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Cost Analysis and Economic Evaluation for The Fabrication Activated Carbon Nanomaterials from Durian Seeds Utilizing Ionic Liquids

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ABSTRACT

Waste Agricultural Biomass (WAB) is a challenging problem in this modern era. The purpose of this study was to evaluate the economic feasibility of manufacturing carbon nanomaterials from durian waste biomass using ionic liquids. Several economic evaluation parameters are analyzed to inform the production potential of valuable materials from Biomass. The results showed that the production of carbon nanoparticles from biomass is quite prospective. Technical analysis for converting 250 kg of waste durian seeds shows the total cost of the equipment purchased was USD 12,086. Adding the Lang Factor, the total investment cost should be less than USD 53,661. This value is relatively economical (ie the project requires less investment funds) to reduce 75 tons per year or 100 tons per 20 project years. Compared to the total amount of degraded durian seed waste, the value is only around 18 USD per ton. Indeed, it is inexpensive to access a problem solver in degrading a ton of durian seed waste. To ensure project feasibility, projects are assessed from ideal to worst conditions in production, including labor, sales, raw materials, utilities, and external conditions (ie, taxes and subsidiaries).

1. Introduction

Waste has become a global issue because of the various adverse impacts it has on environmental ecosystems (Hird, 2017). Any substance that is discarded after its primary use, or is worthless, spoiled and useless is called waste. Currently, various types of waste have been generated in various industrial fields such as electronic waste (de Vries & Stoll, 2021; Parajuly et al., 2019), fashion waste (Nayak et al., 2021), food waste (Tonini et al., 2018), agricultural waste (Anastopoulos et al., 2019), and etc.

Waste Agricultural Biomass (WAB) consists of agricultural residues in the form of residual materials after the plants are harvested and process residues in the form of residual materials after processing plants in factories into valuable products (Mahar et al., 2012). For more than 60 years, this agricultural waste has been studied around the world and research on the subject is even more relevant from 1998 (Duque-Acevedo et al., 2020). This encourages a variety of critical thinking to process and make agricultural waste, such as waste from fruit and seeds, into something more valuable and has a sale value.

Durian (*Durio zibethinus* Murray) only produced in Asia which has tropical climate, such as Indonesia, Malaysia, Thailand, etc (Saputro et al., 2018). It used to be a seasonal fruit, but agricultural advancement allowed the fruit to be available all year round and in large quantities during fruiting seasons (Tey et al., 2016). Information on the average durian production in Indonesia increased from 17,405 tons in 1999 to 741,831 tons in 2003, and at the end of 2011 to 883,969 tons (Cornelia et al., 2015). Only 20% -30% of durian fruit that can be eaten (Saputro et al., 2018; Srisang & Srisang, 2020). Some seeds were used for propagation, while the shells were disposed as wastes after the flesh were consumed. Around 90,000 metric tonnes of durian wastes were generated annually from 2008 to 2010 by the durian industry (Tey et al., 2016). Salah satu pemanfaatan limbah biji buah adalah meruabahahnya menjadi material karbon aktif (Mokti et al., 2021).

Activated carbon refers to a variety of carbonized materials with high porosity and high surface area (Heidarinejad et al., 2020). Because of its characteristic's, activated carbon has many applications in the environment and industry for the removal, retrieval, separation and modification of various compounds in liquid and gas phases (Suzuki, 1994). Precursors used for the production of activated carbons are organic materials that are rich in carbon, such as coal, lignite, and wood. Although coal is the most commonly used as precursor, agricultural by-products in certain conditions are a better choice, likely seeds and shells from durian (Ismail et al., 2010). In its development, nano activated carbon is carbon with the size of nano surrounded by active electrons with high purity and activated carbon atoms (Shokry et al., 2019). The difference between activated carbon and nano active carbon lies in the size of the constituent carbon particles, where the nanoparticle size of activated carbon is below 10-9 m, whereas activated carbon can be larger (Riyanto et al., 2020). To make this material, various other components are needed, such as solvents.

Research interest in ILs was initially based on the issue of environmental problems caused by various chemical activities involving solvents. Solvents themselves have been used in a wide variety of technologies and applications involved in manufacturing (drugs, food, plastics), processing (mineral extraction, analytical separations, surface coatings, energy storage, CO2 capture), and the transport of goods (fuels, lubricants) (Hayes et al., 2015). Most of the types of solvents used are volatile organic compounds, which are the main source of environmental pollution (Rogers & Seddon, 2003). Therefore, ILs are emerging as a new class of solvents that are innovative and have the potential to have an impact in many areas of scientific and engineering research (Dong et al., 2017).

