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Techno-economic analysis and life cycle assessment of poly (butylene succinate) production using food waste

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A R T I C L E I N F O

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A B S T R A C T

In this present study, the production of poly (butylene succinate) (PBS) from food waste was investigated and critical factors were evaluated. The economic feasibility of the process was investigated, as well as the minimum selling price (MSP) of PBS and sensitivity analysis of economic factors based on critical input parameters. 1,4-butanediol price and solvent usage in PBS purification significantly impacted economics during the process. In this process, the MSP of PBS was 3.5 $/kg. The Monte Carlo simulation technique was used to determine the uncertainty in the MSP of PBS. The plant's return on investment (ROI), payback period, internal rate of return (IRR), and net present value (NPV) were 15.79 %, 6.33 years, 16.48 %, and 58,879,000 USD, respectively. The environmental impact factors were evaluated. The results showed the GHG emission from the process was 5.19 kg CO_2-eq/kg of PBS which is low than conventional PBS production.

1. Introduction

Plastics play a major role globally, with demand and application increasing in every sector such as packaging, automobiles, agriculture, electronics, medical and safety equipment, and household products (Serrano-Ruiz et al., 2021). In 2020, global plastic production reached 367 million tons and decreased by 0.3 % compared to 2019 due to the COVID-19 pandemic (PlascticEurope-Association of Plastics Manufactures, 2020). The value of the global plastic market was 579.7 billion USD in 2020 and is expected to increase at a 3.4 % annual rate from 2021 to 2028 (Grand View Research Report, 2021). Plastic safety equipment such as masks, personal protective equipment, gloves, and face shields play an important role in COVID-19, yet improper disposal of plastic waste results in significant environmental pollution (de Sousa, 2020). In developed countries, the municipal solid waste contains 30–35 % plastic waste (Ahamed et al., 2020). Plastic pollution is one of the biggest threats in the world. In the sea, there are around 5.25 trillion microplastic particles (0.26 MT) that are 5 mm in size (Eriksen et al., 2014) wreaking havoc on the marine ecosystem and costing the economy more than $13 billion. Micro and nano plastic particles are considered the most dangerous to the environment (Wang et al., 2019). Bio-based polymers are a viable alternative to petroleum-based plastics due to the lack of fossil fuel demand and their environmental impacts (Tan et al., 2017).

Renewable bio-based polymers are environmentally friendly and non-toxic (Rajendran and Han, 2022; Vasseghian et al., 2022). According to European Bioplastic(nova-institute), global bioplastic production capacity was 2.417 million tons in 2021 and is expected to reach 7.593 million tons in 2026. Currently, polylactic acid, PBS, and poly (3-hydroxybutyrate) are highly recommended bioplastics for industrial applications due to their ease of biodegradability and lack of toxicity in comparison to other biopolymers (Shamsuri and Siti Nurul, 2020). PBS is derived from both fossil fuels and renewable biological resources. By 2021, bio-based PBS output will reach approximately 0.087 million tons (3.5 % of total biopolymer production (2.42 million tons). The packaging sector accounted for a sizable portion of bioplastic use, accounting for 1.15 million tons. Due to its fast degradation duration and flexibility, PBS is mostly employed in packaging and agriculture. PBS is a white

Abbreviations: FW, Food Waste; PBS, Poly (butylene succinate); MSP, Minimum Selling Price; TEA, Techno-economic Analysis; LCA, Life Cycle Assessment; ROI, Return on Investment; IRR, Internal Rate of Return; NPV, Net Present Value; GHG, Green House Gas; FPMF, Fine Particulate Matter Formation; HHD, Human Health Damage; TED, Terrestrial Ecosystem Damage; TA, Terrestrial Acidification; MT, Metric Tons.

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thermoplastic polymer having a melting point of 90–120 °C, which is lower than that of polylactic acid. It is easily blended with other materials (Gowman et al., 2018). The glass transition temperature of PBS is −25 °C and the density is 1.25 g/cm^3 their mechanical properties are similar to polyethylene and polypropylene (Fujimaki, 1998; Tan et al., 2017). PBS can be synthesized from succinic acid and 1,4-butanediol, both of which are produced from renewable and non-renewable natural sources (Ferreira et al., 2015). Bio-based PBS is very difficult to market because its more expensive than fossil-based plastic (Muthuraj et al., 2015). However, the slight modification of PBS has a wide range of applications that also reduce the unit cost. Many research projects are focusing on the cost reduction of bio-PBS. To reduce the cost of polymer production, different waste sources such as agricultural waste, industrial waste, and food waste were utilized (Nanni and Messori, 2020). Moreover, adding cost-effective fillers reduces the polymer price (Gowman et al., 2018).

