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DETERMINANTS OF PRODUCTION AND TECHNICAL EFFICIENCY IN THE SIWALAN SUGAR BUSINESS IN KARDULUK VILLAGE

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Abstract

Despite the economic importance of siwalan sugar for rural livelihoods, studies integrating production determinants and technical efficiency analysis using the stochastic frontier approach remain limited. This study aims to analyse the effects of labour, nira volume, and business capital on siwalan sugar production and to measure the technical efficiency of producers in Karduluk Village, Pragaan Subdistrict, Sumenep Regency. This study employs a quantitative approach using primary data obtained from 101 siwalan sugar producers selected through purposive sampling. The analysis was conducted using Stochastic Frontier Analysis (SFA) approach. The results of the study indicate that the labor force, sap volume, and business capital have a positive and significant effect on siwalan sugar production, suggesting that an increase in the number of workers, sap volume, and business capital is associated with an increase in siwalan sugar production. The average technical efficiency score was 0.9625, indicating that producers operated close to the estimated production frontier, although output could still increase by approximately 3.8% through more efficient utilization of existing inputs. These findings imply that policies should prioritize strengthening raw material management through better utilization of untapped siwalan resources while simultaneously improving production technology and institutional support, including extension services, producer organizations, and market access for small-scale siwalan sugar producers.

Kata Kunci:

Agroindustri;
Produksi;
Gula Siwalan;
Stochastic Frontier Analysis;
Efisiensi Teknis;

Abstrak

Meskipun gula siwalan memiliki peran ekonomi yang penting bagi mata pencaharian masyarakat pedesaan, penelitian yang mengintegrasikan analisis faktor-faktor penentu produksi dan efisiensi teknis dengan menggunakan pendekatan *stochastic frontier* masih terbatas. Penelitian ini bertujuan menganalisis pengaruh tenaga kerja, volume nira, dan modal usaha terhadap produksi gula siwalan serta mengukur efisiensi teknis para produsen di Desa Karduluk, Kabupaten Sumenep. Penelitian ini menggunakan pendekatan kuantitatif dengan memanfaatkan data primer dari 101 produsen gula siwalan yang dipilih melalui metode *purposive sampling*. Analisis menggunakan pendekatan *Stochastic Frontier Analysis* (SFA). Hasil penelitian menunjukkan bahwa tenaga kerja, volume nira, dan modal usaha berpengaruh signifikan terhadap produksi gula siwalan. Hal ini menunjukkan bahwa peningkatan jumlah tenaga kerja, volume nira, dan modal usaha berkaitan dengan peningkatan produksi gula siwalan. Nilai rata-rata efisiensi teknis yang diperoleh sebesar 0,962, yang mengindikasikan bahwa produsen telah beroperasi mendekati batas produksi (*production frontier*) yang diperkirakan, meskipun output masih dapat ditingkatkan sekitar 3,8 persen melalui pemanfaatan input yang tersedia secara lebih efisien. Temuan ini menunjukkan kebijakan perlu memprioritaskan penguatan pengelolaan bahan baku melalui pemanfaatan sumber daya siwalan yang belum optimal, sekaligus meningkatkan teknologi produksi dan dukungan kelembagaan, termasuk layanan penyuluhan, organisasi produsen, serta akses pasar bagi produsen.

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INTRODUCTION

Indonesia is known as an agrarian country with abundant natural resources, particularly in the agricultural sector (Setiyani & Sepfrian, 2025). Among these resources, the siwalan tree has long been recognized as an important component of rural economies and livelihoods. As a result, the siwalan tree provides employment opportunities and improves community well-being. This opportunity has grown as consumer habits have shifted in recent years. Consumers are now paying more attention to health considerations when choosing food products. According to Purwanto (2025), the trend toward healthy eating is growing rapidly both globaly and in Indonesia, reflecting a growing awareness of the importance of proper nutrition. This trend has driven increased demand for natural sweeteners, including brown sugar, which is considered healthier because it has a relatively lower glycemic index and does not undergo chemical refining like cane sugar.

Global trends indicate growing interest in replacing pure sucrose with natural sweeteners, such as palm sugar, which is increasingly popular in developed countries (Rayappa, 2023). This situation indicates strong international market interest in brown sugar. As a result, siwalan sugar has promising export potential, as it is viewed as a healthier, more environmentally friendly alternative to other sweeteners (Sukasih & Sasmitaloka, 2024; Andri 2025). Indonesia is no exception, public demand for the development of siwalan sugar products is also quite high (Putra et al. 2023). Siwalan sugar is becoming increasingly popular because it is a natural, additive-free sugar, which means it can have a positive impact on public health (Sadewo et al., 2023).

