

Increasing value in robusta coffee processing through biogas utilization: An Indonesia case study

Lintje Hutahaean^{1,2*} , Ernan Rustiadi³ , Anas Miftah Fauzi⁴ , Rita Nurmalina⁵ , Rubiyo⁶ 

¹Study Program Doctoral for Natural Resource and Environmental Management, IPB University, Bogor, West Java, Indonesia

²Research Center for Behavioral and Circular Economics, National Research and Innovation Agency, Jakarta, Indonesia

³Department of Regional Planning Sciences, Faculty of Agriculture, IPB University, Bogor, West Java, Indonesia

⁴Department of Agroindustrial Technology, Faculty of Agricultural Engineering and Technology, Bogor, West Java, Indonesia

⁵Department of Agribusiness, Faculty of Economic and Management, Bogor, West Java, Indonesia

⁶Research Center for Estate Crops, National Research and Innovation Agency, Bogor, West Java, Indonesia

*Corresponding author: lintjehutahaean@gmail.com

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ABSTRACT

Robusta coffee is a leading commodity in Indonesia that accounts for 86% of total coffee exports in Indonesia. In addition, the issue of energy scarcity and the push for implementing a sustainable industrial system pose new challenges for Indonesia's coffee industry to transform into a bio-industrial agricultural system. Starting from these issues, this study aims to assess the added value and impact on business profits from robusta coffee processing using biogas and LPG. The study was conducted in a bioindustrial farming system centre based on coffee and dairy cattle integration in Boyolali District, Central Java, Indonesia, from December 2023 to February 2024. The Hayami method was used in analyzing value-added. The analysis findings show that value-added and profit in the biogas-fueled industry have higher values than those in the LPG-fueled industry. Support is needed to develop biogas as an alternative energy and knowledge and training in processing waste as raw material for biogas. It is hoped that this research can improve the welfare of farmers and business actors, help implement sustainable agriculture, and become a model for other regions that want to create bioenergy using local resources.

Key words: Biogas; robusta coffee; added value; hayami.

1 INTRODUCTION

Coffee is a plantation commodity that produces various high-value-added products, which can spur economic growth and improve people's welfare. The coffee commodity ranks fifth as the largest export-contributing commodity and has high economic value in Indonesia (Ministry of Agriculture, 2020). Robusta coffee is one of Indonesia's leading commodities and an essential source of income for farmers and industry players. Robusta coffee accounts for 86% of total coffee exports in Indonesia (BPS-Statistic Indonesia, 2023). The development of Indonesian coffee commodities should focus on improving production quality, optimizing processing techniques, enhancing branding and marketing strategies, and strengthening supply chain efficiency. These efforts aim to increase their selling value in domestic and international trade, positioning coffee as a significant contributor to the Indonesian economy. Through product diversification, value-added product development transforms primary products into competitively processed.

In the context of sustainability, bioindustrial agricultural systems have the perspective of creating intensive ecosystem-based agricultural systems that aim to maximize income and added value through ecological engineering and crop-livestock integration patterns, processing agricultural products to multiply the variety of products and added value of agricultural products and reduce waste; and integrating agricultural-biorefinery businesses to reduce energy dependence, use

of external inputs, be environmentally friendly, and reduce nutrient leakage from agroecosystems on an economic scale (Basit et al., 2015). This system not only reduces dependence on fossil energy but also increases production efficiency, reduces waste, and supports environmental sustainability.

Diversification of value added products is a prerequisite for sustainability in the long-term economic dimension (Munasinghe, 2019). The need for value-added diversification in the coffee industry stems from the dual goals of enhancing product competitiveness and promoting sustainable practices. By aligning value-added diversification with sustainability principles, the coffee industry can cater to consumer preferences, reduce waste through efficient resource utilization, and support long-term growth in domestic and international markets. Value-added products are created by adding product benefits through processing, innovation, diversification, and treatment of inputs in the production process (Coltrain et al., 2000; Anderson; Hanselka, 2009). The challenges of market demand for environmentally friendly products, production efficiency and sustainability are the main focus in producing competitive products. Environmentally friendly coffee production can be done with input treatment in the production process. Using organic fertilizer inputs in the cultivation process and biogas energy in the ground coffee processing process can generate added value with the efficiency of production costs and the quality of ground coffee products (Rahmah et al., 2023).

