The Potential Study of Coffee, Acacia Wood and Corn Cob Residues to produce Biomass Pellets Fuel

Benya Kasantiukl1,*

1Mechanical Engineering Department, Faculty of Engineering, Kasetsart University, Kamphaeng Saen Campus, Nakornpathom, 73140, Thailand

* Corresponding Author: benya.k@ku.th

Abstract
The objective of this research is to study the technical and economic feasibility of biomass pellet production from coffee, corncob and acacia wood residues for using as alternative energy. The biomass pellet in this research was produced by mixing three residues with the amount of tapioca starch not more than 20% by mass. The fuel properties of pellet were analyzed according to PFI and ASTM standards. The test results showed that the heating value of the pellet from coffee, acacia wood and corncob residues are 23.56, 20.43 and 19.46 MJ/kg, respectively. The moisture, ash, and durability index are 0.15-0.43, 0.954-0.957, and 95.37-98.52 %, respectively which are according to the standard. The bulk density is 221.04-277.93 kg/m3. The economic feasibility of pellet production was analyzed using Net Present Value (NPV), Reduction Rate (RR) and payback period (PB). The analysis results show that the production of biomass pellets from the residues of coffee, acacia wood and corncobs are economically feasible with RR = 27.56, 17.88, 14.61%, NPV=186,837 ฿, 91,684 ฿, 62,119 ฿, and payback period = 4 years and 7 months, 5 years and 4 months, 6 years and 8 months, respectively. Moreover, the sensitivity analysis results show that the most influential risk factors of the pellet production are fuel price and the quantity of fuel produced daily, followed by labor wages, production days a year, and price of machines.

1. Introduction
Energy is one of the important factors affecting today's lifestyles of people. Energy consumption in Thailand has continuously increased. In 2017, Thailand had final energy consumption of 83,691 ktoe. This includes traditional renewable energy (firewood wood and rice husk) at the total of about 6.23 per cent of the total final energy consumption and from renewable energy (agricultural waste and biomass) at the total of about 9.16 per cent of the total final energy consumption [1]. Of particular concern is the use of firewood-type fuel may reduce forest resources. At present, Thailand has only the forest area remaining about 30 per cent of the total land area [2]. Therefore, it is necessary to find alternative sources of energy to reduce such problems. A renewable energy source that is easy to find and has a high potential in Thailand is biomass energy from agricultural waste [3]. The use of agricultural
residues to produce biomass can help reduce the use of firewood fuel and can help solve the problem of waste disposal and agricultural waste materials at the same time. In addition, the use of energy from biomass is also environmentally friendly without affecting global warming because the amount of carbon dioxide emissions throughout the life cycle is zero or carbon neutral [4]. The biomass is, therefore, an appropriate source of energy for sustainable development. The processing of agricultural waste which is popular to produce sources the renewable energy is extrusion into biomass pellet fuel. This is a method that is not complicated. It can be easily done in the community to get the fuel with more inflammable ignition point than firewood and charcoal and still be clean energy [5]. Various types of agricultural waste materials such as rice straw, tree branches, leaves and corncob [6], corncob and shell [7], coffee grounds and tea residue [8], rice husk, sugar cane bagasse and sawdust [9] have been investigated to produce as compressed biomass fuel. The properties of this compressed fuel are good to be used as the fuel to replace the firewood and charcoal.

In this study, therefore, such agricultural waste as spent coffee ground (SCG), acacia wood and sawdust mixed corncobs was taken to produce the biomass compressed pellet fuel to determine the feasibility consistent with the Pellet Fuel Institute (PFI) Standards [10], to study the properties to be used as renewable heat energy instead of using charcoal and to reduce the cost of buying fuel from the seller. This not only helps reduce environmental problems but also gets a benefit from agricultural waste and increases the value of the waste materials. Moreover, the biomass compressed pellet fuel is still considered as an alternative and sustainable source of renewable energy.

2. Materials and Methods

This research was divided into 4 steps as follows: analysis of raw materials used in pellet fuel compression, pellet fuel compression, analysis of the technical production of pellet fuel and the economic feasibility study of the production of compressed fuel from coffee grounds, acacia wood and corncobs mixed with sawdust. Each step has the following details.