Succinic acid and 1,4-butanedioic acid are major compounds in the production of PBS. The cost of these chemicals majorly determined the cost of PBS. Succinic acid is a high-value product that is used in different sectors such as chemical and food industries, pharmaceuticals, biopolymer production, etc (Mazière et al., 2017). Currently, researchers are focusing on producing succinic acid from renewable sources such as carbohydrates using a microbial fermentation process to replace petroleum-based succinic acid (Li and Mupondwa, 2021; Moncada et al., 2015). Succinic acid fermentation is carried out with different natural and recombinant microbes such as *Actinobacillus succinogenes* (Lu et al., 2020), Yarrowia lipolytica (Jiang et al., 2021), Aspergillus niger (Yang et al., 2020), Saccharomyces cerevisiae (Liu et al., 2021), Enterobacter cloacae (Su et al., 2021a), Escherichia coli-ZW333 (Su et al., 2021b), *Mannheimia succiniciproducens* (Ahn et al., 2020), and *Corynebacterium glutamicum* (Uchikura et al., 2020). Feedstock selection is an important factor in developing an economically sustainable process. Succinic acid is produced from different sources such as agriculture waste, textile waste (Li et al., 2021), food waste (Gadkari et al., 2021), municipal solid waste (Khoshnevisan et al., 2020), and glycerol (Bumyut et al., 2020). Food waste is a sustainable source of carbohydrates, protein, and fat for bio-based value-added product production (Rajendran and Han, 2021; Yukesh Kannah et al., 2020). Food waste valorization has two advantages: it generates value-added products, and it is easy to handle with minimal environmental impact. Globally, 931 million tons of food waste was generated, which was equal to 17 % of total global food production (Rajendran et al., 2022). In greenhouse gas emissions, 6.8 % were produced from food waste. Food waste valorization is important for reducing environmental impacts. Many PBS articles are published every year, and most of them focus on copolymer binding with PBS to improve the properties and reduce the PBS price. Very few research articles are available on food waste-based succinic acid production. Food waste to PBS has a big research gap, which is shown in the network diagram (Fig. 1). More research focusing on food waste for PBS production is needed to develop a sustainable process. The main novelty of this work is to investigate the economic and environmental sustainability of PBS production from food waste via techno-economic analysis and lifecycle assessment studies.

This study primarily focused on the techno-economic and environmental impacts of producing PBS from food waste. In this study, the production flow was developed using data from a literature review of previous studies. The techno-economic analysis was carried out using SuperPro software, and the environmental impact analysis was carried out using the GREET model. This study aims to identify the economic and environmental challenges in the process and develop a sustainable commercial approach.

2. Materials and methodology

2.1. Process overview

The process for producing PBS from food waste was developed based on previous literature studies because direct PBS production from food waste was not available. The different process sections, such as food waste to glucose (Li et al., 2019), glucose to succinic acid (Thuy et al., 2017), and succinic acid to PBS (Tachibana et al., 2010) were combined in this process. The processing pathway is shown in Fig. 2. The major components of FW are carbohydrates, protein, fat, and water. The dried food waste was mixed with citrate buffer (pH 5.0) with a solid loading of 20 % (w/v). The enzyme hydrolysis was carried out using glucoamylase at an optimized temperature of 50 °C for 18 h and the maximum glucose conversion was 86.5 %. The solid biomass was removed using centrifugation (Li et al., 2019). The solid-free liquid was transferred to the dryer to achieve a glucose concentration of approximately 1000 g/L and the initial fermentation glucose concentration was maintained at 70 g/L. *Actinobacillus succinogenes* (ATCC55618) was used for succinic acid production with an optimized medium and conditions (12 h at 35 °C). The succinic acid yield was 1.51 g/g$_{glucose}$. The cell biomass was removed using a centrifuge, and the protein, ions, and large molecules were removed using a microfilter. The filtrate was heated to a concentration of 250 g/L succinic acids. The concentrated succinic acid was converted to crystals, which were then filtered and washed with cooled deionized water to remove surface impurities and dried to obtain 99.35 % pure crystal (Thuy et al., 2017). The succinic acid crystal was mixed with 1,4 butanediol and titanium tetraisopropoxide at 243 °C for 1 h with nitrogen gas to remove the water content. After the esterification process, the polycondensation process was carried out at 243 °C for 2 h under 10 Pa pressure. The mixture was dissolved in the chloroform and poured into methanol to make the precipitate, which was filtered and

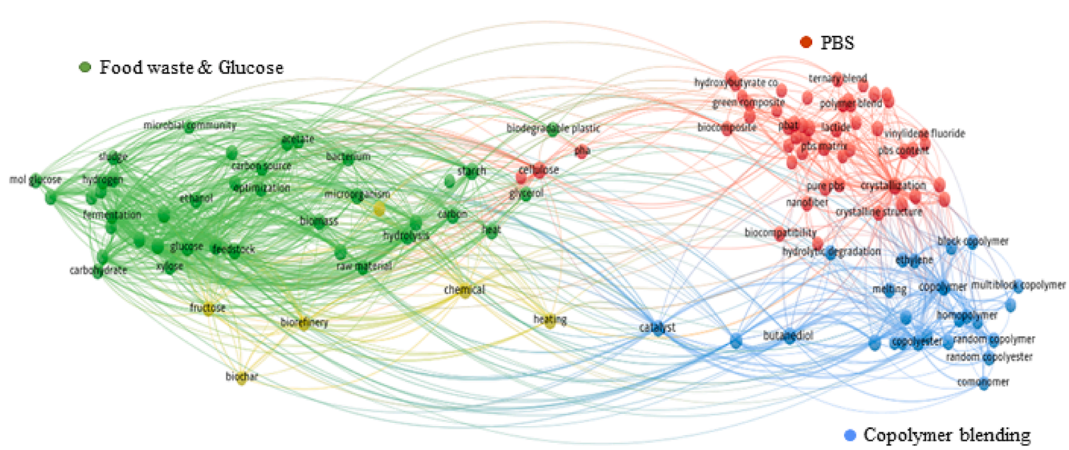

Fig. 1. Research network diagram of PBS production from food waste.

