Jurnal Teknologi Industri Pertanian 34 (3): 218-228, Desember 2024
DOI: https://doi.org/10.24961/j.tek.ind.pert.2024.34.3.218
ISSN: 0216-3160 EISSN: 2252-3901
Terakreditasi Peringkat 2
SK Dirjen Pendidikan Tinggi, Riset, dan Teknologi No. 158/E/KPT/2021
Tersedia online http://journal.ipb.ac.id/index.php/jurnaltin

FEASIBILITY STUDY OF NANOCRYSTALLINE CELLULOSE (NCC) PRODUCTION FROM OIL PALM EMPTY FRUIT BUNCH (OPEFB) FIBER USING BIOPROCESS TECHNOLOGY

STUDI KELAYAKAN PRODUKSI NANOCRYSTALLINE CELLULOSE (NCC) DARI SERAT TANDAN KOSONG KELAPA SAWIT (TKKS) DENGAN TEKNOLOGI BIOPROSES

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Paper: Accepted March 08, 2024; Corrected October 06, 2024; Approved November 06, 2024

ABSTRAK

Tandan kosong kelapa sawit (TKKS) adalah biomassa kepala sawit hasil dari pabrik pengolahan kelapa sawit. Kandungan selulosa pada tandan kosong kelapa sawit yang mencapai 38.70% dapat menjadi potensi bahan baku berbagai produk berbasis selulosa, seperti nanocrystalline cellulose (NCC). NCC bisa digunakan sebagai bahan baku pada berbagai sektor industri seperti industri kertas, industri kemasan, industri pangan, industri farmasi, industri kosmetik dan industri elektronik. Teknologi bioproses untuk produksi nanocrystalline cellulose dari tandan kosong kelapa sawit telah berhasil dikembangkan dan diharapkan dapat diterapkan pada skala industri. Untuk itu maka diperlukan kajian analisis kelayakan ekonomi yang bertujuan untuk menganalisis kelayakan investasi dan pengaruh perubahan parameter terhadap investasi menggunakan analisis sensitivitas pada produksi nanocrystalline cellulose dari tandan kosong kelapa sawit dengan teknologi bioproses. Berdasarkan hasil pengolahan data analisis kelayakan investasi dengan asumsi data biaya dan parameter lainnya menggunakan nilai Internal Rate of Return (IRR), Net Present Value (NPV) dan Payback Period (PP), didapatkan bahwa industri ini layak dan menguntungkan untuk dijalankan dengan nilai IRR 113,99%, NPV $763,804,208.84 dan *Payback Period selama 1 tahun. Selain itu, dengan menggunakan analisis sensitivitas dapat diketahui agar investasi tetap bernilai layak, maka perubahan parameter harga bahan baku hanya dapat ditingkatkan maksimal sebesar 35%, harga jual produk hanya dapat dikurangi maksimal sebesar 15% serta biaya produksi hanya dapat ditingkatkan maksimal sebesar 20%. Hasil penelitian ini diharapkan bisa memberikan informasi kepada stakeholders terkait seperti investor, pemerintah dan industri mengenai peluang pengembangan industri nanocrystalline cellulose dari tandan kosong kelapa sawit di Indonesia.*

Kata kunci: nanocrystalline cellulose, studi kelayakan ekonomi, tandan kosong kelapa sawit, teknologi bioproses

ABSTRACT

Oil Palm Empty Fruit Bunch (OPEFB) is biomass by-products from palm oil processing mills. The cellulose content in OPEFB, which reaches 38.70%, presents a potential raw material for various cellulose-based products, such as nanocrystalline cellulose (NCC). NCC can be used as a raw material in various industrial sectors, including paper, packaging, food, pharmaceuticals, cosmetics, and electronics industries. The bioprocess technology for producing nanocrystalline cellulose from OPEFB has been successfully developed and is expected to be applied on an industrial scale. Therefore, an economic feasibility analysis is required to evaluate investment viability and the impact of parameter changes on investment using sensitivity analysis for the production of nanocrystalline cellulose from OPEFB with bioprocess technology. Based on the data processing of investment feasibility analysis with assumptions of cost data and other parameters using Internal Rate of Return (IRR), Net Present Value (NPV), and Payback Period (PP), it was found that the industry is feasible and profitable with an IRR of 113.99%, NPV of $763,804,208.84, and a Payback Period of 1 year. Additionally, using sensitivity analysis, it was determined that to maintain investment viability, the raw material price can only increase by a maximum of 35%, the product selling price can only decrease by a maximum of 15%, and production costs can only increase by a maximum of 20%. This research is expected to provide information to stakeholders such as investors, government, and industry regarding the opportunities for developing nanocrystalline cellulose production from OPEFB in Indonesia.