Value-added based in the coffee industry includes using organic material inputs in the coffee bean production process (Syofya, 2023), developing downstream end products (Lestari; Winarto; Atasa, 2023; Prathita; Purwatiningsih, 2023; Rizkiawan; Tjahaja; Laily, 2023), enhancing ground coffee processing techniques (Nasution et al., 2020; Dewi; Putra; Astama, 2022), diversifying products based on flavor and variant (Fadli; Tambarta Kembaren; Sinta, 2021; Ting; Chen; Chen, 2024; Sulaiman; Marsyanda; Erika, 2024), and expanding the market chain for ground coffee (Karyani; Djuwendah; Supriyadi, 2018). However, more research is needed on the added value of using energy as a production input in coffee processing. Research mainly concentrates on traditional elements such as production efficiency or environmental impact. However, there has yet to be a thorough analysis of how energy sources such as biogas or LPG directly affect the economic value of the coffee industry. As energy inputs significantly affect production costs, product quality, and market competitiveness, it is crucial to understand these changes. This research can provide important information on optimizing energy use, reducing costs, and increasing the profitability of coffee processing. Ultimately, this will benefit coffee farmers and processors and support continued progress in the industry. Therefore, it is essential to analyze further the added value generated by using energy in the coffee processing process.

Added value with production cost efficiency in ground coffee processing can be achieved by utilizing renewable energy sources, such as biogas, as an alternative energy source in the production process (Ministry of Agriculture, 2022a). An alternative energy source, biogas, is a gas created when microbes break down organic materials through anaerobic processes. Decomposing organic matter will produce biogas consisting of CO₂ and methane. Biogas can be produced from various biomass such as animal manure, agricultural, food, and industrial waste products. A 450 kg dairy cow can produce approximately 25 kg of manure daily. 1 kg of cow dung can produce 0.0023-0.004 m³ of biogas, or 217.4 kg of cow dung is equivalent to 3 kg of Liquefied Petroleum Gas (LPG) (Karki et al., 2005). Research from Malaysia highlight cow dung waste is a potential biogas feedstock, with a higher gas conversion rate than other livestock manure such as buffalo, goats and sheep (Abdeshahian et al., 2016).

Over the past decade (2013–2023), Indonesia's dairy cattle population has grown by 0.27% annually, with Central Java contributing 20.78% of the total national dairy cattle population (Ministry of Agriculture, 2022b). Boyolali district, recognized the centre of the dairy cattle production hub (Ministry of Agriculture, 2018), contributed 49.33% to the dairy cattle population Central Java Province (BPS-Statistic Central Java Province, 2022). The growth in livestock number also increase manure production which includes solids, urine, and gas that can impact livestock product quality and the

environment. However, the livestock waste can be further processed into biogas, providing an alternative energy source for ground coffee processing and promoting sustainable energy use in agricultural production.

Biogas offers an energy-saving solution and is expected to increase the added value of ground robusta coffee processing by reducing production costs and minimizing environmental impact. On the other hand, conventional methods that rely on fossil fuels, such as LPG, tend to result in higher energy expenses and greater environmental impacts (Yuliati; Susilo, 2019; Haryanto, 2021). Given these considerations, this study aims to compare the added value using biogas versus LPG in robusta coffee processing and to assess the impact on the profit of business actors.

2 MATERIAL AND METHODS

2.1 Location, Time and Respondents

The research location was determined purposively in the centre of the bioindustrial farming system based on the integration of coffee plants and dairy cattle in Boyolali Regency, Central Java, Indonesia. The research was conducted from December 2023 to February 2024. Respondents consisted of 2 groups: 1) Business owners using biogas energy, with the brand name “Kopi Ngemplak” in Ampel sub-district, Boyolali Regency; 2) Businesses using LPG energy with the trademark “Omah Kopi”, in Ampel sub-district and “Kopi Sampetan” in Gladagsari sub-district, Boyolali regency, Central Java, Indonesia. An overview of the research location can be seen in Figure 1.

The selection of respondents in this study was based on predetermined characteristics, such as experience, expertise, and the use of specialized technology in the processing process. At the designated research location, only one business is a fostered industry from the Ministry of Agriculture, which applies the bioindustry pattern in the ground coffee industry by utilizing energy from biogas in the processing process. Therefore, Group 1 consisted of only one respondent, as the business had unique characteristics not shared by other businesses in the location. Meanwhile, Group 2 consisted of two respondents representing LPG-fueled coffee processing businesses. The number of respondents was adjusted to the presence of two LPG-fueled coffee processing industries in the research location. This grouping was done to reflect actual conditions and enable relevant comparative analysis between the use of biogas and LPG in the coffee processing process.