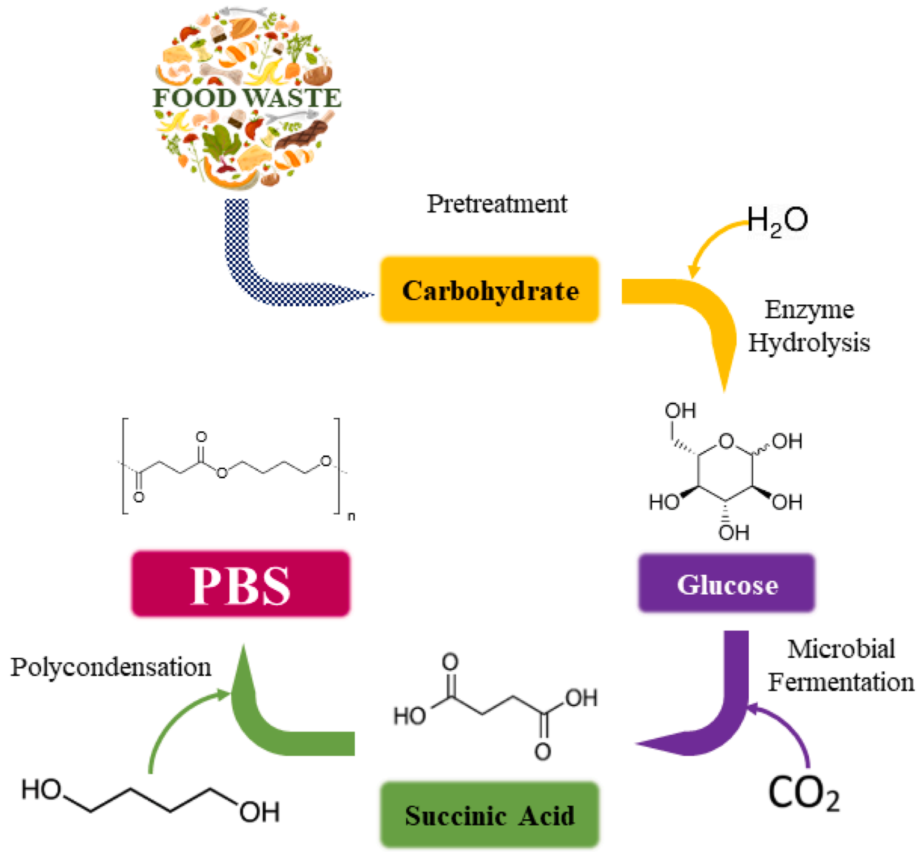

Fig. 2. Process pathway of PBS production from food waste.

dried at 80 °C to obtain pure PBS. 99 % of chloroform and methanol were recovered and reused (Tachibana et al., 2010).

2.2. Simulation and technical description

The simulation process was developed using SuperPro software. The plant processed 50 MT of FW per day. The FW's major composition is carbohydrates (58.4 %), protein (3.47 %), fat (4.8 %), and water (33.33 %) (Chan et al., 2018; Rajendran and Han, 2021). The overall process was developed with different unit operations such as a miller, reactor, centrifuge, fermenter, filter, evaporator, crystallizer, distillation unit, and drier. Based on the literature, the quantity of raw material input and capacity of each unit operation was determined. The process plant time parameters include a construction period of 12 months, a startup period of 4 months, and a project lifetime of 25 years. The discount rate is 10 % (Prasad and Singh, 2020) and the income tax rate is 25 %.

The simulation process flow was shown in Fig. 3. The FW transfers to bead billing with a belt conveyor to reduce the particle size. The FW paste is transferred to a spray dryer to remove the water molecules and reduce microbial contamination and odor. The dried FW was mixed with citrate buffer for 5 min and enzyme hydrolysis was carried out continuously with glucoamylase. The hydrolyzed mixture was transferred to a centrifuge to remove the biomass. The liquid is transferred to a drier to remove water and reach the glucose concentration of 1000 g/L. The seed culture of *A. succinogenes* and glucose solution were transferred to the fermenter containing the fermentation media. The mixture was transferred to the centrifuge and nanofiller to remove cell biomass and minerals, respectively. The evaporator was used to remove the water to achieve a succinic acid concentration of 250 g/L. The crystallization process was carried out to obtain succinic acid crystals, which were then filtered and washed with cooled deionized water to remove surface impurities before being dried using a tray drier. The pure succinic acid crystals were mixed with 1,4 butanediol, and titanium tetraisopropoxide was used as a catalyst. In this study, bio-based 1,4 butanediol was used (Satam et al., 2019). Nitrogen gas was continuously passed through this process to remove the water while a polycondensation process was carried out to obtain crude PBS. The crude PBS was dissolved in chloroform and precipitated with methanol. After filtering and drying the precipitate, pure PBS was obtained. The chloroform and methanol were recovered and reused. The simulation process flow is shown in Fig. 3.

2.3. Economic analysis

2.3.1. Economic factors

Before launching a large-scale plant, it is required to do an economic analysis, which analyzes the overall capital investment, operating costs, revenue, ROI, payback period, IRR, and NPV. The economic analysis is based on various factors such as raw materials, utilities, consumables, labor costs, equipment size, reaction conversion, and product selling price.(Naveenkumar and Baskar, 2020) The equipment size and cost were shown in Table S1. In this process, food waste is assumed to cost 0 $/kg and PBS is assumed to cost 4 $/kg. The 1,4 butanediol price is 1.82 $/kg (Satam et al., 2019). The solid waste from the hydrolysis process was considered revenue which is used as feedstock for biodiesel production and soil fertilizer, which is assumed to cost 0.45 $/kg (Pleissner et al., 2014), and recovered chloroform (0.5 $/kg) and methanol (0.24 $/kg) were considered revenue (Naveenkumar and Baskar, 2021; Rajendran and Han, 2021). The material unit cost and capital investment calculation were shown in Tables S2 and S3.