Keywords: nanocrystalline cellulose, techno-economic study, oil palm empty fruit bunch, bioprocess technology

INTRODUCTION

A product from cellulose that has recently been widely researched is Nanocrystalline Cellulose (NCC). NCC itself, its mechanical and chemical properties are widely used for industrial purposes. The NCC production process can be carried out by breaking down and separating the crystalline part of

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natural cellulose. Cellulose itself means a material that is stable in nature, compatible, non-toxic. Even though cellulose is in nano size, its natural properties are still maintained. NCC can be applied in all sectors because of its cellulosic properties and unique optical and mechanical properties, better rheological properties, crystallinity, molecular alignment, and orientation. It can be applied in the food and beverage, cosmetics, health, and electronics industries (Kian *et al*., 2020). NCC is a material with good biocompatibility characteristics and strong physical characteristics.

Research related to the development of NCC has been carried out previously. There are several methods for nanocellulose synthesis, namely mechanical, chemical, biological and combination methods. Maryam *et al.* (2022) have succeeded in developing environmentally friendly process technology (bioprocess) by utilizing white rot fungi and cellulase enzymes in making nanocrystalline cellulose from Oil Palm Empty-Fruit-Bunch (OPEFB). This is in line with Papilo *et al.* (2020) which states that the most potential agricultural commodity in Indonesia is oil palm. To date, more than 50% of the world's palm oil is produced in Indonesia; and this makes Indonesia listed as a world producer of palm oil (Papilo *et al.*, 2018). In Indonesia, the volume of OPEFB is substantial, estimated at 27.6 million tons annually. However, only about 10% of this OPEFB is currently utilized, primarily for boiler fuel or compost, leaving the majority as waste (Ngadi and Lani, 2014). This is notable considering that OPEFB contains approximately 37.5% cellulose (Herawan and Rivani, 2013). OPEFB could serve as a valuable raw material for producing various cellulose-based products, such as paper, rayon, and bioplastics.

Therefore, it is hoped that this bioprocess technology can be applied by industries that can see the opportunities and potential of OPEFB in Indonesia for the development of the NCC industry. Nanocrystalline cellulose (NCC) is a nanometer-sized biomaterial derived from cellulose, known for its excellent mechanical properties such as tensile strength and modulus, and is also biodegradable. NCC can be applied as a reinforcing material, filler, and carrier in various medical and pharmaceutical products, packaging, composites, wood and paper, and food products. Bioplastics made with NCC are designed for high-value plastic products, offering greater strength and transparency.

According to nanografi.com (2021), the price of NCC is very high, reaching U$877 per kilogram. Producing NCC as an industrial raw material will attract the interest of foreign and domestic investors. Currently, in the global market, NCC producers are still low because NCC is still a fairly new material. Apart from that, the production technology is still quite difficult. This has encouraged researchers to study further about more efficient NCC production technology. The increase in NCC needs can be seen from the Central Statistics Agency (2020) which states that import data for nanocellulose with HS Code 39129090 in 2017 was 3,471,275 kg/year (US$ 25,024,995), in 2018 it was 4,269,139 kg/year (US$ 26,628,483), and in 2019 amounted to 4,359,762 kg/year (US$ 27,309,530). To meet domestic needs and reduce dependence on imports, it is necessary to develop NCC manufacturing in Indonesia. NCC can be used as a reinforcing filler in polymers, an additive for biodegradable products, a membrane enhancer, a thickener for dispersions, and as a drug delivery carrier and implant material. Additionally, NCC finds applications in various industries including the paper industry, packaging industry, food industry, and pharmaceutical industry.

Based on the results of research conducted by Maryam *et al.* (2022) who have developed bioprocess technology for making nano crystalline cellulose (NCC) from Oil Palm Empty Fruit Bunch (OPEFB), so that this technology can be applied by the NCC industry, an economic analysis study (feasibility study) is needed first. The successful development of laboratory scale or pilot scale NCC will open opportunities for a more efficient NCC industry compared to previously existing technology. Therefore, the urgency of this research is the need to carry out an economic analysis to see the feasibility of applying this method in the NCC industry. Research related to the economic study of NCC OPEFB production using the hydrolysis method has been carried out by Rozy *et al.* (2021), where the results of the economic analysis of the NCC factory design show that this factory is feasible to establish with a payback period of 21 months and Break Event Point (BEP) of 13%.

Additionally, research conducted by Handayani et al. in 2020 found that a Nanofibrillated Cellulose (NFC) plant is feasible with an Internal Rate of Return (IRR) of 38.29% and a Payback Period (PPP) of 3 years, 7 months, and 6 days. Ananda and Qusna in 2021 also indicated that a Nanocrystalline Cellulose (NCC) plant using Empty Fruit Bunches (OPEFB) with a capacity of 10,000 tons per year, planned for Air Genting, Hilir Sungai Silau, Asahan Regency, North Sumatra, and employing a hydrolysis process, is viable with a total investment requirement of USD 592,634,168,098. This includes 60% equity capital of USD 355,580,500,859 and 40% debt of USD 237,053,667,239. The Return on Investment (ROI) is 58%, with a payback period of 2 years and 8 months, and a Break-Even Point of 31%. Finally, Candra and Faiqoh (2022) found that a Nanocrystalline Cellulose plant from Corn Cobs (Zea Mays) with a capacity of 30,000 tons per year, using an Acid Hydrolysis process, is feasible with a bank loan interest rate of 8%, an ROI of 25%, an IRR of 28%, and a payback period of 2 years and 11 months.