2.2 Data Collection Technique

Primary data were obtained by interviewing business respondents using a structured questionnaire. Data and information include the production process, inputs, outputs, costs, and income in the calculation of the value-added of ground coffee.

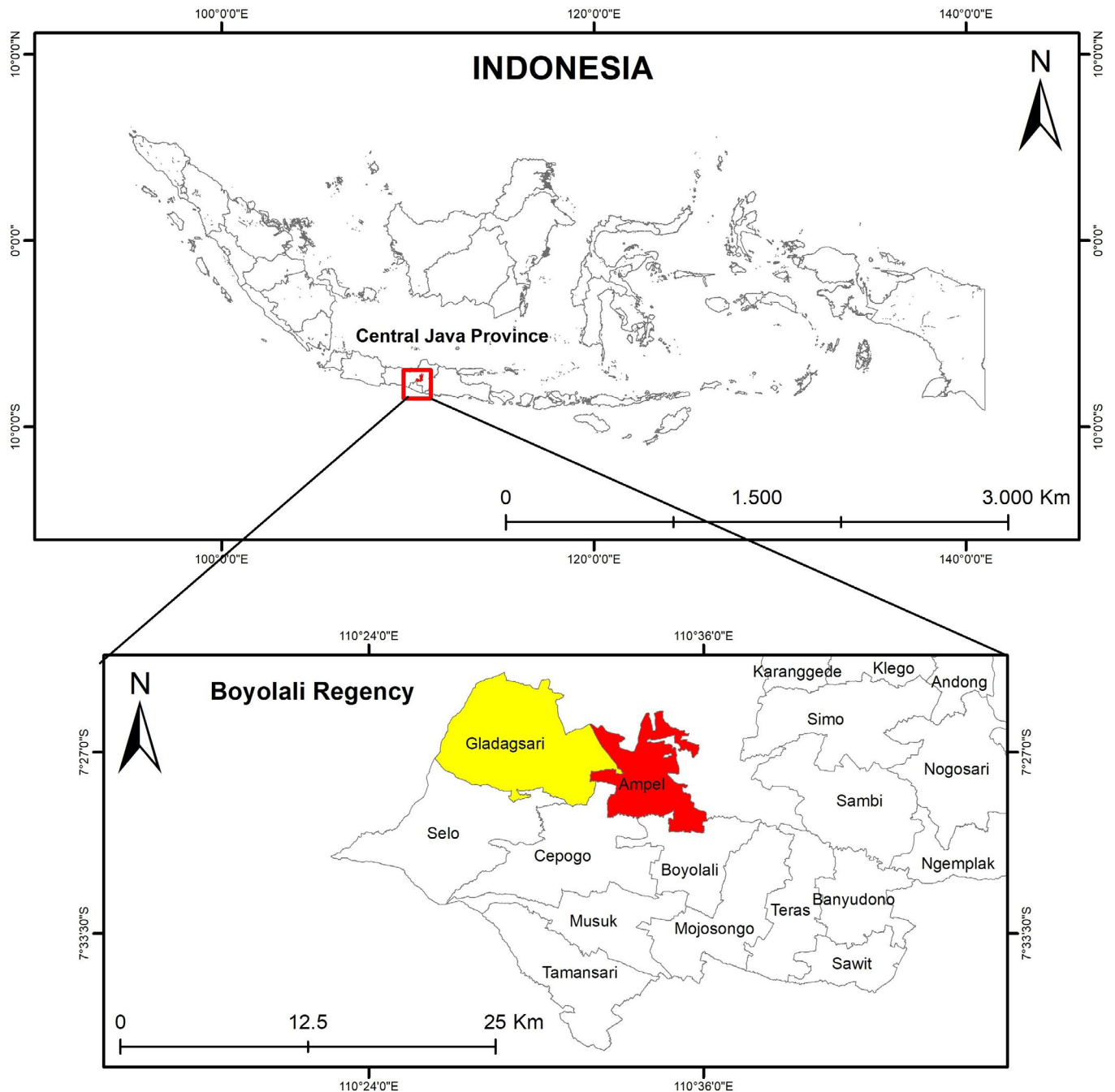


Figure 1: Research Location.

2.3 Data analysis method

The Hayami method compares the added value of processing ground robusta coffee by using biogas versus LPG energy. The analysis's will identify the benefits using biogas as an energy source focusing on its impact on added value, input costs, and business profitability .