2.3.2. Minimum selling price and sensitivity analysis

The MSP of PBS was calculated, and the uncertainty was analyzed using Monte Carlo simulation. The uncertainty analysis was carried out based on different input factors such as chloroform price (0.25 to 0.75

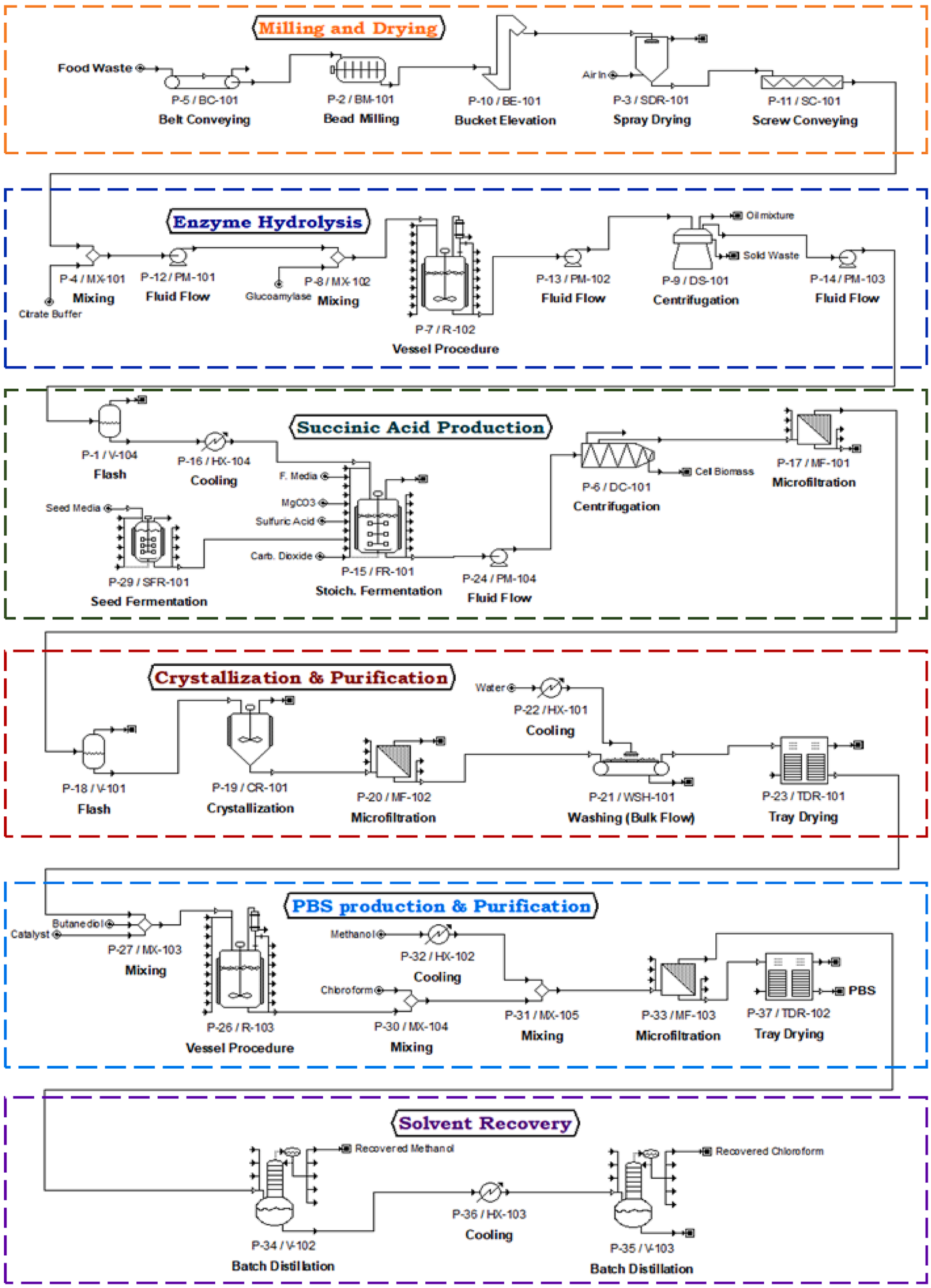

Fig. 3. Process flow of PBS production from food waste.

$/kg), methanol price (0.12 to 0.36), 1,4 butanediol price (0.91 to 2.73 $/kg), methanol and chloroform utilization ratio (±50 %). The uncertainty of MSP was analyzed using a pert distribution with 10,000 iterations. For uncertainty analysis, RISK software (Palisade) was used. The sensitivity analysis was carried out to investigate the determination of the economic feasibility of the process based on raw material cost, PBS selling price, income tax, and project lifetime.

2.4. *Lifecycle assessment*

The LCA was carried out according to ISO 14040/14044 standard procedure. The goal of this study was to investigate the environmental impacts of PBS production from food waste. The LCA was performed to find the GHG emission from producing 1 kg of PBS and the global warming potential stated in kg of CO_2-eq. The system boundary was denoted as well-to-pump, which only focused on the FW-to-PBS production process. In this study, 1,4 butanediol was directly used, which is produced from corn bioethanol and corn stover succinic acid (GREET)

(Satam et al., 2019). The life cycle impact assessment (LCIA) was carried out based on simulation process flow data, which includes materials and energies involved in the production of PBS from FW. The environmental impact (GHG emissions, fine particulate matter formation, photochemical ozone formation, and terrestrial acidification) of PBS production from FW was investigated using the GREET model. In this study, the default GREET database was used without any modifications. In the GREET model, the database was developed by Argonne National Laboratory with United States data. The factors were calculated based on ReCiPe 2016 (Midpoint level – Hierarchist) (Byun et al., 2021; Byun and Han, 2021, 2020).