Business feasibility study analysis is a form of activity to thoroughly study and analyze whether it is feasible or not to operate a business; whether it is used in a business that is currently running or will be run (Qamaruddin *et al.*, 2022). Business feasibility studies aim to assess the sustainability of a business in terms of various economic aspects (Terblanche, 2022). The results of the business feasibility study are to determine whether the business is feasible or not if it continues, looking at all aspects of the business feasibility study, but this research only focuses on the economic aspect. To determine whether an investment is appropriate from an economic aspect, it needs to be measured using several criteria. These criteria really depend on the needs of each industry and which method will be used. Each method used has its own advantages and disadvantages. When assessing a business, the appraiser should use several methods at once. This means that the more methods used, the more complete the picture will be, so it is hoped that the results will be more perfect.

The criteria frequently used to determine the economic viability of a business are Payback Period (PP), Net Present Value (NPV), Internal Rate of Return (IRR) and Profiitability Index (PI) (Aliefah and Nandasari, 2022). PP, NPV, IRR, PI calculation methods are methods used to measure the length of the investment period, long-term projections, comparison of initial cost value with cash flow value, discount rate value, and to measure the ratio of investment value to cash flow value (Brigham and Houston, 2019; Chibili, 2019; Oey & Juliana, 2022). There are three (3) criteria commonly used to measure the profitability of a business, namely Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period (PP).

Economic feasibility analysis was conducted to explore a project's economic feasibility in terms of its efficacy, punctuality, and utilization of finances and resources over the project's duration (Kementerian Keuangan, 2017; Rangkuti, 2012). The purpose of an economic feasibility analysis is to find out whether a business is worth running or not. This economic analysis is part of planning an industry. In business planning, collecting data that is appropriate to current conditions is an absolute necessity for economic feasibility. Errors in determining production technology assumptions, availability of raw materials and their price fluctuations, sensitivity of operational costs, labor estimates can cause inaccurate analysis; so that if the plan is realized, it has the potential to suffer losses. Financial analysis is critical in determining the advantages accrued to individuals or institutional investors as a result of the project's success (Haedar and Kasran, 2017).

Sensitivity analysis provides an understanding of how robust a decision is in the face of changes in factors or parameters that influence it. In investment decision-making, sensitivity analysis is used to study how changes in one independent variable, under several assumptions, would influence the dependent variable (Liu, 2022). Sensitivity analysis aims to see what will happen to the results of the project analysis if there are changes in the cost or benefit calculations.

The results of this research will be used as study material in establishing the NCC industry. Another benefit of the research is providing data to stakeholders (investors, industry, government, and banks) regarding the development of the NCC industry from OPEFB with bioprocess technology and providing data input for the establishment of the NCC industry. The research was conducted to assess the investment feasibility of producing nanocrystalline cellulose from oil palm empty fruit bunches using bioprocess technology and to analyze the sensitivity of changes in various parameters. This is aimed at assisting stakeholders in making informed decisions regarding potential changes.

RESEARCH AND METHODS

This study was conducted in three stages: (1) **Cost Estimation**, this involves estimating various costs such as investment costs, raw material costs, labor costs, and total production costs. The estimation process employs economic approaches found in the literature review. From these cost estimates, the plant's cash flow is derived, which serves as the basis for the economic feasibility analysis. (2) **Economic Analysis**, this stage uses methods including Internal Rate of Return (IRR), Net Present Value (NPV), and Payback Period (PP) to evaluate whether the project is economically viable. All parameters will be analyzed to determine the project's economic value. (3) **Sensitivity Analysis**, this analysis is performed to understand the impact of uncertainties in certain parameters on the feasibility of the project and to assess the effects of changes in critical investment parameters. Sensitivity analyses are conducted on production capacity, operational costs, raw material costs, and the selling price of NCC.

The data used in conducting the economic feasibility analysis here is estimated industrial cost data, namely investment costs, raw materials, labor and total production costs. Apart from the cost data, assumption data is also used, including the interest rate used is 10% (this assumption is based on the bank interest rate (Central Statistics Agency, 2024) and a Minimum Acceptable Rate of Return (MARR) of 20% (subjectively assumed by considering interest rates, cash flow costs, and risk factors) (Abuk and Rumbino, 2020)); NCC price per kg is $877 (this assumption is based on international market prices sourced from nanografi.com (2021)), with NCC specifications including Particle Size, dispersed powder at 2% (w/w) : < 200 nm, Color : white, Cellulose Crystallinity : 90%, Density : 1.5 g/cm3; cost of capital 12%, revenue growth 5% (this assumption is based on the macroeconomic fundamentals used in the preparation of the 2023 State Budget (RAPBN), which project an economic growth rate of 5.3% for 2023.