2.1 Analyzes of the Raw Materials Used in the Fuel Pellet Compression

To compress the fuel pellets in this research, an extrusion technique [11] through a screw compressor was used; furthermore, tapioca starch was used as a binder because it is high-calorific and able to stick the raw materials into a single material with good physical properties [12]. In this step, the properties of the raw materials used for compressed pellet fuel including coffee grounds, acacia wood and corncob mixed with sawdust together with tapioca starch as a binder were analyzed.

2.2 Fuel Pellet Compression

The process is as follows:

2.2.1 The biomass was chopped to a size of not more than 2 mm as shown in Figure 1a.

![Figure 1a. Chopping the biomass through a 2-mm sieve](image1)

2.2.2 The biomass was formed into 3 samples of chopstick-like fuel pellets as follows: Sample 1, coffee grounds: 10-kg coffee grounds 1-kg tapioca starch and 5-litre water Sample 2, corncobs: 5-kg corncobs, 5-kg sawdust, 1-kg tapioca starch and 5-litre water
Sample 3, acacia wood: 10-kg acacia wood, 1-kg tapioca starch and 5-litre water

2.2.3 Then, the fuel pellets formed from the biomass (see Figure 2a) into were taken to be baked to wick moisture away to be more solid and not easily broken while packing or moving. Either drying under the sun (as shown in Figure 2a) or baking in the oven may be used (see Figure 2b).

![Figure 2a. Fuel pellets drying under the sun](image1)

![Figure 2b. Baking the fuel pellets at 103°C](image2)

2.2.4 In Fig.3 the fuel pellets were packed in bags to prevent moisture and waiting for the testing of the properties according to the standards.

![Figure 3. Packing the fuel pellet formed from the biomass](image3)

2.3 Analyze of Technical Suitability of the Fuel Pellet Production

According to the Pellet Fuel Institute (henceforth PFI) Standards and the ASTM, in each test, 13.04kg of compressed fuel biomass is prescribed to be divided and tested according to the ASTM C 702-98 [13], as shown in Figure 4 below:

![Figure 4. Divided Tests of the Biomass Fuel according to the ASTM C 702-98](image4)
The analysis of the fuel pellet properties are as follows:
1. Bulk density according to the ASTM C 702-98 [13]
2. Length and diameter according to the PFI Standard [10]
3. Durability according to the PFI Standard [10]
4. Dust percentage according to the PFI Standard [10]
5. Ash content according to the ASTM D 3174 [14]
6. Moisture values according to the ASTM D 3173 [15]
7. Chloride content according to the PFI Standard [10]
8. Heating values according to the ASTM D 5865 [16]

2.4 Analysis of Economic Value of the Fuel Pellet Production from the Coffee Grounds, Acacia Wood and Sawdust-mixed Corncobs

Apart from its fuel properties, analysis of the economic value of the fuel pellet production from the coffee grounds, acacia wood and sawdust-mixed corncobs were carried out to determine the practical and sustainable feasibility for a community production project. Thus, the rates of return from the production project were assessed whether the benefits obtained from the production are sufficient/worth the investment and management cost or not; whether the production project can be effectively and sustainably implemented in the community or not. In addition, the fuel pellet production was also analyzed to find out the risk factors.

2.4.1 The rates of return from the production project consist of indicators: Net Present Value, NPV, Reduction Rate, RR and Payback Period, PB, as the following details:

(1) The Net Present Value, NPV refers to the cash flow projection throughout the production project at the rate of return as required, which can be found out through the following eq.1 [18]:

\[ NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+i)^t} \]  

Where \( n \) is the production period (year); \( t \) is the respective number of the production period (year) \( t = 1, 2, 3,..., n \); \( CF_t \) is the net cash(in baht) flow at year \( t \) = received cash flow at year \( t \) minus spent cash flow at year \( t \); and \( i \) is the reduction rate or the rate of return (%) as required. Criteria in judgment are: The investment in the production yields a good value when \( NPV \geq 0 \) and it is not worth when \( NPV < 0 \).