3. Results and discussion

3.1. Techno-economic analysis

In this simulation process, 25015 kg of glucose was produced from 50 MT of FW, 37704 kg of succinic acid crystal was produced from 25015 kg of glucose, 53361 kg of PBS was produced from 37704 kg of succinic acid and 31633 kg of 1,4 butanediol. The purity of PBS was 97 %. The plant capital investment was 145,283,000 $, which included a total plant direct cost of 71,713,000 $, a total plant indirect cost of 43,028,000 $, a contractor's fee and a contingency of 17,211,000 $, a working capital of 12,672,000 $, and a startup cost of 660,000 $. Equipment cost plays a major role in capital investment, and all DFC parameter values were determined based on equipment cost. In this process, equipment costs were high due to large capacity requirements. At equipment cost, 71.97 % was covered by FR-101 (19.98 %), MF-103 (14.58 %), V-102 (30.28 %), and V-103 (7.13 %) (Fig. 4 & Table S1). The use of a large amount of solvent and recovery increases the overall equipment costs as well as the capital investment.

The plant operating cost was 156,933,000 $/yr, which included raw materials (130,652,000 $), labor (4,372,000 $), facility dependent (16,369,000 $), lab/QC/QA (656,000 $), consumables (318,000 $), utilities (4,367,000 $), and miscellaneous (200,000 $). Raw materials accounted for 83.25 % of operating costs, with methanol (40.78 %), chloroform (39.89 %), and butanediol (14.54 %) accounting for 95.21 % of raw material costs. The utilization of a large amount of solvent and butanediol increased the overall production cost. The facility dependent covers 10.43 %, which is correlated with the direct fixed cost. The utilities covered 2.78 %. The drying, fermentation, evaporation, polycondensation, and solvent recovery processes required a large amount of steam and cooling water. In this process, 1 kg production of PBS using 34.17 kg of $CaCl_2$ Brine, 101.98 kg of chilled water, 6.54 kg of steam (152 °C and 5 bar), 0.98 kg of steam (High P – 242 °C and 34 bar) and 1.09 kWh of electricity. Both flash evaporators *P*-1 and P-18 used a large amount of steam 2.37 and 2.31 kg/kg of PBS respectively. The overall process energy efficiency was 34.07 % (Fig. 5). The utilization of a large amount of steam in the separation and purification process has a major impact on energy efficiency.

3.2. Profitability analysis

The revenue was split into two major sections: main revenue and other revenue. In this study, PBS was considered the main revenue stream, residual solid biomass, recovered methanol and chloroform were considered other revenue streams. The solid biomass waste from the hydrolysis step was rich in protein, which is used as animal feed. The recovered solvents chloroform and methanol were used in the next cycle. The main annual revenue from PBS was 65,480,000 $, and other annual revenues from solid biomass, chloroform, and methanol were 105,391,000 $. The plant ROI, payback period, IRR, and NPV were 15.79 %, 6.33 years, 16.48 %, and 58,879,000 $, respectively. The cash flow analysis was shown in Table S4.

3.3. Sensitivity and uncertainty analysis of minimum selling price

In this simulation, the MSP of PBS was 3.5 $/kg. In the PBS production process, raw materials accounted for a sizable portion of operating costs. Sensitivity analysis of MSP shows how the major raw materials price and amount impact the MSP of PBS. In MSP sensitivity analysis, methanol usage, 1,4 butanediol price, and chloroform usage show the major impacts on the MSP of PBS (Fig. 6). The 50 % reduction in the price of 1,4 butanediol price reduced the MSP of PBS to 2.92 $/kg and a 50 % increment in the price of 1,4 butanediol increased the MSP of PBS to 4.09 $/kg. Methanol and chloroform usage do not only depend on their price, which is interlinked with whole economic factors (equipment size, utility, capital and operating cost, et). The uncertainty

