TECHNO-ECONOMIC EVALUATION FOR INTEGRATED CULTIVATION OF COFFEE AND STINGLESS BEES IN WEST JAVA, INDONESIA

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ABSTRACT: Coffee is one of the major commodities that contributes to the economic development of rural areas in Indonesia. Regardless of its potential, low productivity of coffee still become one of the obstacles to raise prosperity of small farmers in Indonesia. A biorefinery concept may be applied to raise the economic value of coffee bioindustry. This study investigates techno-economic evaluation for integrated cultivation of coffee and stingless bees in Cibodas, Indonesia. Three scenarios were proposed and compared with each other in terms of gross profit margin. The first scenario considered the production of green coffee bean, whereas the second scenario included additional utilization of coffee pulp by-product to produce cascara. The third scenario integrates the production of green coffee bean and cascara with the cultivation of stingless bees, *Tetragonula laeviceps,* using Modular Tetragonula Hives to produce propolis and honey. A techno-economic evaluation was performed for the latter scenario because it had the highest value of gross profit margin (93%). The production cost of propolis extract from the proposed system was estimated at US$ 15.1/kg with a breakeven point of 1,817 kg. The proposed system also produces green coffee bean, cascara, and honey as the co-products. A sensitivity analysis was also carried out to determine the influence of production capacity, price of raw materials, and employees' salary on the production of propolis. The employees' salary has the strongest influence on the production cost of propolis followed by the price of raw materials and production capacity.

KEY WORDS: *Cascara, Green coffee bean, Propolis, Tetragonula laeviceps, and Production cost.*

1. INTRODUCTION

The worldwide demand of coffee is generally increasing every year with a global production of coffee has increased from 9.5 million ton in 2017/2018 to 10.2 million ton in 2018/2019 [1]. The total production of coffee in Indonesia in 2017/2018 is 716,000 ton and slightly decreased to 714,000 ton in 2018/2019 worth approximately US$ 2.1 trillion [2]. Such a decrease would affect the sustainability of coffee industry in Indonesia that consists of a large group of small-scale coffee producers with low economic capacity [3]. The productivity of coffee in Indonesia could be enhanced to meet the promising global market by applying a biorefinery concept that emphasizes on optimizing valorization of biomass, minimizing waste and maximizing profit to achieve sustainable development [4].

The application of a biorefinery concept in this study includes production of cascara (Spanish word means pulp) from the byproduct of coffee processing integrated with the cultivation of stingless bees in a small-scale coffee industry in Cibodas, West Java. Cascara is a beverage from dried coffee pulp rich with phenolic compounds as antioxidants [5]. Integrated cultivation of stingless bees (*Tetragonula laeviceps*) in a small-scale coffee plantation is particularly interesting because it may increase the coffee fruit-sets up to 16% by pollination and produce propolis and honey as high-value products [6].

Propolis is a brown sticky material from plant resin collected and further processed by stingless bees for construction of their hives [7]. Propolis contains bioactive compounds such as phenolic acids and their esters that act as antioxidants, antimicrobials, and anti-inflammatory [8]. Cultivation of stingless bees commonly uses bamboo hive or wooden box hive. One type of modified wooden box hive that can be used for the cultivation of stingless bees is Modular Tetragonula Hive (MOTIVE) that is equipped with a propolis frame to increase the productivity and quality of propolis [9].

Products from this integrated system have an interesting market analysis. Cascara as a new product on the market is now developing and starting to become famous after its price was significantly higher than the price of coffee beans in America. The demand for cascara reaches thousands of pounds per year with the price is between US$ 15/kg to US$ 33/kg. [10]. Propolis is a promising commodity for health and food industry due to its antibacterial and antioxidant properties [11] whereas honey produced by stingless bees contains high level of gluconic acid which acts as an antioxidant [12]. In 2017, the global production of propolis and honey were approximately 2,900 tons with a price of US$ 62/kg and 2.4 million ton with a price of US$ 48/kg, respectively [13-14].

