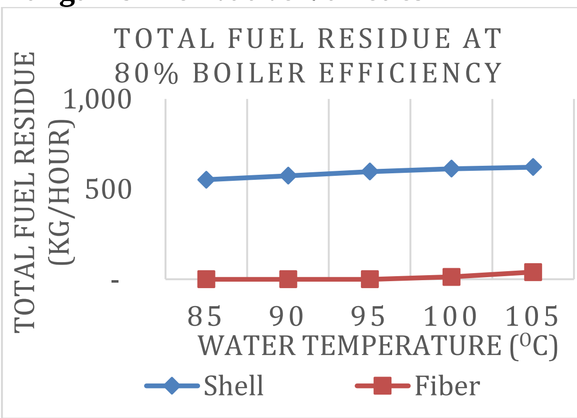

Figure 14. Graph of remaining fuel

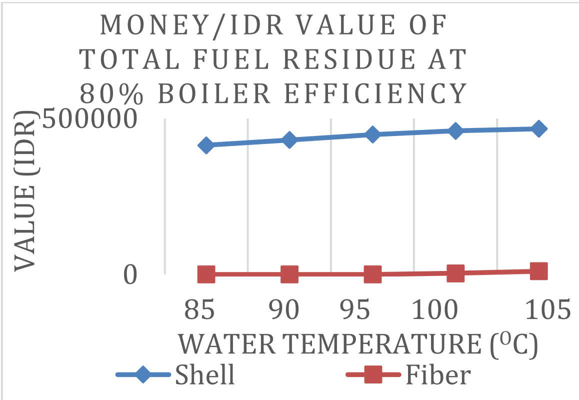

Figure 15. IDR/money value at 80%

In Figure 14 and 15, the potential for fuel savings and the value of IDR based on variations in the water intake temperature and the lowest of 80% boiler efficiency of the palm oil mill is at a temperature of 105° C with a value of 4,231 kg/hour and fuel composition of 1 : 3 (shell : fiber). Shells potential for fuel savings amounted to 662 kg/hour. Fiber savings amounted to 40 kg/hour. The highest fuel consumption is at a temperature of 85° C for 4,373 kg/hour with 1 : 3 fuel ratio (shell : fiber). Shells savings is 587 kg/hour but fiber savings is not mentioned because it is insufficient to meet the required fuel needs (-67 kg/hour). Covering the need for fuel, excess fuel (shell) can be used to cover the shortage of fuel needed by looking at the calorific value of the fuel. According to Laila and Qodori (2019), if there is a shortage of fuel to improve boiler performance, the fuel can be obtained from other fuels such as shells.

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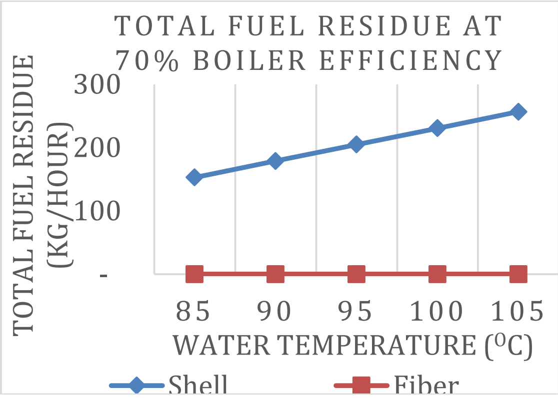