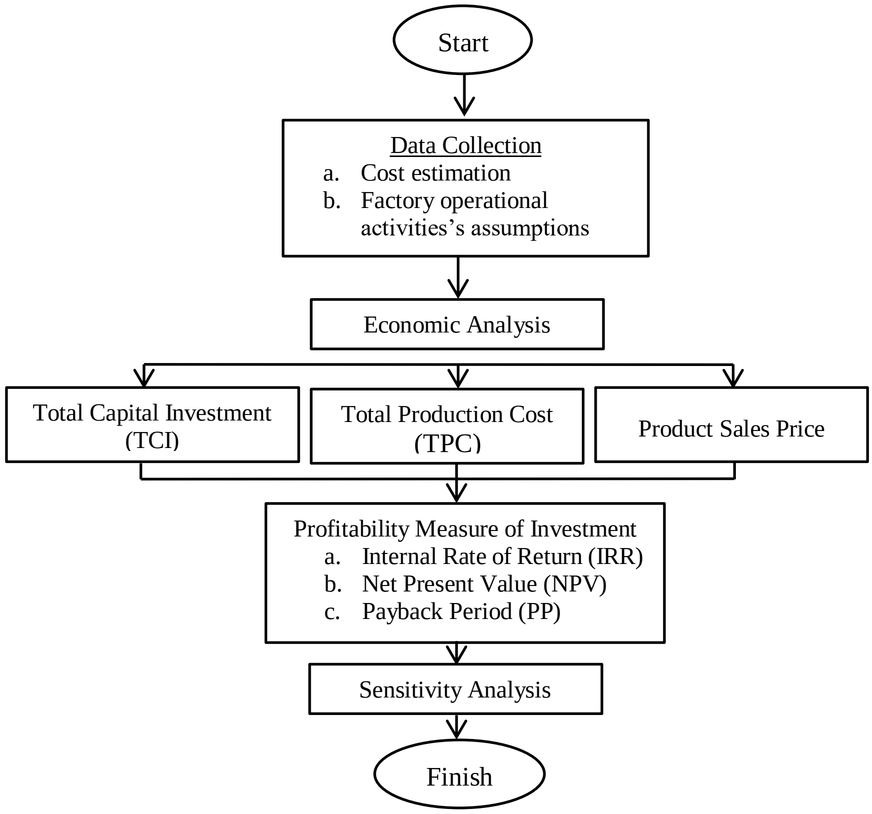

Figure1. Research's Flow Diagram

Based on this, it is assumed that the revenue growth rate will be 5%, and the inflation rate will be 4% (this assumption is based on the average inflation rate in Indonesia over the past 10 years, which is 4.23%. Therefore, an inflation rate of 4% is assumed). The initial step taken is to perform an economic feasibility analysis which includes NPV, IRR and PP. These three factors are analyzed to find out whether the industrial plan that will be implemented is feasible or not. An industry is said to be viable if the NPV value is greater than 0 (NPV > 0); IRR is greater than MARR (IRR > MARR); as well as a faster payback period.

The formula used in calculating Net Present Value (NPV) is shown in equation 1 (Dai *et al.*, 2022).

$$NPV = \sum_{t=0}^{n} \frac{Ct}{(1+D)^n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Information:

NPV	=	Net Present Value (Rp)
Ct	=	Cash flow per year in period t
D	=	Discount rate
t	=	year in period t
n	=	number of years

Feasibility indicators from NPV calculation results:

a. If NPV > 0, then a business is profitable and worth running
b. If NPV < 0, then a business is detrimental and not worth running
c. If NPV = 0, then a business is able to return capital

The IRR value shows the actual value of returns from a business. According to Wahyudi and Nahdalina (2019), the formula used in calculating the Internal Rate of Return (IRR) is shown in Equation 2.

$$IRR = i1 + (i2 - i1)x \frac{NPV\ 1}{NPV1 - NPV2} \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Information:

IRR	=	The interest rate the price is looking for
i1	=	The interest rate value used when the last NPV is positive
i2	=	The interest rate value used when the last NPV is negative
NPV	=	Net Present Value

To make a decision, the IRR criteria are compared with the Minimum Attractive Rate of Return (MARR) if:

- Investment is feasible if IRR > MARR
- Investment is not feasible if IRR < MARR

To find out the return period for investment invested in a business, it is necessary to carry out a payback period analysis. The formula for calculating the Payback Period (PP) is shown in equation 3 below (Febriyan *et al.*, 2017).

$$PP = n + (\frac{a-b}{c-b}) x\ 1\ year \ ………………..……\quad (3)$$

Information:

a = the amount of investment
b = cumulative amount of net cash in the n year
c = cumulative amount of net cash in year n+1
n = last year when net cash has not covered investment costs

Selection criteria:

a. An investment project is feasible if the investment return target is greater than the PP value.
b. An investment project is not feasible if the investment return target is smaller than the PP value