In Indonesia, siwalan is a commodity with national potential due to its ability to produce palm sap, particularly in East Java (Tuban-Madura), West Nusa Tenggara, East Nusa Tenggara, South Sulawesi, and Southeast Maluku (Widyawati, 2025). The largest producer of siwalan on Madura Island is located in Sumenep Regency (Kurniawan et al*.,* 2025), with a total area of siwalan trees reaching 7,388.63 hectares in 2024, this figure represents an increase compared to 2023, when the area was 5,535.7 hectares, spread across 25 subdistricts in Sumenep Regency (BPS Sumenep, 2025). One of the producers of brown sugar in Sumenep Regency is located in Pragaan Subdistrict. Pragaan Subdistrict is situated on highland terrain, with elevations ranging from approximately 5 to 530 meters above sea level, making it suitable for the growth of siwalan trees. Consequently, siwalan trees are abundant in Pragaan Subdistrict, as evidenced by the increasing area of siwalan tree plantations, which grew from 353.02 hectares to 431.56 hectares by 2024 (BPS Sumenep, 2025). Pragaan Subdistrict has a siwalan sugar production center located in Karduluk Village, with a total of 7,763 siwalan trees (Ubaddilah, 2024). As a result, the primary source of livelihood for the residents of Karduluk Village is agriculture, with 2,633 people working in the sector, including those involved in the siwalan industry (BPS Sumenep, 2023).

The rising demand for siwalan sugar should present an opportunity for artisans to increase production. However, producers' ability to achieve optimal production is influenced by their utilization of available production factors. In the siwalan sugar industry, production heavily depends on the availability of nira as the primary raw material, the number of workers involved in the production process, and the capital used to support business operations. Differences in artisans' ability to manage these production factors result in varying production levels among producers. In addition to being influenced by the use of production factors, the success of the siwalan sugar business is also determined by the producer's level of efficiency in utilizing available inputs. Production efficiency reflects the producer's ability to generate maximum output with a given use of inputs (Kabeakan et al., 2022; Kananlua et al., 2024; Putri et al., 2025). Suboptimal use of inputs can result in suboptimal production output (Sinabang et al., 2021). Therefore, measuring producer efficiency is important to determine the extent to which siwalan sugar artisans have optimally utilized production factors in their business operations.

Previous studies have reported inconsistent findings regarding the economic performance of siwalan sugar enterprises. Several studies concluded that the industry contributes positively to

household income and rural livelihoods (Suwatiningsih et al., 2024; Suek et al., 2025; Sintia Ratusehaka, 2024), whereas Fatwah et al. (2025) found that the business merely provides subsistence income with limited economic returns. These contrasting findings suggest that differences in production performance may not solely reflect market opportunities but may also be associated with variations in producers' ability to utilize production inputs efficiently. However, this issue has received limited empirical attention.

Existing studies on siwalan sugar enterprises have primarily focused on business feasibility, value added, income contribution, and product development. Although these studies provide valuable insights into the economic potential of the industry, they have not simultaneously analyzed production determinants and measured producers' technical efficiency using a stochastic frontier approach. Consequently, empirical studies applying Stochastic Frontier Analysis (SFA) to examine production determinants while measuring technical efficiency remain limited, particularly for siwalan sugar enterprises in Karduluk Village, one of the main production centers in Sumenep Regency. To address this gap, this study integrates the Cobb–Douglas production function with Stochastic Frontier Analysis (SFA) to simultaneously estimate the effects of labor, nira volume, and capital on siwalan sugar production while measuring producers' technical efficiency. This integrated approach constitutes the main contribution of this study because it distinguishes production losses resulting from insufficient input use from those caused by technical inefficiency, thereby providing a more comprehensive evaluation of production performance than previous studies. Therefore, this study aims to analyze the effects of labor, nira volume, and capital on siwalan sugar production and to measure the technical efficiency of siwalan sugar producers in Karduluk Village, Pragaan Subdistrict, Sumenep Regency.

H_1: The size of the workforce has a positive impact on production.

Labor is a key factor of production in economic activity; individuals of working age who are capable of producing goods or services in exchange for wages or salaries (Kharismawati et al., 2021; Syamita et al., 2021). In industries that utilize local resources, labor plays a crucial role in supporting the production process (Puspitasari & Sudharma, 2025), particularly in transforming raw materials into finished products, and influences the volume of output produced. The larger the workforce, the greater the production capacity, as the production process becomes faster and more efficient. The concept of labor share indicates that labor contributes to increased output and business value in the long term (Jeon et al., 2023). According to production theory, labor is an input that continuously contributes to output; the greater the labor force, the greater the output (Mandal & Taku, 2025). Previous research supports this theory, including a study by Adhiana et al. (2022), which shows that labor has a significant and positive effect on production. Research by Nursan & Wathoni (2021) also found that labor has a significant effect on production. However, Fauziah et al. (2023) found that labor has only a minor effect on production.