Generally, ILs are defined as compounds consisting entirely of ions with a melting point below 100 °C (Lei et al., 2017). Typically, they contain an organic cation (ammonium, imidazolium, pyridinium, piperidinium or pyrrolidinium), and halogen, fluorinated or organic anions (Flieger & Flieger, 2020). These structures formed between cations and anions provide unique physical and chemical properties and can be engineered to increase the efficiency of a wide range of electrochemical, analytical, synthetic and engineering processes (Wasserscheid, 2006).

The purpose of this study was to evaluate economic feasibility on the fabrication of nano activated carbon from durian seeds by ILs activation.

2. Methods Theoretical Production Nano Activated Carbon Particles from Seeds by Ionic Liquids Activation

Durian seed collected from local durian processing industry was used as a precursor for preparing activated carbon. The ash content was determined by heating the raw material to 650 °C for 4 h and equaled to 1.95% by weight. The results indicated that this precursor is suitable for the preparation of activated carbon because of its high carbon content and low ash content (Ismail et al., 2010).

Figure 1 shows the synthesis route for the production of nano activated carbon particles from durian seeds. To ensure the processing steps, the process flow diagram is also presented in Figure. 2. Based on these figures, at least there are 9 processing steps involving the conversion of durian seeds. The raw materials needed for the production process are durian seeds and solution. However, basic solution types (eg deionized water, and acidic solutions (eg phosphoric acid (H_3PO_4)) are very dangerous and not environmentally friendly so they are replaced with green solvents, namely ILs, $[C_4Py][Tf_2N]$ as an activating agent. Detailed information for the production of nano carbon particles is reported in references (Ismail et al., 2010; Mokti et al., 2021).

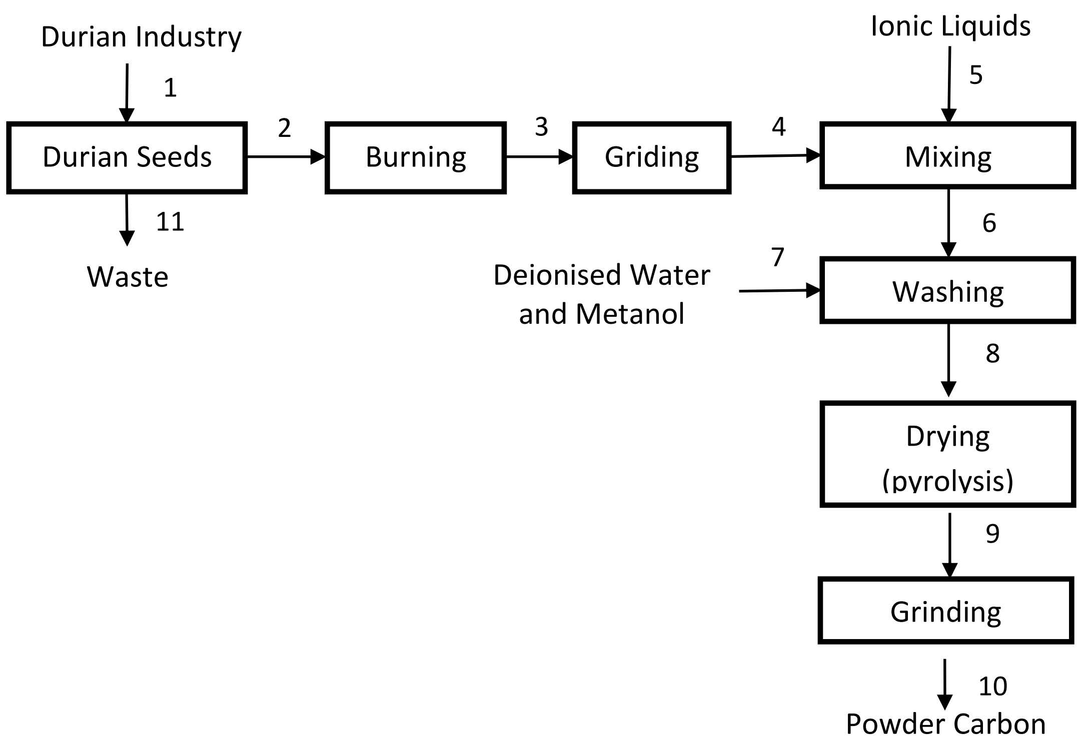

Figure 1. Production of nano activated carbon from durian seeds with ILs.