Figure 16. Graph of remaining fuel

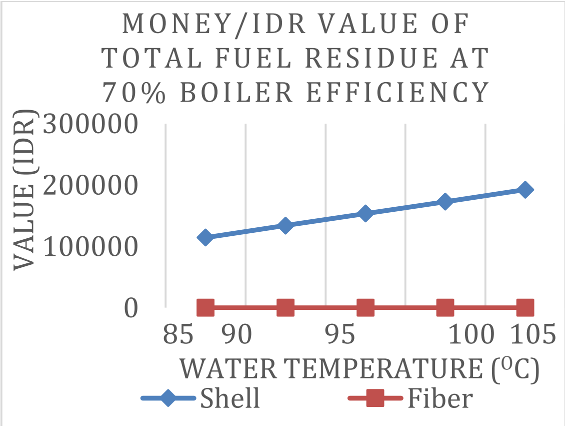

Figure 17. IDR/money value at 70%

In Figure 16 and 17, the total remaining fuel savings and the IDR value are obtained based on variations in the water intake temperature and 70% boiler efficiency for the palm oil mill in which the highest total fuel is at 105° C. Shells saving are 257 kg/hour or IDR 192,474 per hour. Fiber saving is not mentioned because it is used up hence the ideal fuel ratio is 28.2% : 71.8% (shell : fiber). The lowest remaining fuel is at a temperature of 85° C in which the shell is 153 kg/hour with the money value of IDR 114,529 per hour, while fiber is not mentioned because it is used up, with the ideal fuel ratio value is 29% : 71% (shell : fiber). An unbalanced savings ratio can reduce boiler activity that requires too much fuel in the production process. This savings is in accordance with what the factory expects, but it is also hoped that it does not reduce the product quality and work of the boiler (Batubara, 2014).

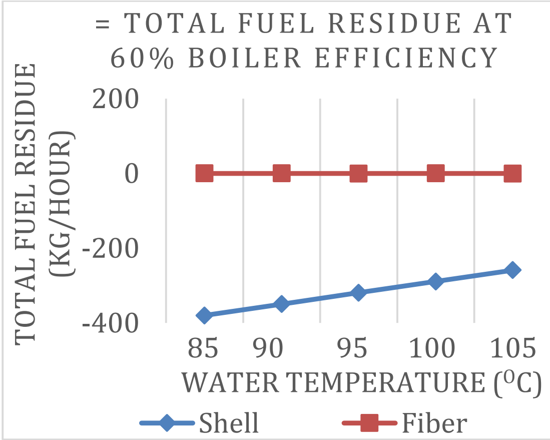

Figure 18. Graph of remaining fuel

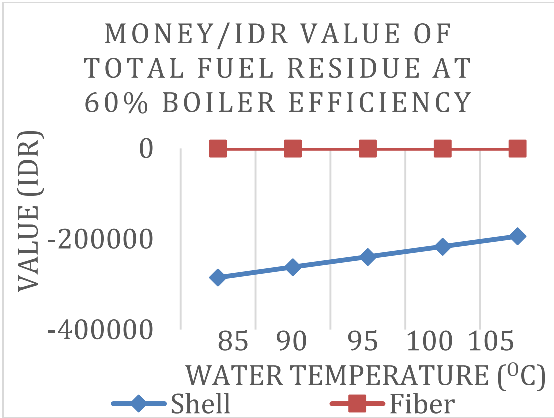

Figure 19. IDR/money value at 60%

In Figure 18 and 19, presented the fuel savings and the IDR value based on variations in the water intake temperature and the 60% boiler efficiency of the palm oil mill in which the lowest is at 105° C with a value of 5,461 kg/hour and fuel composition of 1 : 3 (shell : fiber). Shells potential for fuel savings is 270 kg/hour, while fiber is not mentioned because the available fiber is insufficient for the required fuel needs (-1.018 kg/hour). The highest fuel-used is at a temperature variation of 85° C with a value of 5,830 kg/hour and fuel composition of 1 : 3 (shell : fiber). Shell savings can be done up to 222 kg/hour, while fiber savings cannot be done because it does not meet the required fuel needs (-1,160 kg/hour). Fulfilling the fuel deficiency, excess fuel (shell) is used by looking at the calorific value of the fuel. According to Laila and Qodori (2019), if there is a shortage of fuel to improve boiler performance, hence the

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fuel can be obtained from other fuels such as shells.