(2) The Reduction Rate, RR refers to the rate which makes the net cash flow throughout the production project to be zero and it can be found out through the following eq.2 [18]:

\[ 0 = \sum_{t=1}^{n} \frac{CF_t}{(1+IRR)^t} \]  

Where \( n \) is the production period (year); \( t \) is the respective number of the production period (year) \( t = 1, 2, 3,..., n \); \( CF_t \) is the net cash(in baht) flow at year \( t \) = received cash flow at year \( t \) minus spent cash flow at year \( t \); and \( RR \) is the Reduction Rate (%). Criteria in judgment are: The investment in the production yields a good value when \( RR \geq \) cost of the production project and it is not worth when \( RR < \) cost of the production project. In this research, the cost of the production project is the current interest rate of general commercial banks.

(3) The Payback Period, PB refers to the period where the cumulative received cash flow is equal to the spent cost of the production project. It is an indicator to tell the risk status of a project. Projects that have short PBs will have lower risks than those with longer PBs. Criteria in judgment are: The project will be accepted when \( PB \leq \) target PB and not accepted when the \( PB > \) the target PB. This shows that the investment of the project is not worth.

2.4.1 The Sensitivity Analysis (SA) was used to analyse the risk in the production project. This method is particularly useful when a project does not meet the expectations. And, it is to ensure that there are some factors affect the benefits and expenses of the production project.
Besides, it was done to assess whether it will still be worthwhile to proceed with the project or not. The SA is used to analyze the changes in net cash flow due to various factors, as the following main steps.

1. All variables are to be well defined.
2. The scope of possible data for each variable is also to be well defined.
3. NPV, RR, and PB are to be calculated one by one on condition that variable value is changed one by one while all other variables are constant. Then, the relationship of NPV, RR, and PB to each variable will appear.

In this research, the SA was carried out through five factors including fuel price, amount of fuel produced per day, machinery price, labor cost and the number of production days per year.

3. Results and Discussion

3.1. Results from the Fuel Properties
To study properties of the compressed pellet biomass from coffee grounds, acacia wood sawdust-mixed corncobs were used. The coffee grounds, acacia wood and sawdust-mixed corncobs were compressed and formed into biomass fuel sticks, which were used to test according to the international PFI Standards. It is apparent from the test that the moisture and ash contents and length did not exceed 1 per cent and met all three standard criteria. The durability achieved the standard whereas the bulk density was below 615.59 kg/m$^3$, and is considered as fell short of the standard. Further analysis showed that the dust value, which was greater than 1 per cent, was higher than the standard value. The diameter met the standards, ranging from 5.84 to 7.25 mm. The chloride values of all three types of the biomass that were below 300 ppm; also reached the standards. The heating values of the coffee grounds, acacia wood and sawdust-mixed corncobs were found as 23.56 MJ/kg, 20.43 MJ/kg and 19.46 MJ/kg respectively (see Figure 5 and 6).

![Figure 5. The bulk density and fine properties of the fuel pellets biomass from coffee grounds, acacia wood and corncobs](image-url)
Figure 6. The properties of the fuel pellets biomass from coffee grounds, acacia wood and corncocks.
As mentioned above, the bulk density and dust value were not up to the PFI Standards. This may be because of the improper condition of materials before pelletization. The mixture ratio that the pellet biomass can be successfully made is 1 kilogram biomass per 0.2 liter tapioca starch. The heating values of the pellet fuel were ranged from 19.46 to 23.56 MJ / kg, and appeared to be higher than that of firewood, which is about 15.98 MJ / kg [1]. Regarding the economic worthwhile analyses, the focus is on the cost-effectiveness to replace the fuel from eucalyptus wood and the non-commercial purpose.

3.2 Economic Value Analyses
The economic value analyses of the fuel pellet production from the coffee grounds, acacia wood and sawdust-mixed corncobs were conducted based on the effective pellet compression ratio of the coffee grounds, acacia wood and sawdust-mixed corncobs with a maximum of 0.2 liter/kg of the tapioca starch. The key indicators including the Net Present Value (NPV), the Reduction Rate, the Payback Period (PB) were analyzed for the returns of the production project. Then, the risk analysis of the project investment was carried out by the SA of the returns for the various factors.