Hence, this study was carried out to investigate the techno-economic aspects and potential of an integrated cultivation of stingless bees with a small-scale coffee industry in Cibodas, West Java. Three alternative scenarios were compared and assessed in terms of gross profit margin (GPM). The selected scenario was then studied further with more detailed process design and mass balance analysis for the whole production system. Techno-economical parameters including total production cost, total capital investment, profitability, and sensitivity analysis were conducted to evaluate the potential of the proposed integrated system.

2. TECHNO-ECONOMIC EVALUATION

2.1. Alternative technical scenarios

Three alternative scenarios were compared in this study. The first scenario (Scenario 1) considered an industry processing coffee fruits bought from the farmers to produce green coffee beans, the only product of the industry. The second scenario (Scenario 2) considered a coffee industry from the first scenario plus the valorization of coffee pulp to produce cascara. The third scenario (Scenario 3) integrated the production of green coffee beans and cascara with the cultivation of *Tetragonula laeviceps* using MOTIVEs to produce propolis and honey by collaborating with coffee farmers to build the required cultivation system for stingless bees in the coffee plantation and supply the coffee fruits as raw materials for the proposed system.

The selection of location for the coffee plantation was based on a target market analysis and simulated from a similar condition of a coffee plantation in Cibodas, West Java, Indonesia. The coffee plantation has an area of 25 hectares. It was assumed that there are 100 colonies of stingless bees per hectare in the coffee plantation which was based on an existing local cultivation system of stingless bees in a forest at Subang, West Java, Indonesia. Stingless bees could help to increase the conversion of flower-sets of coffee into fruit-sets by 16% [6]. Therefore, in Scenario 3, the productivity of coffee fruits was 16% higher than the other scenarios. The production of coffee fruits was estimated at 950 kg/year/hectare [15] whereas the productivity of honey and propolis were approximately 100 kg/year/hectare and 10.4 kg/year/hectare, respectively. The gross profit margin for each scenario was calculated using Eq. (1) [16]. The price of each product was estimated based on the local market and online sources (US$ 1 equals to IDR 13,760).

$$Gross\ Profit\ Margin\ (\%) = (Revenue - Cost\ of\ Goods\ Sold)/Revenue\ x\ 100\% \quad (1)$$

2.2 Economic analysis

The detailed production system was designed based on the scenario that has the highest value of GPM, including all process conditions, equipment, and utilities. Furthermore, the mass balance was analyzed for all stages of the production process for each product. The economic analysis involves the calculation of total capital investment (TCI), total production cost (TPC), and profitability of the proposed system. A sensitivity analysis was also carried out to determine the influence of production capacity, price of raw materials, and employees' salary on the production of propolis. The sensitivity bounds from 50 to 150% of the base case.

Total capital investment was determined by calculating fixed capital investment (FCI) and working capital investment (WCI). FCI consists of direct cost (DC) and indirect cost (IC). DC consists of total equipment, control and instrumentation, electrical distribution system, land, and construction whereas IC cost consists of technical and supervision and unexpected cost. Total Production Cost (TPC) was determined by calculating variable cost (VC) and fixed cost (FC). VC consists of material, utility, employee salary, profit-sharing for cooperation, equipment maintenance, and administration. FC includes depreciation of the FCI.

Profitability analysis was determined by calculating the economic parameters such as net profit value (NPV) after 10 years, break-even point, internal rate of return (IRR) compared to a minimum acceptable rate of return (MARR), and payback period. MARR was set at 15%. NPV, IRR, and break-even point were calculated using Microsoft Excel™ function. The payback period was calculated using Eq. (2).

$$Payback\ Period = Y + C/CF_y \quad (2)$$

Where, *Y* is years before full recovery, *C* is unrecovered cost at the start of the year and CF_y is cash flow during the year

3. RESULTS AND DISCUSSION

3.1. Alternative technical scenarios

In the first scenario, the only product sold to the market was green coffee beans. The income that would be generated from the sales of 23.8 tons of green beans coffee per year was US$ 36,744 with a calculated GPM of 62%. In the second scenario, an additional income would be generated from the sales of 3.69 ton of cascara per year. The calculated GPM was 77% with an income of US$ 59,538. The second alternative applies a biorefinery concept by optimizing biomass resources from the coffee fruits and reducing the coffee pulp byproduct that may causes environmental pollution [5].