DxPLangkat varieties

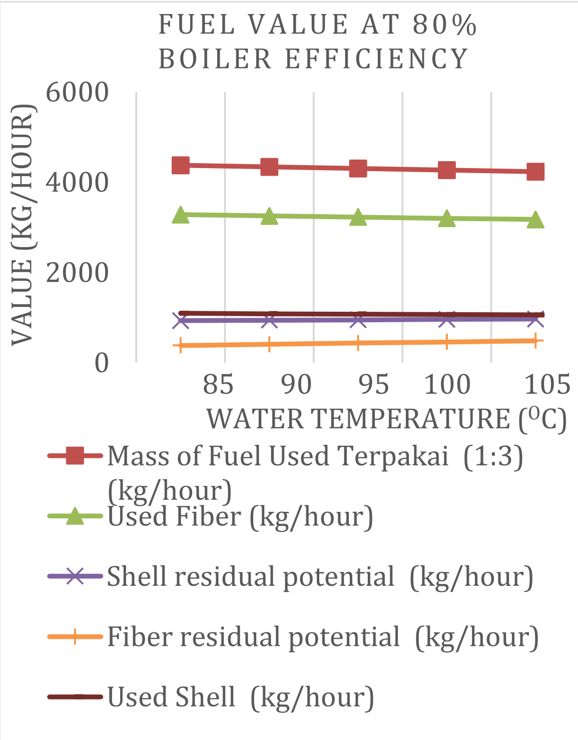

Figure 20. Graph of remaining fuel

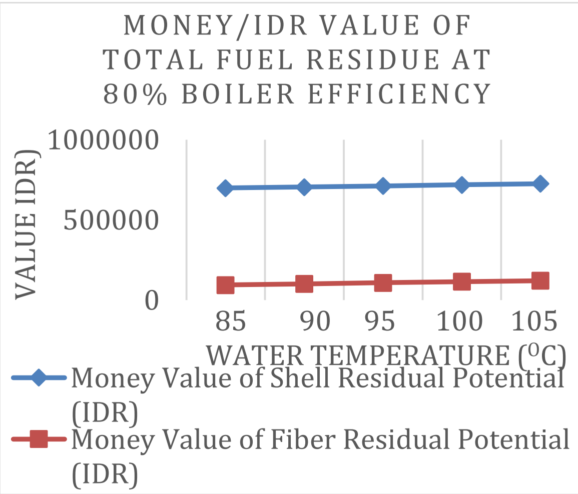

Figure 21. IDR/money value at 80%

In Figure 20 and 21, it can be seen that based on variations in the water intake temperature and 80% boiler efficiency of the palm oil mill, the lowest fuel-used is at 105^o C temperature, amounting to 4,231 kg/hour with a fuel composition of 1 : 3 (shell : fiber). Shells fuel saving is 967 kg/hour or IDR 725,501 per hour. Fiber fuel saving is 487 kg/hour or IDR 121,751 per hour with the ideal ratio is 25% : 75% (shell : fiber). The highest fuel-used is at a temperature of 85^o C with a value of 4,373 kg/hour and with a composition of 1 : 3 (shell : fiber). Shells fuel has the potential to save amounted to 932 kg/hour or IDR 698,837, and fiber fuel amounted to 380 kg/hour or IDR 95,087 with the ideal fuel ratio value of 25%: 75% (shell: fiber). These savings are in line with the factory's expectations but do not reduce the quality of the product and work of the boiler (Batubara, 2014).

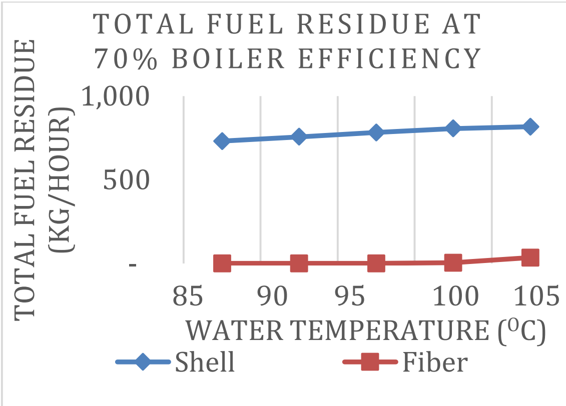

Figure 22. Graph of remaining fuel

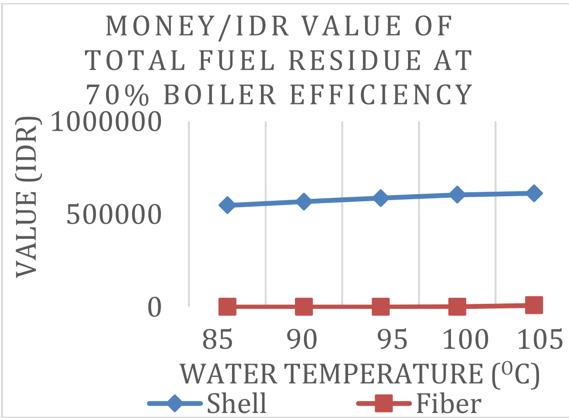

Figure 23. IDR/money value of 70%

In Figure 22 and 23, it can be seen the fuel savings and the IDR value based on variations in the water intake temperature and 70% boiler efficiency of the palm oil mill in which the lowest is at 105^o C with a value of 4,835 kg/hour and fuel composition of 1 : 3 (shell : fiber). Shells savings can be done up to 816 kg/hour, while fiber is 34

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kg/hour. The highest fuel-used is at a temperature of 85° C with a value of 4,998 kg/hour with a fuel composition of 1 : 3 (shell : fiber), in which the shell potential for fuel savings is 776 kg/hour. As for fiber, there are no savings because it is insufficient to meet the required fuel needs (-88 kg/hour), to cover fuel need, excess fuel (shell) is used. According to Laila and Qodori (2019), if there is a shortage of fuel to improve boiler performance, hence the fuel can be obtained from other fuels such as shells.