Table 1, provides the base data for the economic value analyses. As shown in Table 2 and Table 4, the base data are used to find income, investment cost, expenses and net cash flows throughout the production project. In addition, through the net cash flows throughout the production project, the NPV, RR and PB can be calculated and can be seen from Table 6.

| Consideration Topics | Base data for economic value analyses |
|----------------------|--------------------------------------|
| Benefits from the production project | -Using the biomass pellet fuel produced from coffee grounds, acacia wood and sawdust-mixed corncobs can replace the normal household fuel and the biomass pellet fuel production is non-commercial.  
- Referring to Eucalyptus charcoal, it costs 7 baht/kilogram and its heating value is 29.29 MJ/kg.  
- So biomass pellet fuel from coffee grounds with heating value 23.56 MJ / kg in this research will be able to replace the equivalent cost = 7x23.56/29.29 = 5.63 baht/kg.  
- So biomass pellet fuel from acacia wood with heating value 20.43 MJ / kg in this research will be able to replace the equivalent cost = 7x20.43/29.29 = 4.88 baht/kg.  
- So biomass pellet fuel from sawdust-mixed corncobs with heating value 19.46 MJ/kg in this research will be able to replace the equivalent cost = 7x19.46/29.29 = 4.65 baht/kg. |
| Investment cost | - A grinding machine costs 35,000 baht and screw compressor costs 120,000 baht with manufacturing power of 40 kilograms/hour. |
| Expenses | - Labor cost 300 baht/day/person = 600 baht/day  
- Electric power cost = 0.16 baht/kilogram of fuel pellets  
- Water supply cost = 0.0013 baht/kilogram of fuel pellets  
- Tapioca starch cost = 0.78 baht/kilogram of fuel pellets |
| Amount of fuel pellets (produced / day) | - 300 kilogram / day |
| Number of Production Days (day / year) | - 52 days/year (collecting raw materials in the community and producing once a week) |
| Inflation rate | - 3% (average inflation rate for the past 10 years) [17] |
| Reduction Rate required (discounted rate) | - Using interest rate = 7% (referring to current MLR (Minimum Loan Rate as of June 2019)) |
| Production project lifetime | - 10 years |
Table 2. The cash flow projection from the coffee grounds

| Year of | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|---------|----|----|----|----|----|----|----|----|----|----|
| Benefit | $63 | $90 | $113 | $135 | $157 | $179 | $201 | $223 | $245 | $267 |
| kg/ha  | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |
| Total income | $90,418 | $91,310 | $92,204 | $93,104 | $94,004 | $94,904 | $95,804 | $96,704 | $97,604 | $98,504 |
| Labor cost | $2,356 | $3,309 | $4,263 | $5,217 | $6,170 | $7,124 | $8,078 | $9,032 | $9,986 | $10,940 |
| Electricity cost | $0.16 | $0.21 | $0.27 | $0.33 | $0.39 | $0.45 | $0.51 | $0.57 | $0.63 | $0.69 |
| Material cost | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Starch cost | $0.78 | $1.29 | $1.80 | $2.31 | $2.82 | $3.33 | $3.84 | $4.35 | $4.86 | $5.37 |
| Water cost | $0.0012 | $0.0184 | $0.0256 | $0.0328 | $0.0400 | $0.0472 | $0.0544 | $0.0616 | $0.0688 | $0.0760 |
| Total expense | $2,9413 | $47,290.81 | $48,078.63 | $50,138.99 | $51,643.16 | $53,192.46 | $54,788.23 | $56,379.98 | $58,124.33 | $59,889.83 |
| NPI | $114,666.18 | $75,640.16 | $75,485.58 | $72,481.10 | $72,444.27 | $72,482.04 | $77,828.30 | $85,573.55 | $126,305.37 | $119,202.56 |