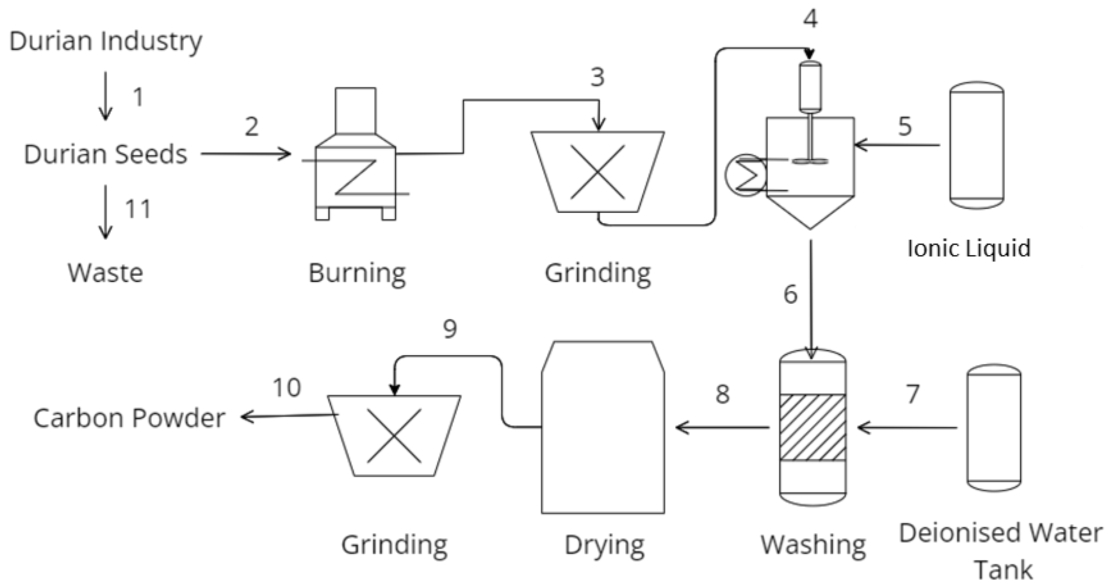

Figure 2. Process flow diagram to produce nano activated carbon from durian seeds with ILs.

The processes involved the following steps (see Figs. 1 and 2). Initially, the from local durian processing industry was used as a precursor for preparing activated carbon (step 1). The durian seeds waste is burned. Indeed, this burning process creates energy that can be used for other processing equipments (step 2). The burned durian seeds waste was grinded using a commercially available crusher/grinder (step 3), and the product was then put into the extractor (step 4). In the same time, ILs (step 5) was mixed with durian seeds waste in the extractor. After the extraction process, the solution was separated by washing with deionised water (steps 6 and 7). After the extraction process, the powder was separated by drying and grinding (steps 8 and 9) in which this creates carbon powder (step 10). The waste in step 11 can be used for fertilizer.

3. Research Method

The present method used several data based on the average price in commercially available products in online shopping web to guarantee the current price of the materials. All data were calculated using a simple mathematical analysis. To confirm the economic evaluation of this project, several economic evaluation parameters were used: CNPV, GPM, PBP, BEP, BEC, IRR, ROI, and PI. Then, when evaluating feasibility, various conditions were tested, including changing of raw material, sales capacity, labor condition, interest rate, etc (Nandiyanto et al., 2020).

4. Results

4.1 Energy and mass balance analysis.

To make the further estimation easier, the balance was predicted based on 1 kg of rice straw waste. The calculation was conducted based on the process discussed in Figs. 2 and 3 using the following assumptions: Based on the balance analysis, for converting 1 kg of seeds durian waste, the amounts of ILs where nano activated carbon particles were 0,5 kg, respectively. Water used for dilution must be at least 1.26 L. Finally, the nano activated carbon particles generated in the process were 0.5 kg, respectively.