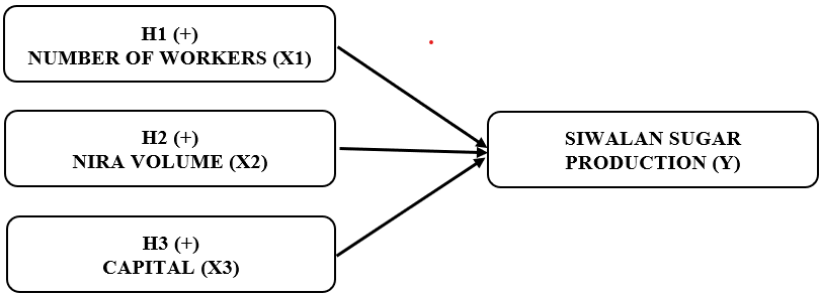
H_2: The volume of nira has a positive effect on production.

Nira is a sweet liquid obtained from plants through grinding, pressing, or tapping, and is used as a raw material for sugar or sweeteners (Kurniawan & Hermanto, 2025). In the processing of nira, nira volume is a key factor because it determines the amount of sugar produced. The greater the volume of nira, the higher the sugar output (Aini et al., 2023; Munawarah & Lisra, 2023). This increase in output has led to higher income and a greater contribution to household income (Nebansi et al., 2025). According to Winangun & Wenagama (2024), the more raw materials available, the greater the quantity of products produced. This is supported by research conducted by Fitriyanti & Wulandari (2025); Ivana et al. (2022); Prananjaya & Wenagama (2023) which found that raw materials affect production output.

H_3: Capital has a positive effect on production.

Capital refers to the funds used to cover all variable inputs (Rahayu & Sari, 2022). Capital can come from various sources, such as personal funds, government assistance, and formal and informal financial institutions (Manggu et al., 2024). Formal capital sources such as banks, credit unions, and government financing programs, as well as informal capital sources such as personal savings and loans

from family or community groups (Peter & Orser, 2024). In the Cobb-Douglas production function, capital plays a key role in increasing output by financing labor, raw materials, and production equipment. The greater the capital, the higher the production capacity and the scale of the business (Arniyasa, 2023). The theory of production function states that capital is a key factor in increasing output and income; the more capital invested, the greater the increase in output (Kurnia *et al.*, 2023). This finding is supported by research conducted by Ardhiyansyah et al. (2024); Hafie & Yunani (2021); Rivai et al. (2023); Sisdiyantoro & Lestari (2022) which found that capital has a significant effect on production output.



Source: Researcher, 2026

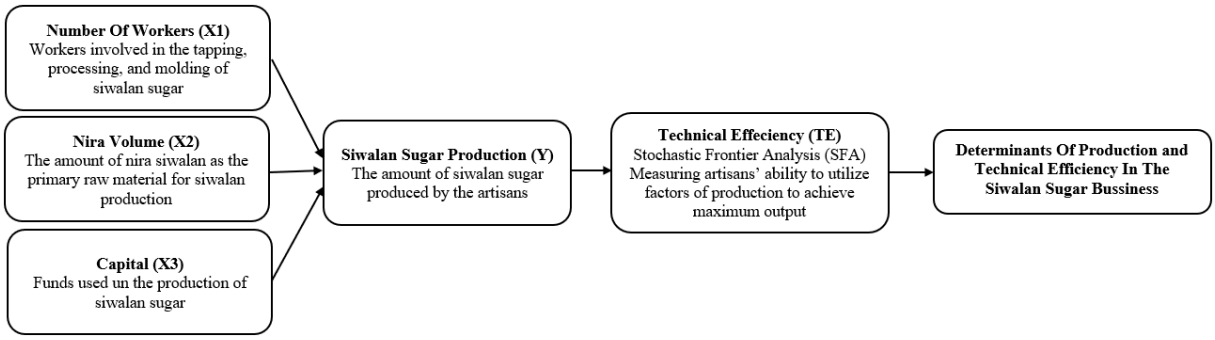
Figure 1. Research Hypothesis Chart

The siwalan sugar industry is one of the main economic activities in Karduluk Village and has considerable potential for further development as demand for natural sweeteners continues to increase. Growing public awareness of healthy eating has increased demand for siwalan sugar as a natural alternative sweetener, creating opportunities for producers to expand production. However, the ability of producers to increase output depends not only on market demand but also on the availability and efficient utilization of production inputs.

In this study, siwalan sugar production is assumed to be influenced by three main production inputs: labour, nira volume, and business capital. Labour supports production activities, including nira tapping, boiling, stirring, and molding. Nira volume serves as the primary raw material and directly determines the maximum quantity of sugar that can be produced. Business capital supports production by financing labour, raw materials, equipment, fuel, and other operational requirements. According to production theory and the Cobb-Douglas production function, these inputs jointly determine production output, although the contribution of each input depends on its output elasticity.