After the industrial plan is assessed as economically feasible, a sensitivity analysis is carried out to see how the impact of uncertainty in a parameter affects feasibility and to see the effect of changes in parameters that are quite important in investment. In this analysis, sensitivity to operational costs, raw materials and NCC selling prices was carried out. Since sensitivity analysis is conducted to determine how much increase or decrease in these parameters can shift the investment criteria from feasible to infeasible, this study performs sensitivity analysis using several percentage simulations for each parameter as follows:

1) Decrease in selling price by 12.5%, 15%, and 17.5%
2) Increase in raw material costs by 30%, 35%, and 37.5%
3) Increase in production costs by 15%, 20%, and 25%

RESULTS AND DISCUSSION

Economic analysis is necessary to determine the amount of capital required to establish and operate a plant, as well as to assess the feasibility of the plant. The factors that need to be reviewed in the economic analysis are:

a. Total Capital Investment (TCI): The investment required to establish a plant and bring it into operation.
b. Total Production Cost (TPC): The cost of production.
c. Selling Price of the Produced Product: The price at which the product is sold.
d. Feasibility of the Investment (Profitability Measure of Investment): This includes metrics such as Internal Rate of Return (IRR), Net Present Value (NPV), and Payback Period (PP).

Total Capital Investment (TCI) refers to the amount of capital invested to establish a plant until it is ready for operation. The calculation of Total Capital Investment has been carried out by Maryam *et al.* (2022) in a previous study, which includes:

a. Estimated cost of equipment + utilities = $ 285,269,126.74
b. Estimated raw material costs = $ 285,269,126.74
c. Estimated labor costs = $ 39,603.33

Apart from using cost estimation data, other data that is needed is assumptions about factory operational activities, which are as follows.

a. Availability of Raw Materials : 2.000 tons/year = 252,53 kg/hour

Based on the location assessment using the value evaluation method and supported by SWOT analysis, the planned industrial site is in Kampar Regency (Maryam et al., 2022). The primary raw material for NCC production is Oil Palm Empty Fruit Bunches (OPEFB), and the availability of this raw material can be assessed based on palm oil mills or crude palm oil (CPO) production facilities in the Kampar region and its surroundings. A list of these mills is provided in Table 1.

Table 1: List of CPO Industries in Kampar, Riau

No	Company Name	Production Capacity	OPEFB Availability	Address
1	PT. Sewangi Sejati Luhur	216,000 tons/year	49,680 tons/year	Desa Sukaramai, Tapung Hulu District, Kampar Regency, Riau Province.
2	PTPN V Sei Pagar	144,000 tons/year	33,103 tons/year	Jl. Hang Tuah, Perhentian Raja, Kampar Regency, Riau.
3	PTPN V Tandun	216,000 tons/year	49,680 tons/year	Talang Danto, Tapung Hulu District, Kampar Regency, Riau
4	PTPN V Terantam	288,000 tons/year	66,206 tons/year	Kasikan, Tapung Hulu District, Kampar Regency, Riau
	Total		198.669 ton/year	

The assumption for thess NCC industries are to utilize 10% of the OPEFB capacity from the CPO industry in the region, which amounts to 2,000 tons per year.

b. Factory Operation Time : 24 hours/day, 7 days/week, 28 days/month, 330 days/year
c. Investment Source : Own capital (50%) = $ 51,633,907.99
   Bank loan (50%)= $ 51,633,907.99

Economic Analysis

Economic analysis is needed to determine the amount of capital needed to establish and operate a factory as well as reviewing the feasibility of a factory. The factors that need to be reviewed in economic analysis are:

a. Total Capital Investment (TCI), namely the investment required to establish a factory until it operates,
b. Total Production Cost (TPC), namely production costs,
c. The selling price of the products produced,
d. Review of the feasibility of investment (Profitability Measure of Investment) which includes Internal Rate of Return (IRR), Net Present Value (NPV) and Payback Period (PP).

Total Capital Investment (TCI)

Total Capital Investment is the amount of capital invested to set up a factory until it is ready to operate. Total Capital Investment is divided into 2, namely:

a. Fixed Capital Investment (FCI)
   Fixed Capital Investment/Fixed cost investment is capital spent to purchase and install factory equipment and other supporting equipment so that the factory can operate.
b. Working Capital Investment (WCI)
   Working Capital Investment/Working cost investment is the capital or costs incurred to operate a factory until it produces its first product. These costs are intended to finance start-up, employee salaries, purchase of raw materials, taxes, and other needs.

Based on existing cost estimation data and assumptions, the results of the Total Capital Investment calculation can be seen in Table 2 below. The total investment required to set up a factory until it operates is obtained from additional capital spent on purchasing and installing factory equipment and other supporting equipment so that the factory can operate (Fixed capital investment) with the capital or costs incurred to operate the factory until it produces its first product (Work Capital Investment).