In the third scenario, the processing of coffee-based products was the same as in the second scenario, but the coffee plantation was integrated with the cultivation of stingless bees. The presence of stingless bees may increase the success rate of pollination of coffee while providing additional bioproducts particularly propolis and honey. Pollination with stingless bees may increase the formation of coffee fruits up to 16% [6] and it was assumed that the amount of green coffee beans and cascara would increase by the same percentage. Production of propolis and honey by the stingless bees would increase the income of this scenario up to US$ 228,833 per year with a GPM value of 93%. From a social perspective, coffee farmers may increase their income through a profit-sharing scheme (set at 45% for this study) from the sales of propolis and honey. Profit-sharing may create another sustainable source of income for coffee farmers besides the annual income from the sales of coffee fruits.

3.2. Process description and mass balance analysis

The production system for Scenario 3 (Fig. 1) was planned to be built near a coffee plantation in Cibodas, West Java with a total area of approximately 25 hectares and equipped with 2,500 MOTIVEs containing colonies of stingless bees. MOTIVEs were placed in the coffee plantation owned by local coffee farmers via a cooperation scheme to produce propolis and honey. The proposed system involves 4 main production processes; production of green coffee bean, production of cascara, production of propolis, and production of honey. The process flow diagram and mass balance for the proposed system are shown in Fig. 1.