In addition to input use, production performance is influenced by producers' ability to utilize available inputs efficiently. Producers using similar quantities of labour, nira volume, and capital may achieve different output levels because of differences in managerial ability and production practices. Therefore, this study not only examines the effects of labour, nira volume, and business capital on siwalan sugar production but also measures producers' technical efficiency using the Stochastic Frontier Analysis (SFA) approach. Unlike conventional production models, SFA distinguishes random statistical noise from technical inefficiency, enabling production losses attributable to inefficient input utilization to be identified. Technical efficiency refers to the ability of producers to obtain the maximum feasible output from a given combination of production inputs (Koye et al., 2022).

Therefore, this study integrates the Cobb-Douglas production function with Stochastic Frontier Analysis to estimate the effects of labour, nira volume, and business capital on siwalan sugar production while simultaneously measuring producers' technical efficiency. This approach provides a more comprehensive evaluation of production performance by distinguishing the effects of input utilization from technical inefficiency, thereby generating evidence to support strategies for improving productivity and sustainability in small-scale siwalan sugar enterprises.



Note: This figure illustrates the conceptual framework of the study. Labor, nira volume, and capital are treated as production inputs affecting siwalan sugar production. Technical efficiency is estimated using the Stochastic Frontier Analysis (SFA) approach to evaluate producers' ability to achieve maximum output from the given level of inputs.
Source: Researcher, 2026

Figure 2. Conceptual Framework Chart

RESEARCH METHOD

This study was conducted in Karduluk Village, Pragaan Subdistrict, Sumenep Regency. It employed a quantitative approach using both primary and secondary data. Primary data were collected through interviews with respondents using a questionnaire, while secondary data were obtained from the Central Statistics Agency (BPS) and other relevant agencies to support the description of the study location and the general conditions of the study area. The study population consists of residents of Karduluk Village who produced siwalan palm sugar during the study period, and sampling was conducted using purposive sampling, a technique that employs specific criteria. The sampling criteria for this study are residents who produce siwalan palm sugar during both the dry and rainy seasons and have been engaged in this activity for at least 10 years. This study involved 101 respondents; the sample size was determined based on Walpoel (as cited in Kusumawati, 2025), which states that a sample of 30 or more is representative of the population.

This study employs a microeconomic approach, specifically in the analysis of agribusiness enterprises, using a production function model with the Stochastic Frontier Analysis (SFA) method to examine the impact of production inputs on siwalan sugar production and to measure producers' technical efficiency. The stochastic frontier production function was specified using the Cobb–Douglas functional form and estimated using the Maximum Likelihood Estimation (MLE) method implemented in Stata version 14. In the stochastic frontier model, the composite error term is expressed as (vi−ui), where $v_i \sim$ iid $N(0, \sigma_v^2)$ represents the random noise component attributable to factors beyond the producer's control, such as weather conditions, fluctuations in the quality and availability of nira, and other random shocks. while $u_i \geq 0$ represents the technical inefficiency component. In this study, the inefficiency term was assumed to follow a half-normal distribution, $u_i \sim |N(0, \sigma_u^2)|$, consistent with the specification of the stochastic frontier model estimated in Stata (Uche et al., 2021).

Production function models using the stochastic frontier approach;

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + (v_i - u_i) \quad \ldots\ldots (1)$$

Description:

Y	= Siwalan Sugar Production (Kg)
X_1	= Number of workers (People)
X_2	= Nira Volume (Liters)
X_3	= Capital (Rp)
β_0	= Intersep
β_1- β_3	= Estimated parameters

v_i-u_i = Error term (vi=error; ui = the effect of technical inefficiencies in the model)

The dependent variable in this study is siwalan sugar production, measured based on the amount of siwalan sugar produced by artisans in one week of production and expressed in kilograms (kg/week). The independent variables consist of the number of workers, nira volume, and capital. The number of workers is measured as the total number of workers involved in the production process in one week and is expressed in people. Nira volume is measured based on the amount of nira used as raw material for production in one week and is expressed in units of liters (liters/week). Meanwhile, capital is measured as the total costs incurred in production activities over one week and is expressed in rupiah (Rp/week).

Technical efficiency in this study was estimated using a stochastic frontier production function model. Technical efficiency (TE), as reflected in the production frontier, indicates a business unit's ability to generate actual output relative to the maximum technically achievable output at a given level of input use (Maaqili et al., 2025). The technical efficiency value is derived from the inefficiency component (u_i) in the model, which represents the deviation between actual production and frontier production. Thus, technical efficiency reflects the producer's ability to optimize the use of production inputs to achieve output that approaches frontier conditions.

$TE_i=\exp(-E[u_i|\varepsilon_i])$ ..... (2)

Description:

TEi = Technical Efficiency of the Siwalan Sugar Industry to-i

exp(-E[ui|εi]) = Estimated production frontier derived from the stochastic production frontier

i =1, 2, 3, ...,n

According to Kumbhakar and Lovell (as cited in Nugraheni et al., 2022), the technical efficiency score ranges from 0 to 1 ($0 \leq TE \leq 1$). An enterprise is considered more efficient as the TE score approaches 1, and less efficient as it approaches 0 (Laili & Fauziyah, 2022).