Total Production Cost (TPC)

Total Production Costs are the estimated costs of running a factory. Production costs are divided into 2, namely:

a. Manufacturing Costs
   Manufacturing costs are costs related to production which consist of Direct Production Costs, Fixed Costs and Plant Overhead Costs.
b. General Expenses (GE)
   General expenses are costs required for administration, distribution, product sales, research, and other financing.

Based on existing cost estimation data and assumptions, the results of the Total Production Cost calculation can be seen in Table 3.

Table 2. Calculation of Total Capital Investment

Parameter	%	Cost (US$)
Direct cost		
Equipment costs + Utilities	1.00	21,142,748.35
Tool installation	0.39	8,245,671.86
Instrumentation and control tools	0.13	2,748,557.29
Pipe installation	0.31	6,554,251.99
Electrical installations	0.1	2,114,274.84
Building	0.29	6,131,397.02
Area development	0.1	2,114,274.84
Service facilities	0.55	11,628,511.59
Land	0.06	1,268,564.90
Total Direct Cost		**61,948,252.67**
Indirect cost		
Engineering and supervision	0.32	6,765,679.47
Construction costs	0.34	7,188,534.44
Contractor costs	0.05	3,097,412.63
Unforeseen expenses	0.1	8,777,764.36
Total Indirect Cost		**25,829,390.90**
Total Direct cost + Indirect cost		**87,777,643.57**
Fixed Capital Investment		**87,777,643.57**
Work Capital Investment		**15,490,172.40**
Total Capital Investment		**103,267,815.97**

Table 3. Total production cost calculation table

Parameter	Fixed Cost (US$)		Variabel Cost (US$)
I. Manufacturing Cost			
a) Direct Production Cost			
Raw material			285,266,906.72
Operating labor			39,603.33
Direct supervisory and clerical labor			3,960.33
Utilities			74,706,055.07
Maintenance and repairs			6,144,435.05
Operating supplies			921,665.26
Laboratory charges			921,665.26
Patent and royalties			14,941,211.01
Total Direct Production Cost			**382,945,502.04**
b) Fixed charges			
Depreciation	8,777,764.36		
Local taxes	1,316,664.65		
Insurance	877,776.44		
Total Fixed Charges	**10,972,205.45**		
c) Plant-overhead cost	**4,331,599.10**		
Total Manufacturing Cost		**398,249,306.59**	
II. General Expenses			
Administrative cost			19,921,614.69
Distribution and selling cost			49,804,036.71
Research and development cost			24,902,018.36
Financing and development cost			5,163,390.80
Total General Expenses		**99,791,060.56**	
Total Production Cost (TPC)		**498,040,367.14**	

Table 4. Product Sales Prices

Product	Production capacity (kg)	Product (kg)	Price/kg (US$)	Total Price (US$)
NCC (rendemen 34.56%)	2,000,000	691,200.00	877	606,182,400.00

Variable costs, including raw material costs, labor costs, and other expenses, represent the operational costs incurred each month. Seen in the table above, Total Production Cost (TPC) is the total costs associated with the process of creating goods. In general, these are costs incurred by companies or business owners during the processing process to produce products that are ready to be sold.

Product Sales Price

The product sales price of 606,182,400.00 can be seen in Table 4 with a process yield of 34.56% and an NCC price of 877 US$ per kg.

Economic Feasibility

In carrying out this economic feasibility analysis, several additional data are needed that were not previously calculated, such as salvage value, revenue growth, inflation, and project length. To obtain the additional data needed, assumptions are made. The assumptions considered are:

Salvage Value of 10%

This assumption is taken from a depreciation value of 10% of the Ficed Capital Investment value.

Revenue Growth of 5%

This assumption is taken from the basic macroeconomic assumptions as the basis for preparing the 2023 RAPBN, namely that economic growth in 2023 is estimated at 5.3 percent. Based on this, the assumption is taken that the revenue growth value is 5%.

Inflation of 4%

This assumption is taken from the average value of inflation in Indonesia over the last 10 years, namely 4.23%. Based on this, the assumption is taken that the inflation value is 4%.

Project for 10 years

This assumption is taken from the company's consideration of borrowing capital for 10 years.

The results of the NCC OPEFB industry feasibility analysis were carried out by considering all costs and business assumptions that would occur for the next 10 years. The economic feasibility analysis carried out is:

Net Present Value (NPV)

This NPV analysis is used to analyze the value of an investment by considering currency values and shows the difference between the present value of profits and costs (Kadir W, 2007). A business is considered profitable and worth running if the NPV value is > 0.

Internal Rate of Return (IRR)

The IRR value shows the actual value of returns from a business. To make a decision, the IRR criteria are compared with the Minimum Attractive Rate of Return (MARR). If IRR > MARR, the investment is worth implementing.

Payback Period (PP)

To find out the return period for investment invested in a business, it is necessary to carry out a payback period analysis. The decision-making criteria for this PP are that the economic value of the industry is considered feasible if the payback period is smaller than the investment time.