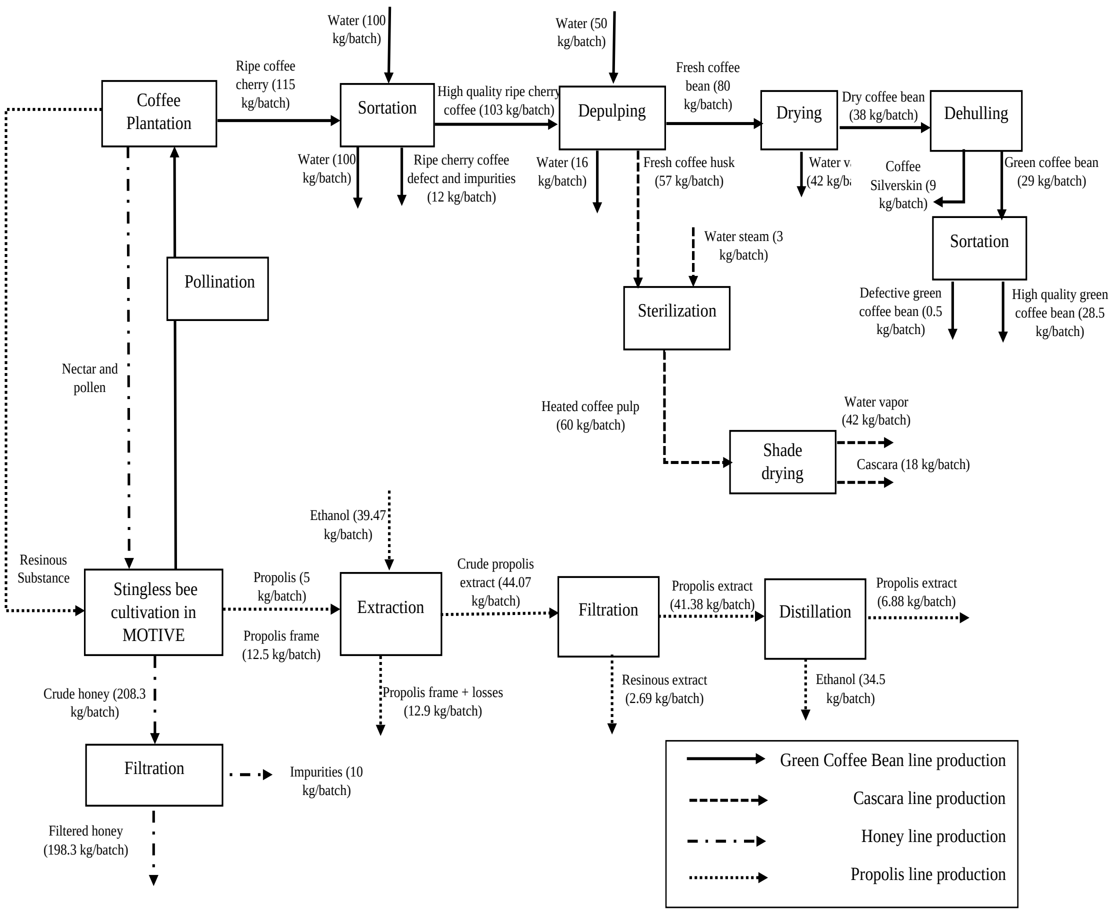

Fig. 1. Block flow diagram and mass balance for the integrated cultivation of coffee and stingless bees.

3.2.1 Production of green coffee bean

The production scale was set at an input of 115 kg/batch of ripe coffee fruits and set to be operating for 8 months. Each batch had an operating time of 1 week including the drying time. It was assumed that 28.5 kg of green coffee beans can be produced per batch. Based on this assumption, the annual green coffee beans production was 6.9 ton. Ripe coffee fruits were collected by the farmers during the harvesting season. Immediately after harvesting, the fruits were soaked to separate only the ripe fruits. Then, the ripe fruits were peeled using a pulper machine to produce green coffee beans. After that, all the coffee beans were dried in a screen house until the beans reached a moisture content of 12% and the mucilage had hardened. The green coffee beans were then peeled using a huller machine to eliminate the beans' cuticle. Finally, the free-cuticle green coffee beans were sorted using a sorting machine to separate defected beans from the final product of green coffee beans. The remaining pulp produced during the processing of green coffee beans would be further processed to produce cascara.

3.2.2 Production of cascara

The production scale of cascara was set at an input of 115 kg/batch of coffee pulps for a period of 8 months. Similar to the production of green coffee beans, each batch had an operating time of 1 week with an estimated productivity of 18 kg of cascara per batch which resulted in an annual cascara production of 5.9 ton. Initially, coffee pulps were steamed for 3-5 minutes for sterilization from fungi. The pulps were shade-dried in a screen house until a moisture content of 10-11.5%.

3.2.3 Production of propolis

The production scale of propolis was set at an input of 2 g per hive per week of crude propolis. The coffee plantation could accommodate 2,500 colonies of stingless bees cultivated using MOTIVEs. Therefore, in this scenario, 5 kg of crude propolis would be produced weekly and set to be operating for 52 weeks. It was assumed that the annual production of ethanol propolis extract was 0.35 ton. Propolis frames containing crude propolis in MOTIVEs were collected by farmers throughout the year. The harvesting of propolis frames was carried out by replacing the filled propolis frame with a new frame containing empty holes to be refilled with new propolis. The crude propolis was then extracted using a maceration technique with ethanol at room temperature (27°C) for 24 hours followed by filtration to remove the resinous extract.

3.2.4 Production of honey

The production scale of honey was set at 208 kg honey/hive/month and set to be operating for 52 weeks. It was assumed that the annual production of honey was 2.5 ton. Honey was collected from the honey pots inside the MOTIVEs using a honey pump by farmers throughout the year. The crude honey was processed further using a filtration unit to remove any impurities.