RESULTS AND DISCUSSION

Table 1.
Descriptive Statistics of the Research Variables

Variabel	Mean	Minimum	Maximum	Std. Deviasi
Siwalan Sugar Production (Kg/Week)	349	154	576	91
Nira Volume (Liter/Week)	1,807	770	2,880	481
Number of workers (People)	2.316	2	3	0.460
Business Capital (Rp/Week)	797,487	276,800	4,788,200	917,454
Total Revenue (Rp/Week)	5,344,341	2,212,000	8,424,000	1,397,335

Source: Processed Data, 2026.

Based on Table 1, the average production of siwalan sugar reached 349 kg per week, with a maximum of 576 kg and a minimum of 154 kg, indicating variations in production capacity among business operators due to differences in input use and business management. In the production process, the average nira volume used was 1,807 liters per week, while the number of workers was only 2–3, reflecting that the siwalan sugar business is still dominated by household enterprises using traditional production systems. From an economic perspective, the average business capital expended was Rp797,487 per week of production, with average revenue reaching Rp5,344,341 per week.

Tabel 2.
Stochastic Frontier Production Function Estimation Results

Variable	Coef.	Std. Err.	z	P-Value
Number of workers (lnX1)	0.001	0.000	360	0.000
Nira Volume (lnX2)	0.989	0.000	840,000	0.000
Business Capital (lnX3)	0.010	0.000	26,000	0.000

Variable	Coef.	Std. Err.	z	P-Value
Constant	-1.656	0.000	-17,0000	0.000
/lnsig2v	-39.312	228.409	-0.170	0.863
/lnsig2u	-5.704	0.140	-40.540	0.000
sigma_v	0.000	0.000		
sigma_u	0.058	0.004		
sigma2	0.003	0.000		
lambda	19,900,000	0.004		

Note: Log likelihood = 214.759; Wald chi2(3)= 1,020,000,000,000; Prob > chi2 = 0.000; Likelihood-ratio test of sigma_u=0: chibar2(01) = 73.040; Prob>=chibar2 = 0.000
Source: Processed Data, 2026.

Table 2 shows that all production input variables have a positive effect on siwalan sugar production. The number of workers has a positive and significant effect on siwalan sugar production, with a coefficient of 0.001 and a p-value of 0.000 (<0.05). Although statistically significant, the relatively small coefficient indicates that labor contributes only marginally to production growth compared with other production factors. This finding suggests that simply increasing the workforce is unlikely to substantially increase output, as production appears to be primarily constrained by the availability of nira as the main raw material. In household-scale siwalan sugar enterprises, production activities such as sap boiling, stirring, and molding are highly dependent on the quantity of nira available. Consequently, additional workers are unlikely to substantially increase production unless they are supported by a sufficient supply of raw materials and adequate production capital. According to production theory, labor is a primary production input that contributes to output by increasing production capacity through specialization and the division of labor (Mandal & Taku, 2025). However, according to the Cobb–Douglas production function, the contribution of each input depends on its output elasticity. Therefore, when production is primarily constrained by raw material availability, the marginal productivity of labor tends to be relatively low, resulting in only a modest increase in output despite an increase in the number of workers. This explanation is also consistent with the concept of labor share, which suggests that labor contributes to output generation, although the magnitude of its contribution varies depending on production technology and industrial characteristics (Jeon et al., 2023). This finding is consistent with Fauziah et al. (2023) who reported that labor had only a limited influence on production, although it differs from the findings of Adhiana et al. (2022); Nursan & Wathoni (2021), who showed a significant influence of labor on production, thus supporting the research hypothesis.

The nira volume variable has a positive and significant effect on siwalan sugar production, with a coefficient of 0.989 and a p-value of 0.000 (<0.05). The estimated elasticity, which is close to one, indicates that a one-percent increase in nira volume is associated with an almost proportional increase in siwalan sugar production, holding other inputs constant. According to the Cobb–Douglas production function, the output elasticity of an input reflects its relative contribution to output (Baláž & Corejova, 2024). The high elasticity of nira volume therefore indicates that nira is the dominant production input in the siwalan sugar industry. This finding is consistent with production theory, which emphasizes that output is fundamentally constrained by the availability of essential production inputs. Since nira is the primary raw material used directly in the sugar-making process, its availability determines the maximum quantity of sugar that can be produced. Additional labor or capital is unlikely to substantially increase production when the supply of nira remains unchanged because the production process cannot proceed without sufficient raw materials. This explains why siwalan sugar production is highly responsive to changes in nira volume and indicates that the production process is primarily constrained by the availability of the main raw material. Furthermore, because nira is a perishable and seasonal raw material, fluctuations in its availability directly influence production capacity and output levels. These findings are consistent with those of Winangun & Wenagama (2024), who reported that greater availability of raw materials increases production output. Similar results were also reported by Fitriyanti & Wulandari (2025); Ivana et al. (2022); Prananjaya &

Wenagama (2023), who found that raw materials are the dominant determinant of production output. Therefore, the proposed hypothesis is accepted.