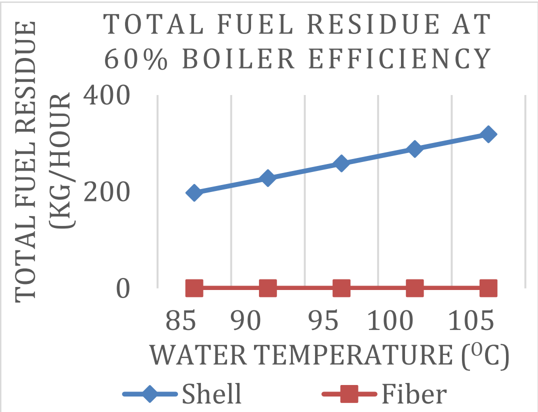

Figure 24. Graph of remaining fuel

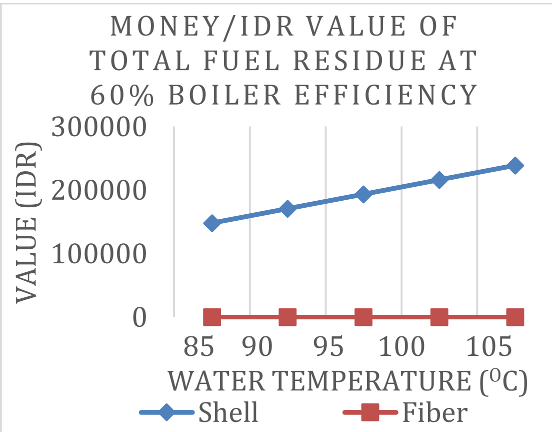

Figure 25. IDR/money value at 60%

In Figure 24 and 25, it can be seen the calculation results of the total remaining fuel savings and the IDR value based on the variation of water intake temperature and 60% boiler efficiency at palm oil mill, in which the highest temperature was at 105° C. Shell fuel saving amounted to 318 kg/hour or IDR 238,836 per hour, while for fiber saving is not mentioned because it is used up hence the ideal fuel ratio is 28.7 : 71.3% (shell : fiber). The lowest remaining fuel was at 85 °C temperature. Shell is 197 kg/hour or IDR147,900 per hour, while for fiber is not mentioned because it is used up hence the ideal fuel ratio is 27.1 : 72.8% (shell : fiber). An unbalanced savings ratio can reduce boiler activity that requires too much fuel in the production process. This savings is in accordance with what the factory expects, but it is also hoped that it does not reduce the product quality and work of the boiler (Batubara, 2014).

CONCLUSION

The results of the research concluded that :

The fuel used at temperature variations, types of superior seed varieties and 80% boiler efficiency obtained the highest fuel savings, namely the DxP Langkat variety with water intake temperature of 105° C, for shells amounted to 967 kg/hour with IDR 725,701, for fiber amounted tp 487 kg/hour with IDR 121,751. Meanwhile, in the analysis of fuel-used mass at temperature variations, types of superior seed varieties and 80% boiler efficiency, the lowest fuel savings were obtained in the Yangambi variety with water intake temperature of 85° C, for shells amounted to 552 kg/hour with IDR 414,130, and for the fiber does not have because it is used up.

Based on the analysis of the fuel-used mass at variations in temperature, types of superior seed varieties and 60% boiler efficiency, the highest fuel savings were obtained in the DxPLangkat variety with water intake temperature of 105° C, for shells amounted to 318 kg/hour with IDR 238,836 value, for the fiber does not have because it is used up.In the analysis of the fuel-used mass at variations in temperature, types of superior seed varieties and 60% boiler efficiency, the lowest fuel savings were obtained in Yangambi varieties with water intake temperature of 85° C, for shells amounted to -380 kg/hour,and there is no fiber because it is used up. In other words,

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the available fuel is less, so additional fuel is needed. Additional fuel can be done by asking for another palm oil mill unit or buying. If you buy a shell with a requirement of 380 kg/hour, the funds required are IDR 284,939.

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