3.3. Economic analysis

Estimation of TCI and TPC of propolis are based on a cost estimation procedure reported in the literature [4] and the results are shown in Table 1-2. Several parameters such as research, financing, marketing cost, and overhead were excluded from the estimation of TPC. Propolis extract was chosen as the major product in this techno-economic analysis due to the high price in the market compared to green coffee beans, cascara, and honey as the co-products of the integrated system. The TCI was estimated at US$ 113,613 which comprises of US$ 90,890 for FCI and US$ 22,770 for WCI. The cost of total equipment

(US$ 28,520) and acquisition of land (US$ 16,460) were approximately 25% and 14% of the entire TCI, respectively.

Table 1: Estimated total capital investment for integrated cultivation of coffee and stingless bees in Cibodas, Indonesia

Item	Cost (US$)
Direct Cost (DC)	
Total Equipment (E)	28,520
Control and instrumentation	1,820
Electrical Distribution System (0.1 E)	2,870
Equipment Installation (0.45 E)	12,920
Land	16,460
Construction (0.05 FCI)	4,560
Total DC	67,150
Indirect Cost (IC)	
Technical and Supervision (0.15 DC)	10,100
Unexpected Cost (0.15 FCI)	13,640
Total IC	23,740
Fixed Capital Investment	
FCI = DC + IC	90,890
Working Capital Investment (0.2 TCI) (WCI)	22,770
Total Capital Investment	
TCI = WCI + FCI	113,613

From Table 2, the largest contribution of TPC was employees’ salary (US$ 72,510) which made up to almost 40% of the sub-total production cost followed by profit-sharing expenses (45%) with the farmers for the sales of propolis and honey. The sub-total production cost of propolis extract (354 kg/year) from the integrated cultivation of coffee and stingless bees was approximately US$ 181,700. This cost can be further reduced by selling the green coffee beans, cascara, and honey as co-products which resulted in a lower production cost of US$ 5,370 for producing 354 kg of propolis extract per year. The production cost of propolis extract estimated in this study was US$ 15.1/kg while the market price for similar product quality was approximately US$ 200/kg. As a result, the integrated cultivation of coffee and stingless bees is promising to reduce the overall production cost and increase the income of farmers.

Fig. 2 shows the cumulative cash flow of the proposed integrated cultivation of coffee and stingless bees in Cibodas, Indonesia. The proposed system is expected to reach a payback period of approximately 4 years of operation with a break-even point of 1,817 kg of propolis extract (Fig. 3). The net present value of the proposed system after 10 years is US$ 216,675 with an internal rate of return of 28.5%. A sensitivity analysis was also carried out to determine how the changes of the input variables affect the TPC. The results of sensitivity analysis are shown in Fig. 4.

The employees' salary has a very strong influence on the TPC followed by the price of raw materials and production capacity. A 50% increase in employees' salary tremendously increased the production cost from US$ 15.1/kg to US$ 119/kg. Therefore, the production system must carefully maintain its number of employees as well as their salary. The increase in labor efficiency may reduce the overall production cost due to almost all operational cost could be covered from the sales of the co-product if the employees’ salary was reduced by 50%.

Table 2: Estimated total production cost of propolis produced from an integrated cultivation of coffee and stingless bees in Cibodas, Indonesia

Item	Cost (US$)
Variable Cost (VC)	
Raw Material	16,780
Utility System	12,800
Employees' Salary per year	72,510
Profit Sharing	65,930
Equipment Maintenance	910
Administration Cost	3,660
Total	172,590
Fixed Cost (FC)	
Depreciation Cost (0.1 FCI)	9,110
Total	9,110
TPC = VC+FC	181,673
Co-product Credit (CC)	
Green Coffee Bean	63,100
Cascara	36,690
Honey	76,540
Total	176,330
TPC – CC	5,343
TPC-CC/kg propolis	15.1