4.2 Economic Evaluation

To ensure the economic analysis, several assumptions were used. This assumption is required to analyze and predict several possibilities happening during the project. The assumptions are:

i. All analyses used USD using currency of 1 USD = 14,500 IDR.
ii. Based on commercially available prices, the price of Durian Seeds, and Deionised Water were 0.00; and 3 USD/kg, respectively. The price of H_3PO_4 (85%) was 3-5 USD/L. All materials were approximated based on the stoichiometry.
iii. The price of equipment with its process condition is fixed based on the commerically available equipment (See Table 1).
iv. The Lang Factor was used for analysing the total investment cost (TIC) (Garrett, 2012). (See Table 2) The calculation showed that the TIC of this project is about four times of the total equipment cost.
v. TIC was prepared at least into two steps. The first step is 40% in the first year and the second step is the rest (during the construction of the project).
vi. The manufacturing cost is changeable and predicted from the beginning of the project. The estimation of manufacturing cost is shown in Table 3.
vii. Land is purchased. Thus, the cost of land was added in the beginning of the plant construction and re-gained in the end of the project.
viii. Depreciation was estimated using the direct calculation (Garrett, 2012).
ix. One cycle of the process (the process from putting durian seeds waste step into gaining nano carbon) requires 4 hours. Since one-year project contains 300 days (assuming holiday and is an off-day production), the maximum total production per year was 900 processing cycles.
x. To simplify the utility system, the unit of utility can be described and converted as an electricity unit. Then, the electricity unit is converted into cost by multiplying with standard minimum electricity cost.
xi. The length of the project operation is 20 years.

Table 1. Price of equipment and the process condition. All the prices as well as apparatus information are adopted from current available apparatuses in online shopping web.

No	Item	Temp. (°C)	Process Time (h)	Unit/s	Price (USD)
1	Reactor	150-600	4	1	$ 2.500,00
2	Oven (for durian seeds)	100	12	1	$ 250,00
3	Mechanical Grinder	-	4	2	$ 1.200,00
4	Tank (For ILs and Deionised Water)	-	-	1	$ 600,00
5	Plastic Pipe	-	-	6	$ 6.000,00
6	Pump	-	-	2	$ 236,00
7	Furnace	105	2	1	$ 100,00
8	Factory scale	-	-	1	$ 200,00
9	Strorage tank (drying)	-	-	1	$ 1000
Total					$ 12.086

Table 2. Lang factor for estimating total investment cost. Table was adopted from reference (Garrett, 2012) .

Komponen	Faktor	Biaya
PC (equipment)		
Purchased Equipment	1	$ 12.086,00
Piping	0,5	$ 6.043,00
Electrical	0,1	$ 1.208,60

Instrumentation	0,2	$ 2.417,20
Utilities	0,5	$ 6.043,00
Foundations	0,1	$ 1.208,60
Insulations	0,06	$ 725,16
Painting, fireprofing, safety	0,05	$ 604,30
Yard Improvement	0,08	$ 966,88
Environmental	0,2	$ 2.417,20
Building	0,08	$ 966,88
Land	0,5	$ 6.043,00
Subtotal 1		$ 40.729,82
PC (management services)		
Constructions, engineering	0,6	$ 7.251,60
Contractors fee	0,3	$ 3.625,80
Contigency	0,2	$ 2.417,20
Subtotal 2		$ 13.294,60
Total PC (=equipment + management service)		$ 54.024,42
TPC (=Total PC - Land)		$ 47.981,42
Starting-up fee		
Off-site facilities	0,2	$ 2.417,20
Plant strart-up	0,07	$ 846,02
Working capital	0,2	$ 2.417,20
Subtotal 3		$ 5.680,42
TIC (=TPC + Starting up fee)		$ 53.661,84
TIC-Land		$ 47.618,84

Table 3. Factor for estimating manufacturing cost (Garrett, 2012).