Table 3. The cash flow projection from the acacia wood

| Year of | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|---------|----|----|----|----|----|----|----|----|----|----|
| Benefit | $4.88 | $78.495 | $76.757 | $93.380 | $76.676 | $88.246 | $89.285 | $90.324 | $91.363 | $92.402 |
| kg/ha  | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |
| Total income | $76,957.66 | $10,751.97 | $83,180.67 | $83,765.09 | $85,246.38 | $85,727.99 | $86,209.58 | $86,691.17 | $87,172.76 | $87,654.35 |
| Labor cost | $2 | $3.23 | $3.10 | $4.30 | $5.49 | $6.68 | $7.87 | $9.06 | $10.25 | $11.44 |
| Electricity cost | $0.16 | $0.21 | $0.27 | $0.33 | $0.39 | $0.45 | $0.51 | $0.57 | $0.63 | $0.69 |
| Material cost | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Starch cost | $0.78 | $1.29 | $1.80 | $2.31 | $2.82 | $3.33 | $3.84 | $4.35 | $4.86 | $5.37 |
| Water cost | $0.0013 | $0.0254 | $0.0505 | $0.0756 | $1.0007 | $1.0007 | $1.0007 | $1.0007 | $1.0007 | $1.0007 |
| Total expense | $2,9413 | $47,290.81 | $48,078.63 | $50,138.99 | $51,643.16 | $53,192.46 | $54,788.23 | $56,379.98 | $58,124.33 | $59,889.83 |
| NPI | $114,666.18 | $75,640.16 | $75,485.58 | $72,481.10 | $72,444.27 | $72,482.04 | $77,828.30 | $85,573.55 | $126,305.37 | $119,202.56 |

Table 4. The cash flow projection from the sawdust-mixed corncobs

| Year of | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|---------|----|----|----|----|----|----|----|----|----|----|
| Benefit | $4.65 | $74,838.12 | $76,923.61 | $76,231.12 | $81,808.26 | $84,056.51 | $86,578.20 | $89,375.55 | $91,850.82 | $94,046.34 |
| kg/ha  | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |
| Total income | $74,838.12 | $76,923.61 | $76,231.12 | $81,808.26 | $84,056.51 | $86,578.20 | $89,375.55 | $91,850.82 | $94,046.34 | $97,444.53 |
| Labor cost | $2 | $22,126.00 | $33,100.08 | $34,093.45 | $35,117.28 | $36,182.30 | $37,281.24 | $38,411.00 | $39,559.72 | $40,738.92 |
| Electricity cost | $0.16 | $2.576 | $2.640 | $2.705 | $2.771 | $2.837 | $2.903 | $2.969 | $3.036 | $3.103 |
| Material cost | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Starch cost | $0.78 | $12,533.04 | $12,909.05 | $13,296.30 | $13,695.19 | $14,106.05 | $14,529.23 | $14,965.11 | $15,414.66 | $15,876.48 |
| Water cost | $0.0013 | $26,818.84 | $22,52 | $22,16 | $22,81 | $23,51 | $24,21 | $24,94 | $25,69 | $26,46 |
| Total expense | $2,9413 | $47,290.81 | $48,078.63 | $50,138.99 | $51,643.16 | $53,192.46 | $54,788.23 | $56,379.98 | $58,124.33 | $59,889.83 |
| NPI | $115,000.00 | $76,814.95 | $78,070.30 | $73,014.68 | $73,075.02 | $73,135.36 | $73,195.70 | $73,256.04 | $73,316.38 | $73,376.72 |

Table 5. Results from the economic value analyses
As can be seen from Table 5 (above), it can be concluded that the production of the biomass pellet fuel is economically worthwhile because all three indicators have achieved the standards. Results are shown in Tables 6–10. The results are obtained from risk analysis by the sensitivity analysis of returns from biomass pellet fuel production; from all three types of raw materials, when various factors have changed from the expected results.

From Tables 6–10, it can be seen that the return appears when the fuel price, amount of production per day (day), labor cost, number of production days (day/year), and machinery price have changed, in comparison with the returns in base cases.

Table 6. Results from the sensitivity analysis: fuel price

| Fuel price (baht / kg.) | RR          | NPV         |
|-------------------------|-------------|-------------|
| coffee grounds          | 27.56%      | 186,828     |
| acacia wood             | 17.88%      | 91,684      |
| sawdust-mixed corncobs  | 14.61%      | 62,199      |

Table 6, above illustrates if the fuel prices decrease, the RR and NPV decrease. Therefore, the fuel prices decrease by 26% (coffee grounds), 15% (acacia wood) and 10% (sawdust-mixed corncobs), respectively. It was observed that the lowest levels of the return for each type of biomass are acceptable. However, if the prices are lower than these, the production project will not be worth to proceed.