Added value was derived from transforming of primary products into processed products. The value-added analysis involves three parts, namely inputs and prices, revenues

and profits, and services from production factors (Fudjaja et al., 2023). According to (Hayami et al., 1987), there are two methods of calculating added value: added value in the processing process and added value in marketing. Technical factors influence the inputs used in production and the volume of raw materials, while market factors encompass final product prices, raw material costs, and other input values. Table 1 provides an overview of the procedure for calculating added value.

Table 1: Procedure for Calculation of Value Added by Hayami Method.

Variables		Formula	Unit
Output, Input, Price			
1	Total output	a	Kg/production
2	Raw material input	b	Kg/production
3	Labor	c	hour/production
4	Conversion factor (1/2)	$d = a/b$	persen
5	Labor coefficient (3/2)	$e = c/b$	hour/kg
6	Output price	f	Rp/kg
7	Average labor wage	g	Rp/hour
Revenue and Profit (Rp/raw material)			
8	Raw material price	h	Rp/kg
9	Other input contribution	i	Rp/kg
10	Output value	$j = d \times f$	Rp/kg
11	a. Value added	$k = j - h - i$	Rp/kg
	b. Value-added ratio (11a/10)	$l (\%) = (k/j) \times 100\%$	persen
12	a. Labor income	$m = e \times g$	Rp/kg
	b. Labor share (%) (11a/12a)	$n (\%) = (m/k) \times 100\%$	persen
13	a. Profit	$o = k - m$	Rp/kg
	b. Provit level (13a/10)	$p(\%) = (o/j) \times 100\%$	persen
Reply to Factor of Production			
14	a. Margin	$q = j - h$	Rp/kg
	b. Labor (12a/14a)	$r(\%) = (m/q) \times 100\%$	persen
	c. Capital (Other input contributions) (9/14a)	$s (\%) = (i/q) \times 100\%$	persen
	d. Processing advantages (13a/14a)	$t (\%) = (o/q) \times 100\%$	persen

A descriptive approach was used to assess the impact of biogas utilization on business profits by looking at the contribution of biogas energy to production costs.

3 RESULT

3.1 Overview of the ground coffee processing industry

3.1.1 Characteristic Respondent

In this study, respondents consisted of 3 groups of ground coffee processing industry players, namely Ngemplak Coffee, Omah Kopi, and Sampetan Coffee. Kopi Ngemplak operates as a bioindustry-oriented business, utilizing biogas as the primary energy source for coffee processing. This approach is in line with sustainable practices and emphasizes the integration of environmentally friendly technologies. Ngemplak Coffee business has been running since 2015 with an initial capital of IDR 226,699,500 and 2 family workers. And two family workers. In addition, this business is fostered under a Ministry of Agriculture program that aims to implement and serve as a role model for bioindustrial practices in coffee processing industries.

In contrast, Omah Kopi and Kopi Sampetan represent more conventional processing models, relying on LPG as the primary energy source. The Omah Kopi business was established in 2016 with five workers, while Kopi Sampetan was established in 2022 with three workers. On the other hand, Omah Kopi and Kopi Sampetan operate independently, with an initial business capital of IDR 227,108,000. These differences highlight different operational models, which provide a valuable basis for analyzing each energy source's added value and sustainability impacts in coffee processing. Table 2 provides an overview of the different characteristics of each respondent.

3.1.2 Robusta Ground Coffee Processing Performance

Coffee beans that will be processed into ground coffee have undergone a series of preparation processes, including washing, drying, pulping, and hulling to obtain green bean coffee. Furthermore, green bean coffee will go through further stages to become ground coffee. The process that must be passed is as follows:

Table 2: Characteristic Respondent.

	Kopi Ngemplak	Omah Kopi	Kopi Sampetan
Capital	IDR 226.699.500	IDR 227.108.000	IDR 227.108.000
Education	Senior high school	Senior high school	Senior high school
Labour	2	5	3
Year of business establishment	2015	2016	2022
Source of capital	Own capital and assistance from the ministry of agriculture program	Own capital and assistance from the local government program	Own capital and assistance from the local government program

1. Sorting

Sorting is a meticulous process, where each coffee bean is carefully selected according to the quality standards set by the business unit. The average sorting process, carried out by ground coffee processing businesses in the research location, is a testament to the dedication and precision of the industry. It's done manually with traditional sieves, ensuring that only the finest coffee beans make it through. This process is crucial in selecting quality coffee beans and removing any impurities from the green bean coffee, guaranteeing a high-quality end product.