No	**Item**	**Factor**		**Value**		
	Total Life Time	**20**	**years**	**(/day)**	**(/mouth)**	**(/Years)**
1	Raw Materials			$ 853,33	$ 21.333,33	$ 339.200,00
2	Utilites			$ 52,80	$ 1.320,00	$ 15.840,00
3	Loan Interest	7%	of loan			
4	Operating Labor			$ 85,71	$ 5.357,14	$ 64.285,71
5	Labor related cost					
	a. Payroll overhead	30 %	of labor	$ 25,71	$ 1.607,14	$ 19.285,71
	b. Supervisory, misc. labor	25 %	of labor	$ 21,43	$ 1.339,29	$ 16.071,43
	c. Laboratory charges	12 %	of labor	$ 10,29	$ 642,86	$ 7.714,29
6	Capital related cost					
	a. maintenance	6%	of (TPC-land)	$ 2.857,13	$ 2.857,13	$ 2.857,13

	b. Operating supplies	1,75%	of (TPC-land)	$ 833,33	$ 833,33	$ 833,33
	c. Enviromental	2,25%	of (TPC-land)	$ 1.071,42	$ 1.071,42	$ 1.071,42
	d. Depreciation	5,00%	of (TPC-land)	$ 2.380,94	$ 2.380,94	$ 2.380,94
	e. Local taxes, insurance	4%	of (TPC-land)	$ 1.904,75	$ 1.904,75	$ 1.904,75
	f. Plant overhead cost	3%	of (TPC-land)	$ 1.428,57	$ 1.428,57	$ 1.428,57
7	Sales related cost					
	a. Packaging	1%	of sale	$ 18,00	$ 450,00	$ 5.400,00
	b. Administration	2%	of sale	$ 36,00	$ 900,00	$ 10.800,00
	c. Distribution and marketing	2%	of sale	$ 36,00	$ 900,00	$ 10.800,00
	d. Research and development	1%	of sale	$ 18,00	$ 450,00	$ 5.400,00
	e. Patents and royalties	1%	of sale	$ 18,00	$ 450,00	$ 5.400,00
	Total Manufacturing Cost			$ 11.651,42	$ 45.225,91	$ 510.673,29

4.2.1 Ideal condition

Figure 3 shows the CNPV with various economic evaluation parameters (eg, GPM, PBP, BEP, breakeven capacity, IRR, ROI, and PI) under normal conditions. The analysis shows that the conversion of durian seed waste into activated carbon nanoparticles using ILs is very prospective, as shown by the economic evaluation analysis which is very good and promising.

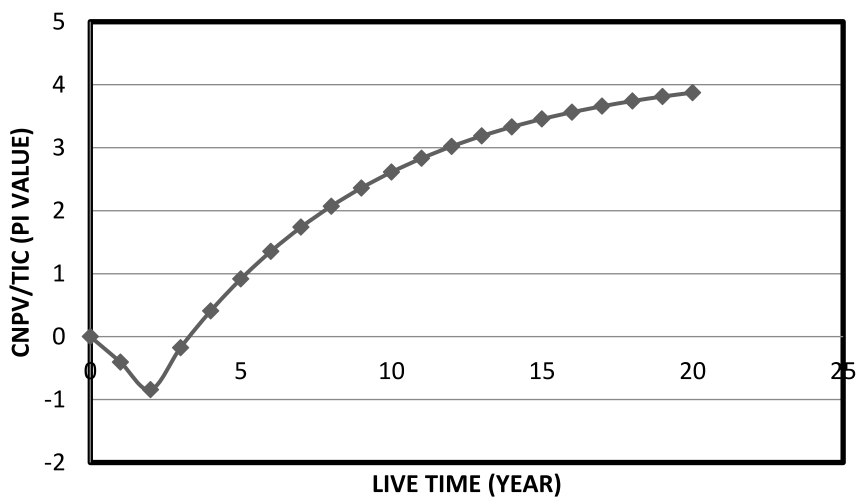

Figure 3. CNPV with various economic evaluation parameters in the ideal condition.

4.2.2 Changing price material and sales

CNPV analysis to get the minimum capacity requirements is shown in Figures 4 and 5. As shown in this figure, CNPV can predict in detail when the project starts to be profitable. This graph can also estimate the project's PBP. The results show that capacity plays an important role for project profitability. The reduction in capacity affects directly to the CNPV final. Indeed, this also affects the value of PBP. From the figure, the minimum capacity to maintain the project must be more than 60%. In short, less than 60% capacity utilization will make the project unprofitable.

Based on PBP analysis, the maximum tax for obtaining BEP (the point where there is no profit or loss in the project) is 10%. Changes in the price of starting materials to more than 10% lead to project failure.