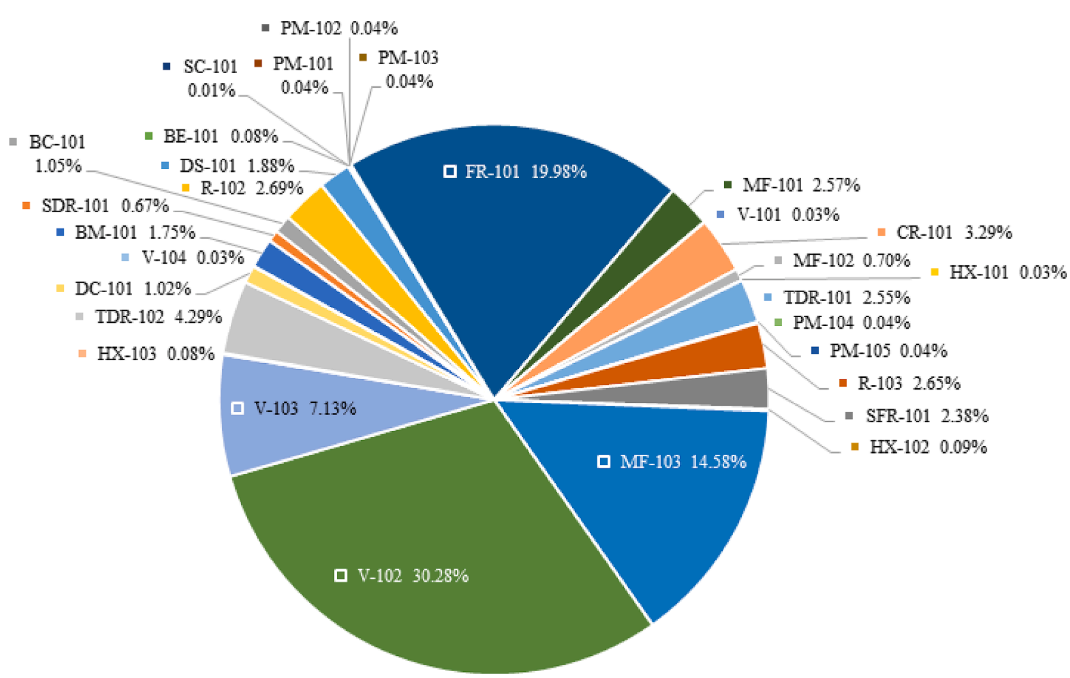

Fig. 4. Equipment cost of PBS production from FW.

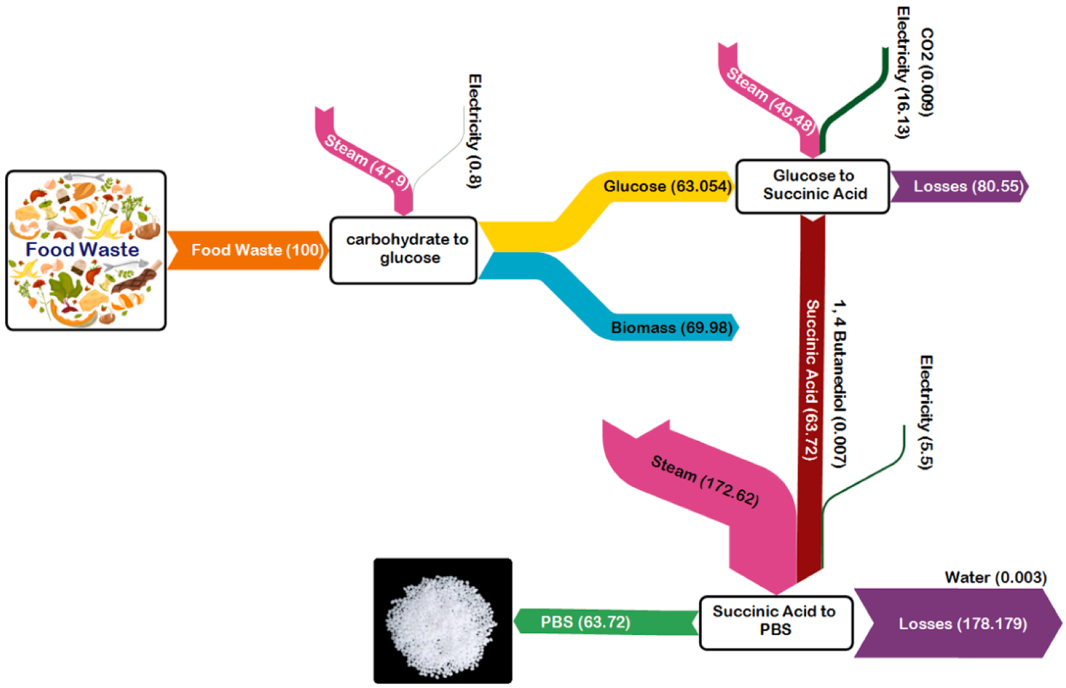

Fig. 5. Energy balance of FW to PBS production.

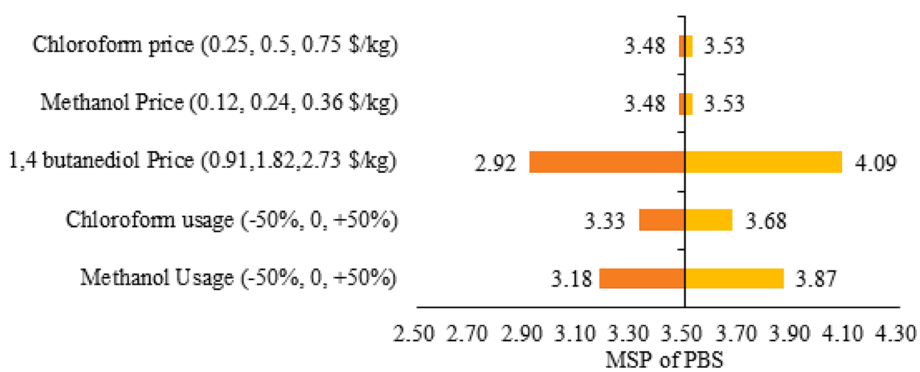

Fig. 6. Minimum selling price of PBS based on various inputs.