The business capital variable has a positive and significant effect on siwalan sugar production, with a coefficient of 0.010 and a p-value of 0.000 (<0.05). The relatively low elasticity indicates that increases in business capital contribute only marginally to output growth compared with other production factors, particularly nira volume. According to the Cobb–Douglas production function, the output elasticity of capital reflects the responsiveness of production to changes in capital input while holding other inputs constant. The small estimated elasticity suggests that capital plays a complementary rather than dominant role in the siwalan sugar production process. From the perspective of production theory, capital facilitates production by financing labor, raw materials, fuel, equipment, and other operational requirements, thereby improving producers' capacity to conduct production activities efficiently (Arniyasa, 2023; Kurnia et al., 2023). However, in household-scale siwalan sugar enterprises, additional capital may not automatically translate into higher production because production remains constrained by the availability of nira as the primary raw material. Additional financial resources may facilitate the procurement of production inputs and improve operational capacity, but they cannot substantially increase output when the quantity of nira available for processing remains unchanged. Moreover, the use of relatively simple production technology limits the productivity gains that can be achieved through additional capital investment. These conditions explain why capital contributes positively to production, although its marginal effect remains relatively small. This finding is consistent with those of Ardhiyansyah et al. (2024); Hafie & Yunani (2021); Rivai et al. (2023); Sisdiyantoro & Lestari (2022), who also reported that capital has a significant positive effect on production output. Therefore, the proposed hypothesis is accepted.

Table 3.
Technical Efficiency Test Results

Indicator	Value
Mean Technical Efficiency	0.962
Minimum TE	0.849
Median TE	0.977
Maximum TE	1
Gamma	1
Likelihood Ratio Test	73.040
Prob > chibar²	0.000

Source: Processed Data, 2026.

Based on Table 3, the average technical efficiency (TE) of siwalan sugar producers in Karduluk Village was 0.962, with a minimum value of 0.849, a median of 0.977, and a maximum value of 1. In the stochastic frontier framework, the production frontier represents the maximum feasible output that can be achieved with a given combination of labor, nira volume, and capital under the existing production technology. The estimated TE values indicate that most producers operate close to this frontier, suggesting that they utilize the available labor, nira volume, and capital efficiently to achieve output levels that are close to the maximum attainable under the existing production technology. This finding is consistent with those of Karakaya (2025); Ntakirutimana et al. (2025); Sithole et al. (2025), who reported that producers with high technical efficiency are generally able to utilize production inputs effectively and achieve output levels close to the production frontier. The estimated TE values ranged from 0.849 to 1, indicating that all sampled producers achieved relatively high levels of technical efficiency, although the average TE score of 0.962 still implies an output gap of approximately 3.8 percent. This indicates that production could potentially increase by about 3.8 percent using the existing quantities of labor, nira volume, and capital if all producers were able to achieve full technical efficiency. Although producers exhibit relatively high technical efficiency, field observations indicate that many siwalan trees remain untapped, production technology is still relatively simple, and business development programs are limited. Therefore, the remaining

production potential depends not only on improving technical efficiency but also on expanding the utilization of available raw materials, adopting more efficient production technology, and strengthening institutional support for producers.

CONCLUSION AND SUGGESTION

This study demonstrates that labour, nira volume, and business capital have positive and significant effects on siwalan sugar production in Karduluk Village, with nira volume being the dominant production factor. The relatively small elasticities of labour and business capital indicate that increasing these inputs alone is unlikely to substantially increase production because the production process remains primarily constrained by the availability of nira as the main raw material. In contrast, the high elasticity of nira volume confirms that raw material availability is the principal determinant of production. Furthermore, the average technical efficiency score of 0.9625 indicates that producers operate close to the estimated production frontier, suggesting that the existing combination of labour, nira volume, and business capital has generally been utilized efficiently, although output could still be increased by approximately 3.8 percent through full technical efficiency.

This study is limited because it only considers labour, nira volume, and business capital as production inputs and focuses on a single study area, which may limit the generalizability of the findings. In addition, other factors that may influence production and technical efficiency, such as production technology, producers' education, business experience, market access, and institutional support, were not included in the analysis. Based on these findings, efforts to improve siwalan sugar production should prioritize strengthening raw material management through better utilization of untapped siwalan resources while simultaneously enhancing production technology and institutional support, including extension services, producer organizations, and market access. Furthermore, future studies are recommended to incorporate these additional variables and expand the geographical scope to provide a more comprehensive understanding of the determinants of production and technical efficiency in siwalan sugar enterprises.