Table 7. Results from the sensitivity analysis: amount of fuel produced per day
The amount of fuel produced per day (day) | RR | NPV
--- | --- | ---
coffee grounds | 300 (base price) | 27.56% | 186,828
 | 285 (-15%) | 16.54% | 79,404
 | 222 (-26%) | 7% | 0
acacia wood | 300 (base price) | 17.88% | 91,684
 | 270 (-10%) | 10.77% | 29,583
 | 355 (-15%) | 7% | 0
corncocks mixing sawdust | 300 (base price) | 14.61% | 62,199
 | 285 (-5%) | 11.14% | 32,623
 | 270 (-10%) | 7% | 0

Table 7 shows if the amounts of fuel produced per day decrease, the RR and NPV also decrease. Thus, if the amounts of fuel produced per day decrease by 26% (coffee grounds), 15% (acacia wood) and 10% (sawdust-mixed corncocks), respectively. We can see that the lowest levels that the return for each type of biomass is acceptable. If the amounts of fuel produced per day are lower than these, the production project will not be worth to proceed.

Table 8. Results from the sensitivity analysis: machinery price

| machinery price (baht) | RR | NPV |
|---|---|---|
| coffee grounds | 155,000 (base price) | 27.56% | 186,828 |
 | 119,231 (+30%) | 19.62 | 140328 |
 | 341,000 (+120%) | 7% | 0 |
| acacia wood | 155,000 (base price) | 17.88% | 91,684 |
 | 119,231 (+30%) | 11.39 | 45,184 |
 | 246,450 (+59%) | 7% | 0 |
| corncocks mixing sawdust | 155,000 (base price) | 14.61% | 62,199 |
 | 186,000 (+20%) | 10.33% | 31,199 |
 | 217,000 (+40%) | 7% | 0 |

From Table 8, if the machinery prices increase, the RR and NPV decrease. In general, therefore, it seems that the machinery prices increase by 120% (coffee grounds), 59% (acacia wood) and 40% (sawdust-mixed corncocks), respectively. These findings suggest that the highest levels of the return for each type of biomass are acceptable. If the machinery prices are higher than the specified price, the production project will not be worth to proceed.

Table 9. Results from the sensitivity analysis: labor cost

| labor cost (baht) | RR | NPV |
|---|---|---|
| coffee grounds | 300 (base price) | 27.56% | 186,828 |
 | 390 (+30%) | 19.88% | 110,467 |
 | 519 (+73%) | 7% | 0 |
| acacia wood | 300 (base price) | 17.88% | 91,684 |
 | 360 (+20%) | 12.12 | 40,778 |
 | 408 (+36%) | 7% | 0 |
| corncocks mixing sawdust | 300 (base price) | 14.61% | 62,199 |
 | 330 (+10%) | 11.64% | 36,746 |
 | 372 (+24%) | 7% | 0 |
As Table 9 shows, if the labor costs increase, the RR and NPV decrease. Thus, the labor costs increase by 73% (coffee grounds), 36% (acacia wood) and 34% (sawdust-mixed corncobs), respectively. The results of this study indicate that the highest levels that the return for each type of biomass are acceptable. If the labor costs are higher than this specified price, the production project will not be worth to proceed.

Table 10. Results from the sensitivity analysis: number of production days (day / year)

| Number of Production Days (day / year) | RR     | NPV    |
|---------------------------------------|--------|--------|
| coffee grounds                        |        |        |
| 52 (base price)                       | 27.56% | 186,828|
| 42 (-20%)                             | 12.45% | 43,596 |
| 38 (-26%)                             | 7%     | 0      |
| acacia wood                           |        |        |
| 52 (base price)                       | 17.88% | 91,684 |
| 47 (-10%)                             | 10.77% | 29,583 |
| 43 (-15%)                             | 7%     | 0      |
| corncobs mixing                       |        |        |
| 52 (base price)                       | 14.61% | 62,199 |
| 49 (-5%)                              | 11.14% | 32623  |
| sawdust                               |        |        |
| 47 (-10%)                             | 7.4%   | 3,046  |

From Table 10, if the numbers of production days (day/year) decrease, the RR and NPV also decrease. Thus, the numbers of production days (day/year) decreased by 26% (coffee grounds), 15% (acacia wood) and 10% (sawdust-mixed corncobs), respectively. This result may be explained by the fact that the lowest levels that the return for each type of biomass are acceptable. If the numbers of production days (day/year) are fewer than specified, the production project will not be worth to proceed.