analysis of the MSP of PBS using pert distribution is shown in Fig. S1. The uncertainty of MSP input factors such as chloroform price (0.25 to 0.75 $/kg), methanol price (0.12 to 0.36 $/kg), 1,4 butanediol price (0.91 to 2.73 $/kg), chloroform usage (±50 % from basic value), and methanol usage (±50 % from basic value). The analysis was carried out individually for each factor. The 90 % confidence level of MSP of PBS was noted in the graph at 3.489 to 3.518 $/kg (Chloroform price), 3.488 to 3.518 $/kg (Methanol price), 3.141 to 3.866 $/kg (1,4 butanediol price), 3.398 to 3.613 $/kg (Chloroform usage), and 3.301 to 3.728 $/kg (Methanol price). The above results show that the low cost of 1,4 butanediol price and low solvent utilization in the purification stage is reducing the MSP of PBS. Besides materials and solvent usage, plant capacity also plays an important role in MSP. The plant capacity (FW) was varied by ± 50 % (25, 50, 75 MT/day) and the MSP of PBS varying 3.32 to 3.98 $/kg. The food waste composition is one of the major factors to determine the yield and MSP of PBS. Rajendran and Han, 2021 investigated poly (lactic acid) production from different FW compositions based in different countries such as China, India, Brazil, and the USA (Rajendran and Han, 2021). The four different country FW composition was applied in this study and the MSP of PBS was investigated (China – 8.6 $/kg, India – 6.5 $/kg, Brazil – 5.4 $/kg, USA – 5.7 $/kg). The carbohydrate was an important compound in this study, low carbohydrate FW reduce the PBS yield and increases the MSP of PBS. The market selling price of bio-based PBS is around 4 to 5.21 $/kg (Ioannidou et al., 2022; Ratshoshi et al., 2021). Ratshoshi et al. (2021) produced PLA and PBS from sugarcane molasses, bagasse and harvesting residues. The MSP of PBS produced from molasses is 2.98 $/kg (Ratshoshi et al., 2021). Ioannidou et al. (2021) reported the MSP of PBS was 1.37 $/kg, which was produced from sugar beet pulp with crude pectin extract as a by-product (Ioannidou et al., 2022). In this study, the author did not consider solvent separation and purification. In biopolymer production, purification accounts for a large amount of production costs, which increases the MSP of PBS. The MSP of PBS is determined by different affecters such as source, process type, reaction conversion, quality, and by-products. Different studies have proposed different sources, processes and product qualities, and the MSP of PBS varies based on these factors.

3.4. Sensitivity analysis of economic factors

Significant economic factors such as ROI, IRR, payback period, and NPV were investigated in sensitivity analysis for various material and solvent prices and usages such as PBS selling price (3 to 9 $/kg), chloroform (0.25 to 0.75 $/kg), methanol (0.12 to 0.36 $/kg), 1,4 butanediol

(0.91 to 2.73 \$/kg), chloroform usage (315872 ± 50 % kg), methanol usage (672808 ± 50 % kg), project lifetime (20 to 30 Yr) and income tax (15 to 35 %) (Fig. 7). In sensitivity analysis, PBS selling price and methanol usage show a major impact. The PBS retail price is not determined by the manufacturer; rather, it is determined by market demand and value. The use of methanol reduction improves the economic sustainability of the process.

3.5. Lifecycle assessment

GHG emissions, fine particulate matter formation, human health damage, terrestrial ecosystem damage, and terrestrial acidification were all quantified using LCA analysis based on LCI data from simulation (Table S5). The system boundary was shown in Fig. S2. The production of PBS from FW GHG emissions is around 5.88 kg CO_2-eq/kg of PBS (raw materials: 16.62 %, steam: 63.47 %, and electricity: 19.91 %) (Fig. 8) and GHG emission from food waste was reduced by this process (0.69 kg CO_2-eq/kg) and net GHG emission was 5.19 kg CO_2-eq/kg. Tecchio et al. (2016) reported the GHG emission of PBS production from maize starch was 6.35 kg CO_2-eq/kg of PBS, which was higher than in this study (Tecchio et al., 2016). Tecchio et al. (2016) used petroleum-based 1,4 butanediol, which increased GHG, emissions. The GHG emissions from this study are lower than those from fossil-based PBS (6.6 kg CO_2-eq/kg of PBS). In this process, a large amount of steam was used for biomass drying, polycondensation, and solvent separation and recovery. In GHG emission 43.74 % of the emission comes from the separation and purification (including solvent recovery) process. Ioannidou et al. (2022) reported the GWP of PBS from glucose syrup, corn stover and sugar beet