2. Roasting

Green coffee beans from the sorting process are roasted using a roasting machine. The roasting process requires an electrical energy source and LPG or biogas fuel obtained from the biogas installation by utilizing cow dung.

3. Milling

The roasted coffee is then ground with a grinder machine to produce ground coffee.

4. Packaging

The packaging process uses a sealer machine, and the ground coffee products are packaged in 100- and 250-gram packages. The sealer machine will help maintain the quality and flavour of the ground coffee as the packaging becomes impermeable to the outside air. An overview of the flow of the ground coffee processing process using LPG and Biogas fuel gas can be seen in Figure 2.

3.2 Value Added of Ground Coffee

The integration system of coffee plants and dairy cattle has been widely applied in the research location. This system utilizes livestock manure waste as raw material in producing biogas (Obileke et al., 2021; Bathaei; Streimikiene, 2023). Biogas is used as an alternative energy for the processing of ground coffee production and household fuel needs. This aligns with the principle of sustainability, where local resources are optimally utilized to increase efficiency and reduce dependence on external energy sources (Singh et al., 2023). The results of the comparative analysis of added value between industries can be seen in Table 3.

The coffee processing industries in the study locations operate at different business scales. Large-scale industries use

LPG as fuel in the roasting process of ground coffee, while small-scale industries use biogas because it is integrated with dairy farming. Based on Table 2, a biogas-fueled business with a production input of 25 kg of green beans will produce an output of 12 kg of ground coffee. In comparison, an LPG-fueled industry can produce an input of 42.9 kg of green beans to produce an output of 24 kg of ground coffee. The production results show the value of the conversion factor obtained by each industry. The conversion factor is a ratio that compares the production amount with the raw materials used. The roasting process with LPG fuel has a conversion factor of 0.56. In contrast, the process with biogas fuel will produce 0.48 kg of ground coffee, which means that every 1 kg of raw material processed by the LPG-fueled industry will produce 0.56 kg of ground coffee and 0.48 kg in the process with biogas fuel.

The use of biogas fuel in the coffee processing industry has a lower labour coefficient value, which is 0.48 hours/kg compared to 0.71 hours/kg with LPG gas. The labour coefficient is calculated as the ratio between the number of working hours and raw materials used in one production cycle. In addition to providing a small labour coefficient value, biogas fuel also provides a lower input contribution of Rp6,000 compared to the industry with LPG gas fuel with other input contributions of Rp27,499. The components accounted for in other input contributions include fuel, electricity, packaging, and milling costs. The low contribution of other inputs will contribute to an increase in the value added. The value added generated from biogas is IDR 48,000 compared to IDR 42,389 when using LPG. Using biogas increases the value added and profit earned by the business. When businesses use biogas, the profit per kg of coffee product reaches Rp42,000, compared to Rp29,167 with LPG.

The margin value is the difference between the output value and the price of raw materials; the margin describes the gross income a business generates. The small margin value in the industry with biogas fuel is due to the small value of other cost contributions, and the scale of the industry will also affect the margin results obtained. The biogas industry is on a smaller scale than the LPG gas industry. Therefore, biogas has a higher profit value than LPG gas even though the margin is smaller.