REFERENSI

Adhiana, Martina, Riani, & Suryadi. (2022). Analisis efisiensi teknis usahatani cabai merah di Kecamatan Sawang Kabupaten Aceh Utara dengan pendekatan stochastik frontier. *Jurnal Pemikiran Masyarakat Ilmiah Berwawasan Agribisnis*, *8*(1), 265–278. https://doi.org/10.25157/ma.v8i1.6640

Aini, R. N., Sjah, T., & Ibrahim. (2023). Analisis faktor-faktor yang mempengaruhi produksi gula aren di Desa Kekait Kecamatan Gunungsari Kabupaten Lombok Barat. *Agrimansion*, *24*(1), 131–142. https://doi.org/10.29303/agrimansion.v24i1.1388

Andri, K. B. (2025). *Menggali potensi lontar : Dari warisan lokal ke inovasi global*. Kementerian Pertanian. https://perkebunan.brmp.pertanian.go.id/berita/menggali-potensi-lontar-dari-warisan-lokal-ke-inovasi-global

Ardhiyansyah, A. M., Istanto, Wibowo, H., & Hastuti, D. (2024). Pengaruh modal, tenaga kerja, luas lahan, dan teknologi pertanian terhadap hasil produksi usaha tani padi di Desa Sriwulan Kecamatan Limbangan Kabupaten Kendal. *Prosiding Seminar Nasional Pembangunan Dan Pendidikan Vokasi Pertanian*, *2*(September), 243–257. https://doi.org/10.47687/snppvp.v5i1.1110

Arniyasa, P. Y. P. (2023). Pengaruh modal usaha, tenaga kerja, dan penggunaan e-commerce terhadap pendapatan UMKM bidang kuliner di Kota Denpasar. *Public Service and Governance Journal*, *4*(2). https://doi.org/10.56444/psgj.v4i2.938

Badan Pusat Statistik (2025). *Luas areal tanaman perkebunan rakyat menurut jenis tanaman di Kabupaten Sumenep (ribu ha)*. BPS Kabupaten Sumenep. https://sumenepkab.bps.go.id/id/statistics-table/3/UWpGUlpUZzJZbkJhWlhGdUwzUkhXVzA0WmpoMFVUMDkjMw%3D%3D/luas-areal-tanaman-perkebunan-rakyat-menurut-jenis-tanaman-di-kabupaten-sumenep--ribu-ha---2022.html

Badan Pusat Statistik (2023). *Kecamatan Pragaan Dalam Angka*. BPS Kabupaten Sumenep. https://sumenepkab.bps.go.id/id/publication/2023/09/26/0e4bf11f97631d98f2fa3ca9/kecamatan-pragaan-dalam-angka-2023.html

Baláž, M., & Corejova, J. V. and T. (2024). Evaluation of the impact of the internet of things on postal service

efficiency in Slovakia. *Economies*, *12*(10), 1–19. https://doi.org/10.3390/economies12100271

Fahrizal, Jasman, Yeheskial Nggandung, & Kartiwan. (2019). Formulating strategies for development of lontar sugar industry in Rote Ndao District, East Nusa Tenggara Province, Indonesia. *Tropical Drylands*, *3*(2), 41–48. https://doi.org/10.13057/tropdrylands/t030202

Fatwah, A., Yunus, L., Dedu, L. O. A., & Saediman, H. (2025). Feasibility of brown sugar home industry in Batu Putih Village in Southeast Sulawesi. *International Journal of Management and Business Intelligence (IJBMI)*, *3*(4), 259–274. https://doi.org/10.59890/ijmbi.v3i4.102

Fauziah, S. W., Dawud, M. Y., & Djohar, N. (2023). Efisiensi teknis usahatani pisang cavendish menggunakan stochastic frontier analysis (SFA) di Kabupaten Bojonegoro. *Jurnal Viabel Pertanian*, *17*(1), 33–41. https://doi.org/10.35457/viabel.v17i1.2709

Fitriyanti, E., & Wulandari, A. (2025). Efficiency and economies of scale in the Indonesian halal food MSMEs : Evidence from Pangkalpinang City. *Journal of Islamic Economics and Finance*, *14*(2), 680–696. https://doi.org/10.22373/share.28631

Hafie, A., & Yunani, A. (2021). Pengaruh modal, tenaga kerja, dan bahan baku terhadap hasil produksi industri pengolahan kayu di Kelurahan Alalak Selatan dan Kelurahan Alalak Tengah Kecamatan Banjarmasin Utara. *JIEP: Jurnal Ilmu Ekonomi Dan Pembangunan*, *4*(2), 344–355. https://jiep.ulm.ac.id/index.php/jiep/article/view/2312

Kharismawati, K. H. D., & Karjati, P. D. (2021). Pengaruh luas lahan dan jumlah tenaga kerja terhadap produksi padi di 10 Kabupaten Jawa Timur tahun 2014–2018. *Economie: Jurnal Ilmu Ekonomi, 3*(2), 146–162. https://doi.org/10.30742/economie.v3i1.1571