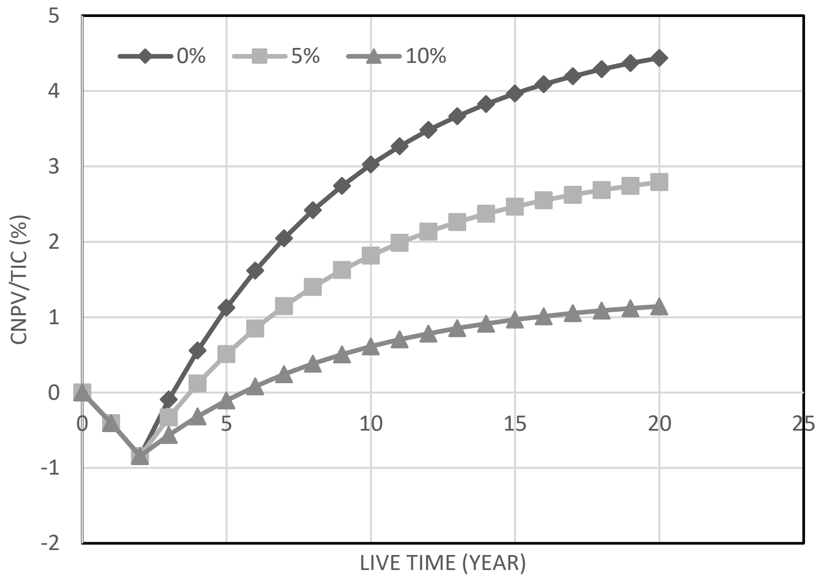

Figure 4. CNPV curve according to project life time with various increases in the price of basic materials.

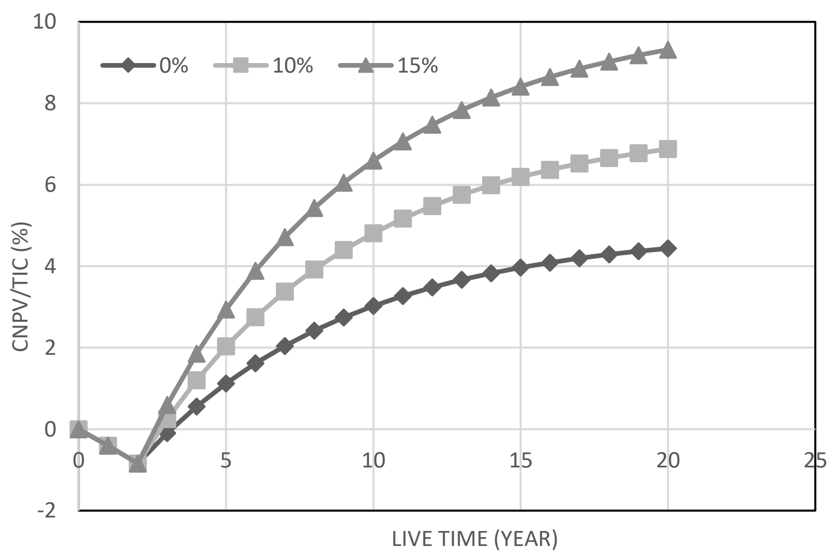

Figure 5. CNPV curve according to project life time with various product price increases.

4.2.3 Impact of external condition

For project success, the economic conditions in the country where the project is implemented are external parameters that are very influential. This relates to financial fees or other fees imposed on state projects or the state equivalent to finance various public expenditures. The impact of domestic economic conditions can be in the form of taxes or subsidies from the government itself.