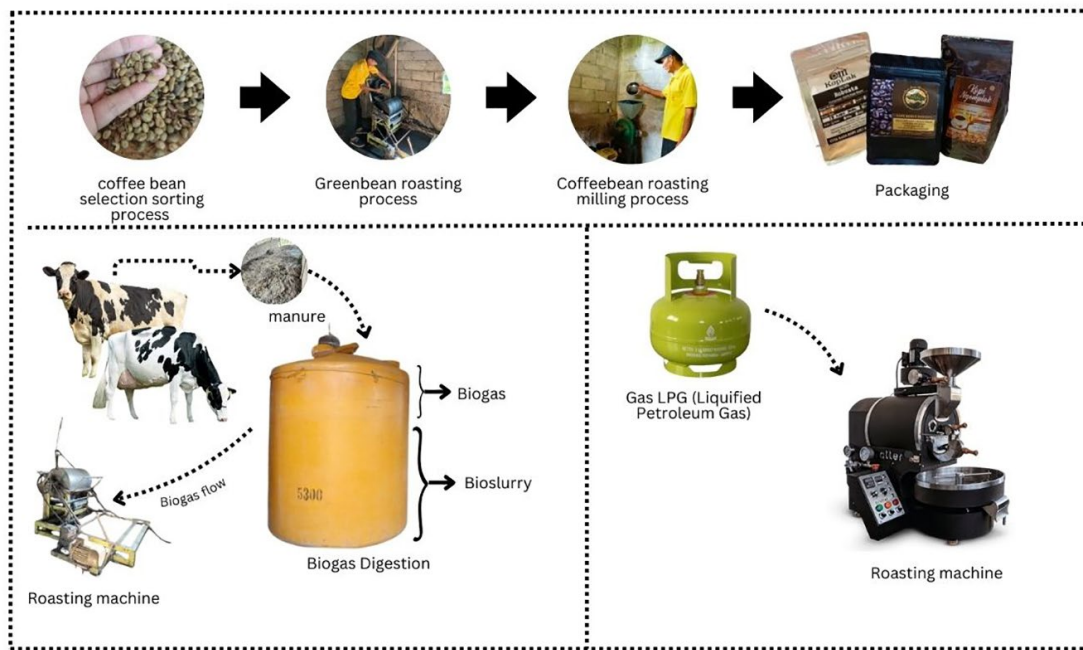


Figure 2: Industrial flow of coffee processing with biogas and LPG gas.

Table 3: Comparative Analysis of Coffee-Added Value Between LPG and Biogas Fuel Use.

Variable		LPG Gas Fuel	Biogas Fuel
Output, Input, Price			
1	Total output (Kg/production)	24	12
2	Raw material input (kg/production)	42.9	25
3	Labor (hour/production)	30.31	12
4	Conversion factor (%) (1/2)	0.56	0.48
5	Labor coefficient (hour/kg) (3/2)	0.71	0.48
6	Output price (Rp/kg)	Rp 200.000	Rp 200.000
7	Average labor wage (Rp/hour)	Rp 18.714	Rp 12.500
Revenue and Profit (Rp/raw material)			
8	Raw material price (Rp/kg)	Rp 42.000	Rp 42.000
9	Other input contribution (Rp/kg)	Rp 27.499	Rp 6.000
10	Output value (Rp/kg)	Rp 111.888	Rp 96.000
11	Value added (Rp/kg)	Rp42.389	Rp48.000
	Value-added ratio	38%	50%
12	Labor income (Rp/kg)	Rp 13.222	Rp 9.000
	Labor share (%)	31%	13%
13	Profit (Rp/kg)	Rp29.167	Rp42.000
	Provit level (%)	26%	44%
Reply to Factor of Production			
14	Margin (Rp/kg)	Rp 69.888	Rp 54.000
	Labor (%) (12a/14a)	19%	11%
	Capital (Other input contributions) (9/14a)	39%	11%
	Processing advantages (13a/14a)	42%	78%

The margin in the value-added analysis will be contributed to labour rewards, other input contributions, and processing profits. In the industry with biogas feedstock, the margin contribution on labour is (19%), on other input contributions is (39%), and on processing, profit is (42%). At the same time, the industry with biogas raw materials has a margin contribution on the labour of (11%), other input contributions of (11%), and processing profits of (78%).

4 DISCUSSION

The bioindustrial agricultural system is an agricultural system that will accommodate the optimal utilization of biological resources, including agricultural organic waste or biomass, in order to build a sustainable agricultural system for the welfare of the community (Harwono et al., 2021). The coffee processing process using biogas fuel in this study is a form of implementing a bio-industrial agricultural system in the research location by utilizing livestock manure waste into valuable and environmentally friendly products. Biogas, an alternative energy source for bioindustrial coffee processing, showed higher cost efficiency than LPG in this study. This system reduces energy costs and processes livestock waste into an economically valuable resource, resulting in a more environmentally friendly production cycle.

Based on the results of the analysis, biogas fuel use in the ground coffee processing industry has several advantages over the LPG gas-fueled industry. Some of these advantages include,

1. Higher Value Added with Biogas

As an energy source, Biogas offers much higher added value than LPG. The value-added ratio of Biogas is 50%, higher than LPG's at only 38%. This significant difference underscores the potential of Biogas to increase the value of coffee products, thereby improving the competitiveness of local coffee businesses. By (Hubeis, 1997), added value is classified as low if below 15%, medium between 15%-40%, and high if above 40%. Previous studies show that robusta coffee powder processing enterprises in Tapin Regency (Putri et al., 2024) and Kepahiang Regency (Yenti; Sumantri, 2023) offer higher value-added, at IDR 70,156 and IDR 64,444, respectively, compared to the three enterprises in this study. However, the value added of these three enterprises is still higher than that of similar enterprises in Pasuruan District, at IDR 9,179 (Lestari et al., 2023) and in Banjar District, at IDR 7,701 (Rahman et al., 2020). This indicates that the three coffee processing businesses in Boyolali Regency have the potential to improve the efficiency and competitiveness of the local coffee they produce.