The results of the economic feasibility carried out can be seen in Table 4.

Table 4. Results of feasibility analysis of the economic value of the NCC OPEFB industry

Parameter	Value	Information
IRR	113.99%	Worthy
NPV	$ 763,804,208.84	Worthy
Payback Period	1 year	Worthy
ROI	23%	Worthy

There are several stages for processing data in analyzing the financial aspect of a business feasibility study, namely as follows.

Cash In Flow

The cash in flow data here uses income data of $606,182,400.00, which is taken from the selling price of the product for 1 year (the product of annual production capacity of 2,000,000kg with the NCC price per kg of $877/kg). To obtain cash in flow for 10 years, data is used as an assumption of income growth of 5%, resulting in a total value of cash in flow for the NCC TKKS industry of $606,182,400.00 to $940,387,861.15.

Cash out flow

Cash out flow consists of an initial investment of $103,267,815.97 which is obtained from the total capital investment value. Production costs consist of fixed costs and variable costs. Fixed costs are obtained from the total depreciation costs and local taxes. Meanwhile, variable costs are obtained from the sum of direct costs (raw materials, labor, utilities, patents and royalties) with general expenses (administration, distribution and sales, research and development and finance). Total production costs are the sum of fixed and variable costs. The total cash in flow is $498,040,367.14 to $708,866,737.62.

Net Present Value (NPV)

The NPV value obtained is $763,804,208.84, which means > 0 so the investment is considered feasible for the next 10 years.

Internal Rate of Return (IRR)

The IRR value obtained is 113.99%, which means > MARR 20% so the investment is considered feasible. Value: An IRR value that has a value of more than 100% indicates that the cash in value at the beginning of the period is greater than the cash out value.

Payback Period (PP)

The PP value obtained is for 1 year with an ROI level of 23%. From this value, the NCC TKKS industry can be carried out because the investment costs can be returned with an investment return period of less than 10 years, that is, from the specified time. An ROI value of 23% means that the investment made will generate profits and increase income by 23%.

Several similar economic feasibility studies regarding the establishment of NCC production plants have been conducted. Pre-Feasibility Study of a Nanocrystalline Cellulose (NCC) Plant from Corn Cobs (Zea Mays) with an Acid Hydrolysis Process and a Plant Capacity of 30,000 tons per year: This study concluded that the plant is feasible with a bank loan interest rate of 8%, a Return on Investment (ROI) of 25%, an Internal Rate of Return (IRR) of 28%, a Payback Period (PBP) of 2 years and 11 months, and a Break-Even Point (BEP) of 38.87% (Candra and Faiqoh, 2022).

Pre-Design of a Cellulose Nano Crystals (CNC) Plant from Oil Palm Empty Fruit Bunches (OPEFB) with a Production Capacity of 200 tons/year: This study found the plant to be feasible with a total investment requirement of USD 21,272,547.70 or IDR 300,070,557,842.23, financed by 50% bank loans and 50% equity. The Return on Investment (ROR) is 57.30%, with a payback period of 1 year, 9 months, and 4 days, and a Break-Even Point (BEP) of 13% (Rozy, 2021).

Pre-Design of a Nanocrystalline Cellulose Plant from Empty Fruit Bunches (EFB) with a Capacity of 10,000 tons/year: This study indicated that a plant with this capacity, located in Air Genting, Hilir Sungai Silau, Asahan Regency, North Sumatra, is feasible with a total investment requirement of USD 592,634,168,098, comprising 60% equity (USD 355,580,500,859) and 40% loans (USD 237,053,667,239). The Return on Investment (ROI) is 58%, with a payback period of 2 years and 8 months, and a Break-Even Point (BEP) of 31% (Ananda and Qusna, 2021).

Pre-Design of a Nanofibrillated Cellulose (NFC) Plant from Palm Oil Empty Fruit Bunches (OPEFB) with a Capacity of 10,000 tons/year: This study concluded that the NFC plant is feasible with a Total Capital Investment of IDR 546,340,918,806 (63.40% equity = IDR 346,340,918,806 and 36.60% bank loan = IDR 200,000,000,000). The Internal Rate of Return (IRR) is 38.29%, and the Minimal Payback Period (MPP) is 3 years, 7 months, and 6 days (Handayani *et al.,* 2020).

Sensitivity Analysis

Sensitivity Analysis is a simulation analysis technique for measuring risk, where the values of important variables are changed to find out how they impact possible outcomes. This analysis is carried out to determine the influence of several causal variables on changes in cash flow, such as the influence of market size, number of products sold, selling price per product, variable costs per product, fixed costs per product and others. If the market size, number of products sold and selling price per product increases, this will affect the increase in profits for the company, and vice versa.