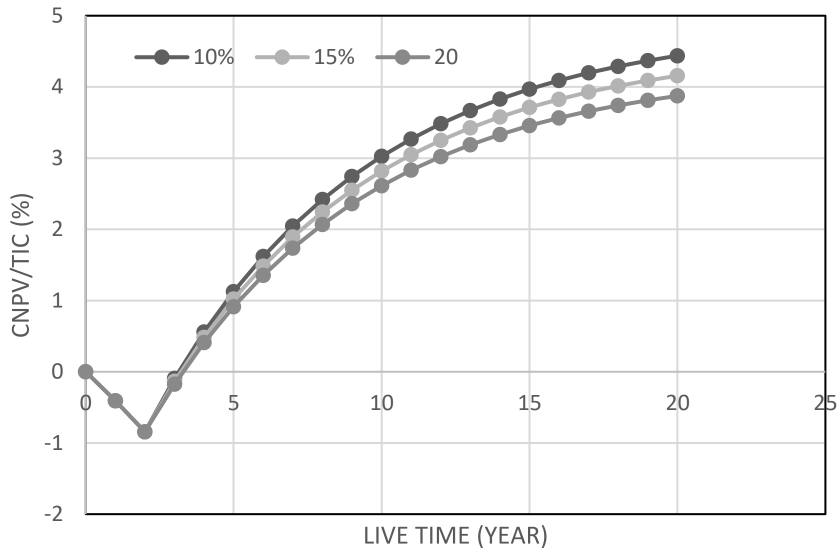

Figure 7. CPNV curve with an increase in corporate tax of 10%, 15% and 20%.

Figure 7 shows the CPNV curve with corporate tax increases of 10%, 15% and 20%. As shown in the figure, the initial conditions (from 0 to 2 project years) of CNPV at various taxes are identical. The reason is, these years are related to project development. The tax effect on CNPV can be obtained after the project is established (starting 2 years). The more taxes added to the project (indicated by clear dots; from 10 to 20%), the less profit is made. Indeed, these benefits pertain to the PBP project.

5. Discussion

5.1 Engineering perspective

The results from an engineering point of view confirm that the project is promising. Because the equipment to support the process can come from commercially available tools/equipment. By calculating projects with 900 processing cycles per year, the scheme proposed is prospective to consume more than 75 tonnes of durian seed waste per year. In fact, if you count the total project for 20 years, the project is capable of handling 100 tons of durian seed waste.

Furthermore, an analysis of the total cost of equipment to convert 250 kg of durian seed waste per batch requires a total cost of equipment purchased of USD 12,086. Adding the Lang Factor, TIC is less than USD 53,661. This value is relatively economical (ie the project requires less investment funds). Compared to the total amount of degraded durian seed waste, the value is only around 18 USD per tonne.

5.2 Economic analysis

Based on the analysis, a project under ideal conditions is possible. However, when there is a change in economic conditions, the nano activated carbon fabrication project from durian seed waste is only profitable under certain economic conditions. In short, if the project is carried out under circumstances outside of certain economic conditions, the project will lose money. In addition to the economic prospects, an analysis of the attractiveness of the project must be carried out. In short, although GPM, BEP and BEP show positive values, other economic parameters (eg final CNPV) give negative prospects. This project seems to be an unattractive perspective for industrial investors. This perspective is based on Indonesian capital market standards.

PBP analysis shows that the investment will turn around after more than 5 years. Compared to the capital market PBP standards, the results show conditions that are not competitive. Investment less than 25000 USD within 5 years is considered too long. Standard Indonesian capital market for USD 25000 usually promotes PBP around 1-2 years (Nandiyanto et al., 2021).

In the case of the final CNPV, the final value appears to be quite high for a 20 year project. However, when calculated per year, this CNPV is relatively less. This is also reinforced by the relatively smaller PI value. Indeed, this typical long-term investment will not be attractive to investors.

Another parameter is the IRR which determines the IRR value for 20 years. A rough calculation of IRR per year gives relatively low results, reaching around 2%. This response IRR can be categorized as unpromising, causing a conflict with local Indonesian bank interest of around 5-6%.

In addition, nothing new in the engineering process is presented in this study. But the new idea in this research is to provide information and knowledge about the feasibility of making carbon nano from durian seed waste. Based on the above results, although the durian seed waste conversion process is not suitable for industrial applications, other perspectives should be reconsidered. Candidate for conversion of durian seed waste to address environmental issues. Therefore, building this project is unavoidable and must be done in agrarian countries. Indeed, to sustain this project, financial support must be obtained, both from the social responsibility of the government and industry.

6. Conclusion

Based on the analysis above, the project of converting durian seed waste into nanoscale activated carbon using ILs is very prospective from both an engineering and environmental perspective. This analysis is also supported by the economic parameter cost analysis which gives a positive value. The analysis shows some limiting conditions for profits. However, the economic perspective shows a completely opposite result. Thus, the process of converting durian seed waste is less attractive to industrial investors. However, because this project is one of the prospective methods for overcoming the problem of agricultural waste with relatively smaller investment funds, the construction of this project cannot be avoided. This project should be carried out in agrarian countries. Therefore, to sustain this project, it is necessary to add support in the form of social responsibility from the government or industry.

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