2. Cost Efficiency and Reduced Dependence on Other Input

With the contribution of other inputs (costs other than raw materials and labour), the efficiency value of using Biogas becomes higher. This efficiency value is obtained because of

the low additional cost of other inputs due to the absence of expenditure to buy fuel. Utilizing Biogas as an alternative fuel for processing ground robusta coffee will significantly affect the efficiency of this business. The production and use of agricultural waste will benefit product diversification and increase farmers' income (Borowski; Barwicki, 2023) research (Wikayonggo, 2023) shows that the use of Biogas can save the cost of purchasing LPG by Rp 1,140/day or Rp 34,200/month.

3. Fairer Distribution of Margins for Capital and Labor

With biogas, the margin earned from the production process is shared more fairly between capital (other inputs) and labour. For example, the labour share when using LPG gas is 19%, and the processing profit is 42%. However, when businesses use biogas, the labour share is 11%, and the processing profit is much higher at 78%. This confirms that biogas reduces dependence on fossil fuels and improves profit distribution among businesses.

4. Time is more efficient with biogas

Using biogas to produce ground robusta coffee provides production time efficiency in processing ground coffee. The considerable calorific value produced in biogas will make the time in food processing more efficient, shorter and better (Shaibur; Husain; Arpon, 2021). When compared to the value of other resources, the amount of energy produced by biogas, if it can be stored, is equivalent to 6 kWh of electrical energy, 0.62 litres of kerosene, 0.52 litres of diesel, 0.46 kg of LPG, 3.5 kg of firewood, and 0.80 litres of gasoline. When compared to the value of other resources, the amount of energy produced by biogas, if it can be stored, is equivalent to 6 kWh of electrical energy, 0.62 litres of kerosene, 0.52 litres of diesel, 0.46 kg of LPG, 3.5 kg of firewood, and 0.80 litres of gasoline (Elizabeth, 2021a). Research from (Nguyen et al., 2024) also shows that using biogas in households will save 1.75 hours per day.

The conversion factor value in the biogas-fueled industry is smaller than that of the LPG gas-fueled industry. The process of converting coffee beans into ground coffee produces a weight reduction of 44.1-52.0%. Compared to the results of previous studies, the value of the conversion factor of the coffee processing business at the research location is still lower than the value of the conversion factor of the ground robusta coffee processing business in Kepahiang Regency (0.8) (Yenti; Sumanti, 2023), in West Lampung Regency (0.8) (Analianasari et al., 2024), however, this value is still higher than the conversion factor of ground coffee processing in Bandung Regency (0.18) (Herdiani et al., 2024) and Bangli Regency (0.13 - 0.2) (Dewi et al., 2015). The conversion factor is an indicator of efficiency in the ground coffee production process, where the higher the conversion value, the more efficient the process is because it produces more ground coffee. Various factors, such as processing technology, labour skills, or the quality of raw materials, can influence different conversion factor values.

4.3 Impact of biogas energy utilization on business profits

Energy produced from biomass is known as Bioenergy, and it is a sustainable energy source. Over the next 20 years, bioenergy energy produced from biomass is anticipated to become a more sustainable energy source (Ramirez-Contreras; Faaij, 2018). Biogas, bioethanol, and biodiesel are Bioenergy that play an essential role in increasing the added value of agricultural products by utilizing renewable resources efficiently in the future (Massari, 2014). Organic materials' anaerobic (oxygen-free) breakdown produces biogas, such as animal dung, agricultural, or organic waste. Biogas consists mainly of methane and can generate electricity, heat, or as a vehicle fuel. The use of biofuels and other forms of Bioenergy can reduce carbon emissions from agricultural sector activities, mitigate environmental damage, and contribute to sustainable development goals by promoting low-carbon fuel alternatives (Juarez-Hernandez; Castro-Gonzalez, 2016).