Sensitivity analysis is conducted by changing the values of the causal variables to be able to see various measurable possibilities for the company so that it can develop further and gain greater profits as an investment alternative in the future. Sensitivity analysis was conducted to determine how much the parameters could increase or decrease before the investment criteria shift from feasible to infeasible. In this research, three scenarios were evaluated in the feasibility analysis of the NCC OPEFB industry:

1) A decrease in the selling price by 12.5%, 15%, and 17.5%
2) An increase in raw material costs by 30%, 35%, and 37.5%
3) An increase in production costs by 15%, 20%, and 25%

The results of the sensitivity calculation for the parameter. of selling price reduction are shown in Table 5. Based on Table 5 above, three simulations of the selling price reduction parameter are shown in relation to investment feasibility. The data analysis indicates that for the investment to remain feasible, the selling price of the product can only be reduced by a maximum of 15%. This is because, according to the analysis, if the selling price is reduced by more than 15%, such as 17.5%, the resulting IRR would fall below the MARR of 20%, yielding only 17.35%. With the IRR being lower than the MARR, the investment is deemed infeasible. The results of the sensitivity calculation for the parameter of raw material cost increase are shown in Table 6.

Based on Table 6 above, three simulations of the raw material cost increase parameter are shown in relation to investment feasibility. The data analysis indicates that for the investment to remain feasible, raw material costs can only be increased by a maximum of 35%. This is because, according to the analysis, if the increase in raw material costs exceeds 35%, such as 37.5%, the resulting IRR will fall below the MARR of 20%, yielding only 19.77%. With the IRR being lower than the MARR, the investment is deemed infeasible.

The results of the sensitivity calculation for the parameter of production cost increase are shown in Table 7. Based on Table 7 above, three simulations of the production cost increase parameter are shown in relation to investment feasibility. The data analysis indicates that for the investment to remain feasible, production costs can only be increased by a maximum of 20%. This is because, according to the analysis, if production costs increase by more than 20%, which is 25%, the resulting IRR falls below the MARR of 20%, yielding only 4.18%, and the NPV is -56,510,485.51. With the IRR being lower than the MARR and the NPV being less than zero, the investment is deemed infeasible.

Table 5. Sensitivity analysis results for selling price reduction.

Parameter	Selling price (-12,5%)	Selling price (-15%)	Selling price (-17,5%)
IRR	44,81%	31,28%	17,35%
NPV	245,262,872.07	141,554,604.71	37.846.337,36
PP	3 years	4 years	7 years
ROI	7%	44%	1%

Table 6. Sensitivity analysis results for the increase in raw material costs

Parameter	Raw material cost (+30%)	Raw material cost (+35%)	Raw material cost (+37,5%)
IRR	37,86%	25,83%	19,77%
NPV	199,973,700.80	106,001,949.46	59,016,073.79
PP	4 years	5 year	6 year
ROI	5%	3%	1%

Table 7. Sensitivity analysis results for the increase in production costs

Parameter	Cost Production (+15%)	Cost Production (+20%)	Cost Production (+25%)
IRR	47,10%	26,03%	4,18%
NPV	271,615,408.43	107,552,474.96	-56,510,485.51
PP	3 years	5 year	10 year
ROI	8%	3%	-2%

The study shows that the economic feasibility assessment indicates that the NCC industry is viable and recommended for establishment in Kampar, Riau. The industry has the capacity to produce 691,200 kg/year, which is expected to reduce imports of NCC, where the import value in 2019 was 4,359,762 kg/year (BPS, 2020). The production value of NCC is not yet sufficient to meet domestic demand, thus there are still many opportunities for investment or establishing NCC industries in Kampar, Riau, or other potential regions. Stakeholders can use this information to assess the prospects and basis for developing the NCC industry in Kampar, Riau. The NCC industry also has significant potential for increasing its production capacity. Given the significant potential of OPEFB as a raw material in Indonesia, and supported by various studies conducted by other researchers regarding the economic feasibility of establishing an NCC (Nano Cellulose Composite) industry, it is highly recommended to proceed with further studies involving larger capacities and feasibility assessments in other regions. The researcher recommends that local and central governments, investors, and other stakeholders assist by providing various policies and strategies to support the establishment of the NCC industry.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The economic feasibility study indicates that the NCC industry is viable and recommended for establishment in Kampar, Riau. An analysis of the economic feasibility of the NCC industry from OPEFB with bioprocess technology has been carried out, showing that the industry is declared feasible to be established with an IRR value of 113.99%, NPV Rp. 763,804,208.84. From the results of the analysis that has been carried out, the NCC industry in Kampar Riau is considered feasible with a production capacity of 2.000 tons per year, where the return on investment is 1 year and the Return of Investment rate is 23%. Recommendations are based on the sensitivity analysis conducted concerning changes in the specified parameters.

Recommendations

The recommendations are as follows: to ensure that the investment remains viable, the increase in raw material costs should not exceed 35%, the selling price of the product can only be reduced by a maximum of 15%, and the production costs should not be increased by more than 20%. With this, the industry can carry out at least one of the three recommendations above to get even better results. The results of this study can be used as information to assess the prospects and basis for developing the NCC industry in Kampar, Riau.

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