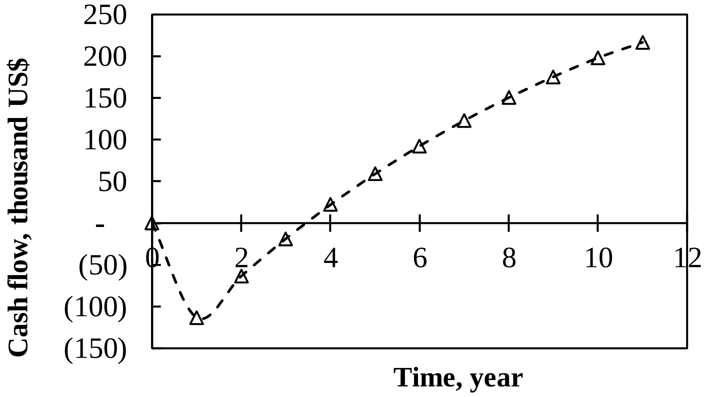

Fig. 2. Cumulative cash flow for integrated cultivation of coffee and stingless bees in Cibodas, Indonesia.

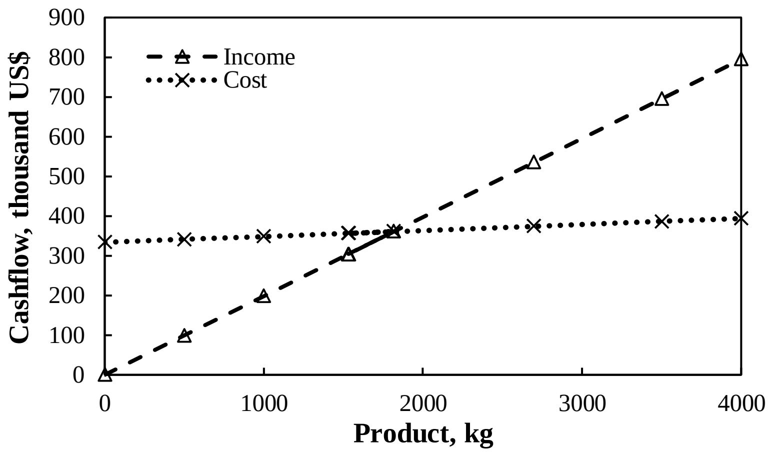

Fig. 3. Break-even point analysis for integrated cultivation of coffee and stingless bees in Cibodas, Indonesia.

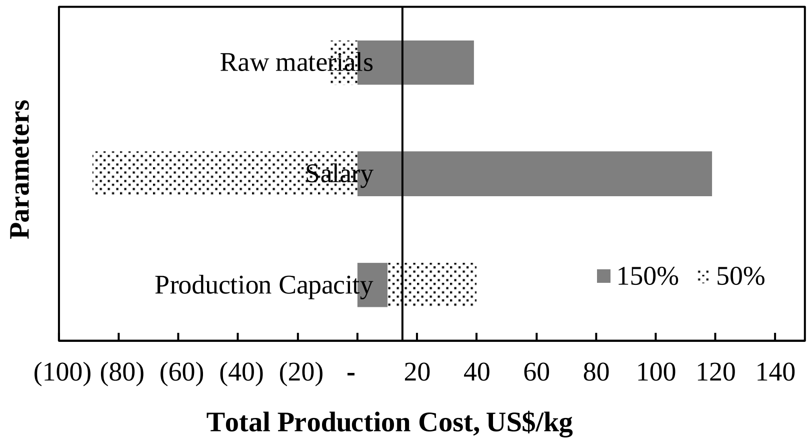

Fig. 4. Sensitivity analysis for integrated cultivation of coffee and stingless bees in Cibodas, Indonesia.

4. CONCLUSION

The gross profit margin for an integrated cultivation of coffee and stingless bees to produce green coffee bean, cascara, propolis, and honey were calculated. The value of the gross profit margin (93%) was higher compared to the conventional cultivation of coffee to only produce green coffee bean. The production cost of propolis extract based on the proposed system was estimated to be US$ 15.1/kg with a breakeven point of 1,817 kg. The proposed system also produced green coffee bean, cascara, and honey as the co-products. The sensitivity analysis demonstrated that employees' salary has a very strong influence on the production cost of propolis followed by the price of raw materials and production capacity.

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