The Indonesian government is developing appropriate and affordable technologies considering social, economic, and geographical aspects (Budhijanto *et al.*, 2019). Valorization of agro-industrial wastes and by-products through bioenergy production not only helps reduce environmental pollution but also creates value-added compounds for various industries. In addition, By offering substitute energy sources, lowering reliance on fossil fuels, and diversifying the economy by creating biomass-based goods for a range of industries, bioenergy can favour economic growth and development. Ground coffee is one industry that requires alternative fuels, such as biogas, in the processing process.

The biomass potential of Indonesia's rich natural resources is enormous. Utilizing livestock manure waste into biogas raw materials to support the ground coffee production process will benefit farmers as business actors. The conversion of fuel from Liquefied Petroleum Gas (LPG) to biogas is essential because the continued use of LPG causes various problems, such as scarcity of raw materials, increased prices, and the issue that Indonesia is projected to become a gas importer by 2028 due to the inability of national gas supplies to meet future needs (Rianawati *et al.*, 2021). In addition, replacing the use of LPG with biogas is also one of the potential methods to mitigate emissions generated at the coffee roasting stage (Irawan; McLellan, 2024). Utilizing agricultural and livestock waste minimizes negative impacts on the environment and maximizes profits for farmers (Elizabeth, 2021b). Research results from (Hartono; Maharani, 2021) show that using biogas in the long term can be a solution to poverty reduction. Biogas can also increase household income through energy savings and increased agricultural productivity. In addition, using biogas among businesses can increase their investment returns (Ali *et al.*, 2023).

Scientific management of manure waste will lead to better environmental conditions; household income will also increase compared to household expenditure (Shaibur *et al.*, 2021). Utilizing biogas can reduce household expenditure's overall cost structure (St.Aisyah; Syarif, 2021). The amount of fuel required for domestic cooking will be decreased with the use of biogas. Other advantages, including cooking fuel saving time and workload, will follow this condition. This strength should be taken into account because using biogas can result in the creation of new jobs in rural areas (Iqbal *et al.*, 2021).

The benefits of installing biogas installations for farming households will create various kinds of welfare for households, including financial welfare which will affect household improvements due to increased income, health welfare due to better household health conditions due to reduced fuel use and the use of environmentally friendly energy such as biogas, welfare of crop productivity as a result of increased production due to the effect of using biogas residues as crop fertilizer as a substitute or complementary material for chemical fertilizers, food security welfare through the assurance of household nutritional needs due to integrated agricultural activities and increased production resulting in lower agricultural prices in the market, time saving welfare through the utilization of more efficient time in energy use so that time allocations can be used for other activities, environmental welfare, and micro and macro welfare as the effect of improving the household economy and resulting in national economic growth (Ahmad; Jabeen, 2023).

The benefits of biogas implementation have been felt in the Selo Boyolali region. Energy savings from biogas installations will significantly reduce fossil energy by 50 per cent with an overall workload reduced by 30 per cent; the 40 existing digesters will save 90 tons of CO₂ per year (Hnyine *et al.*, 2016). As in the Selo region, adopting biogas in Mauritania also provides benefits in the form of economic returns after 74 months, with significant results reaching US\$ 1750/month (Sidi; Tori, 2024).

5 CONCLUSIONS

This study shows that using biogas as an energy source in the processing of ground robusta coffee in Boyolali Regency, Central Java, results in more significant value-added compared to the use of LPG. The value-added from processing with LPG fuel is Rp42,389, while processing with biogas is Rp48,000. In addition, the profit obtained by business actors was 44% higher than LPG at 26% because biogas increased income and significantly reduced input costs in the coffee production process. This research is also important for advancing of bioenergy from local resources, especially livestock waste that can be processed into biogas. Integrating n coffee processing

and dairy farming establishes a circular farming system that promotes sustainable agriculture, reduces dependence on fossil fuels, and improves farmers' welfare through increased value-added products. This paves the way for future applications and innovations in sustainable agriculture.

6 AUTHORS CONTRIBUTIONS

Conceptual Idea: Hutahaean, L.; Rustiadi, E.; Fauzi, A.M; Methodology design: Hutahaean, L.; Rustiadi, E.; Nurmalina, R.; Data collection: Hutahaean, L.; Data analysis and interpretation: Hutahaean, L.; Nurmalina, R.; Rubiyo.; Writing and editing: Hutahaean, L.; Critical revision of the article: Rustiadi, E.; Fauzi, A.M.; Nurmalina, R.; Rubiyo.

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