According to the risk analysis of the production of the biomass fuel pellets from coffee grounds acacia wood and sawdust-mixed corncobs, this research found that the returns of the production project are the most sensitive to the fuel prices, the amounts of fuel produced and the numbers of production days. Thus, the fuel prices, amounts of fuel produced and numbers of production days increase by 10% (sawdust-mixed corncobs), 15% (acacia wood) and 26% (coffee grounds) for the biomass fuel pellets. Besides, the production project’s rates of return cannot be economically worthwhile (RR < 7 %, NPV < 0). Another important finding was that some factors can also have an impact on the production project i.e. the labor costs and machinery prices. Therefore, the management of fuel production for renewable energy should be done in communities especially with sufficient amounts of these products: coffee, acacia wood and corncobs grounds (approximately 300 kg) before compressing the fuel pellets. These results are likely to be related to suitability of the compress fuel pellets and adequate amounts of the raw materials with appropriate frequency rather than doing it frequently in small amounts.

4. Conclusion
This study has identified the use of coffee grounds acacia wood and sawdust-mixed corncobs to produce biomass pellet fuel with extrusion method using tapioca starch (e.g. binder). The research has also shown that fuel pellets can be extruded well. This study has found that generally, the ratio with the best fuel properties is 1 kg of acacia wood and sawdust-mixed corncobs per 0.2 liters of tapioca starch. These experiments confirmed that the coffee grounds, acacia wood and sawdust-mixed corncobs have the heating values at 23.56 MJ/kg, 20.43 MJ/kg and 19.46 MJ/kg, respectively. Besides, their moisture content and ash content was at 0.15-0.43 at 0.954-0.9957%. While the durability index was at 95.37-98.52%. The investigation of the properties has shown that they are sufficient to be used as a renewable fuel and can replace the firewood in the community. However, based on the PFI’s standard diameters ranging from 5.84 to 7.25 mm., the biomass pellet fuel’s diameter, therefore, meets the standard. The chloride contents of all 3-type biomass which are less than 300 ppm; also meet the
standards. The values of the bulk density range from 221.04 to 277.93 kg/m³ which less than 615.59 kg/m³, below the standard and the dust value which is greater than 1%. This may due to the improper condition of materials before pelletization. The findings of this study suggest that a more suitable binder should be acquired to increase the values of the bulk density and can be able to reduce the dust value to meet the standards. The economic feasibility of pellet production was analyzed using the Net Present Value (NPV), Reduction Rate (RR) and Payback Period (PB). The analysis results show that the production of biomass pellets from coffee, acacia wood and corncob Residues are economically feasible with RR = 27.56, 17.88, 14.61%, NPV = 186,837฿, 91,684฿, 62,119฿. The findings reported here shed new light on the returns which are worth the investment and can be implemented in practice. Meanwhile, the Payback Period of the fuel pellets from coffee, acacia wood and corncob residues are 4 years and 7 months, 5 years and 4 months, and 6 years and 8 months respectively. These periods are considered not too long as compared to the normal lifetime of the machines resulting in a low risk for loss for the production project. Based on the Sensitivity Analysis, it was found that the returns of the production project are most sensitive to the fuel prices, amounts of fuel produced and numbers of production days followed by the labor costs and machinery prices, respectively. Therefore, to manage the production of this fuel as renewable energy in the community or selling in the industrial sector, various raw materials should be collected adequately before the pellet fuel is processed. In general, therefore, it seems that this method is more suitable than compressing fuel pellets in small amounts frequently. Processing coffee grounds acacia wood and sawdust-mixed corncobs into biomass pellet fuel is taking agricultural waste materials to produce as alternative energy for communities or for further selling in the industrial sector. The general properties of the fuel can be used as an effective fuel. This is an effective way to use resources that can help solve the problem of eliminating agricultural waste and help reduce the impact on the environment at the same time.

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