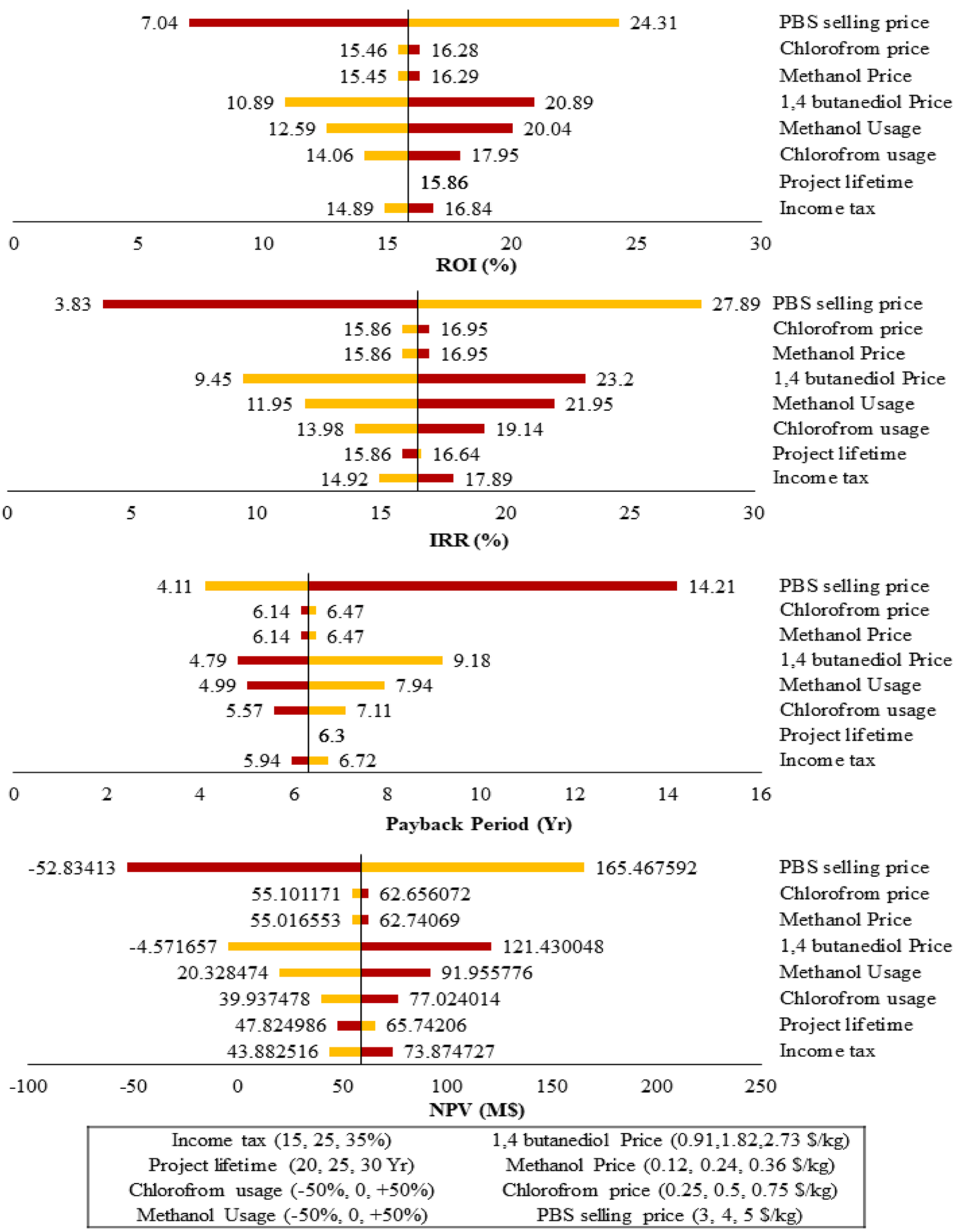

Fig. 7. Sensitivity analysis on economic factors ROI, IRR, Payback period, NPV.

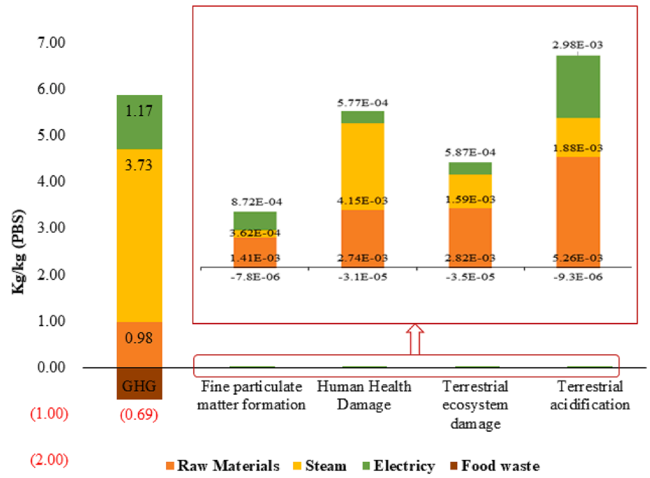

Fig. 8. Environmental impact analysis of PBS production from food waste.

pulp to be −0.24 kg CO_2-eq/kg, 0.25 kg CO_2-eq/kg and 2.35 kg CO_2-eq/kg respectively. The glucose syrup shows a negative value due to the biogenic CO_2 of corn cultivation (Ioannidou et al., 2022). The utilization of waste feedstock helps to reduce the environmental impact. The FPMF, HHD, TED, and TA of the process were 0.00263 kg PM2.5 eq/kg of PBS, 0.00743 kg NOx-eq/kg of PBS, 0.00497 kg NOx-eq/kg of PBS, and 0.0101 kg SO_2 eq/kg of PBS. The LCA impact is shown in Fig. 8. The drying process after hydrolysis and PBS separation and purification used a large amount of steam. The succinic acid fermentation process (fermenter) uses a large amount of electricity. Increasing the biomass loading ratio in hydrolysis and reducing the solvent utilization in PBS separation or alternative processes, and alternative steam and electricity sources will reduce the environmental impacts (Kang et al., 2021).

3.6. Critical review

According to the literature review, most hydrolysis processes use a low percentage of solids loading, which increases the equipment size and the amount of power and steam consumed. Due to the high solid loading, the glucose solution is highly concentrated and does not need the use of an evaporator (*P*-1/V-104) to remove the water to increase the glucose concentration. In most studies, PBS was separated and purified using a substantial amount of chloroform and methanol. It is not economically and environmentally feasible. High solvent use increases the equipment size, and the recovery process is difficult due to the use of a large volume of steam and process time. Low solvent use reduces the equipment size and cost (P-34/V-102 & P-35/V103) and utilities (Steam & cooling water). Advanced separation and purification processes with low solvent use improve the process's economic and environmental benefits.

4. Conclusion

This study investigated the economic and environmental impacts of producing PBS from FW based on published data. PBS had an MSP of 3.5 $/kg. The price of 1,4 butanediol and the amount of solvent used were important factors in determining the MSP of PBS. This procedure emits approximately 5.19 kg of CO_2-eq/kg of PBS. This study described the FW-based sustainable PBS production technique and investigated critical economic and environmental concerns. This study contributes to the future development of a more sustainable FW-PBS production process.

CRediT authorship contribution statement

Naveenkumar Rajendran: Conceptualization, Methodology, Investigation, Software, Resources, Visualization, Writing – original draft. **Jeehoon Han:** Conceptualization, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.wasman.2022.11.037.

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