Ivana, I., Suhel, S., & Mukhlis, M. (2022). Technical efficiency of traditional medicine raw material industry in Indonesia. *Eurasia: Economics & Business*, *12*(66), 76–81. http://econeurasia.com/issue-2022-12/article_08.pdf

Jeon, H., Cui, X., & Zhang, C. (2023). The effects of labor choice on investment and output dynamics. *Journal of Corporate Finance*, *83*(July), 102497. https://doi.org/10.1016/j.jcorpfin.2023.102497

Kabeakan, N. T. M. B., Habib, A., & Manik, J. R. (2022). Efisiensi teknis penggunaan faktor-faktor produksi pada usahatani jagung di Desa Pintu Angin , Laubaleng , Kabupaten Karo , Sumatera Utara , Indonesia. *Agro Bali : Agricultural Journal*, *5*(1), 42–49. https://doi.org/10.37637/ab.v5i1.841

Kananlua, A. B., Bafadal, A., & Indarsyih, Y. (2024). Analisis efisiensi alokatif penggunaan faktor produksi pada usaha perkebunan cengkeh Kabupaten Kolaka. *Jurnal Akuntansi dan Keuangan*, *09*(1), 1–9. https://doi.org/10.33772/jak.v9i1.81

Karakaya, E. (2025). Technical efficiency, energy balance, and economic analysis of honey production in Bingöl , Turkey. *Scientific Reports*, *15*(1), 1–12. https://doi.org/10.1038/s41598-025-94425-z

Koye, T. D., Koye, A. D., & Mekie, T. M. (2022). Analysis of technical efficiency of irrigated tomato production in North Gondar Zone of Amhara Regional. *Letters in Spatial and Resource Sciences*, *15*(3), 599–620. https://doi.org/10.1007/s12076-022-00314-8

Kurnia, Y., Nursolih, E., & Rustendi, E. (2023). Analisis fungsi produksi keripik pisang menggunakan Metode Cobb Douglas pada UPPKS Lestari di Kecamatan Cipaku Kabupaten Ciamis. *Jurnal Ilmiah Mahasiswa Agroinfo Galuh*, *10*(2), 1529–1542. https://jurnal.unigal.ac.id/agroinfogaluh/article/view/10513/pdf

Kurniawan, D. T., Yuniastri, R., Pramasari, I. F., Tukiran, Imron, A., & Ruhana, A. (2025). Peningkatan nilai jual gula semut melalui design kemasan dan digital marketing. *JMM (Jurnal Masyarakat Mandiri)*, *9*(1), 1–2. https://doi.org/10.31764/jmm.v9i1.27921

Kurniawan, H., & Hermanto. (2025). Faktor-faktor yang mempengaruhi pendapatan petani gula aren di Desa Lubuk Bondar Kecamatan Batang Natal Kabupaten Mandailing Natal. *Journal of Management and Bussines (JOMB)*, *7*(2), 129–140. https://doi.org/10.31539/jomb.v7i2.14975

Kusumawati, R. (2025). Dampak inovasi Patriot Desa terhadap upaya Pembentukan Manusia Pancasila dan pengentasan kemiskinan di Jawa Barat. *Ikraith-Informatika*, *9*(1), 143–152. https://doi.org/10.37817/ikraith-informatika.v9i1

Laili, Z., & Fauziyah, E. (2022). Pengukuran efisiensi teknis dengan pendekatan Fungsi Produksi Stochastic Frontier Translog pada usahatani bawang merah. *Jurnal Ekonomi Pertanian dan Agribisnis (JEPA)*, *6*(3), 861–871. https://doi.org/10.21776/ub.jepa.2022.006.03.8

Maaqili, Y. El, Mhandez, M. T., & Ouchen, A. (2025). Evaluating the performance of moroccan social incubators: An SFA Analysis of youth platforms under The National Initiative For Human Development. *Business, Management And Economics Engineering*, *23*(2), 243–264. https://doi.org/10.3846/bmee.2025.22086

Mandal, R. K., & Taku, C. (2025). The Cobb-Douglas Production Function : Applicability and limitation. *Agriculture Archives*, *4*(1). https://doi.org/10.51470/AGRI.2025.4.1.43

Manggu, B., Beni, S., Silvester, & Kusnanto. (2024). The influence of the environment , business capital and creativity of marketing strategies in increasing the competitiveness of UMKM in Bengkayang city. *Jurnal Ekonomi*, *13*(01), 1492–1503. https://doi.org/10.54209/ekonomi.v13i01

Munawarah, & Lisra. (2023). Analisis pendapatan home industry gula aren di Dusun Pasangridi, Desa Leppangeng, Kecamatan Pitu Riase di Kabupaten Sidenreng Rappang. *Lajumen : Lajagoe Journal Management And Business*, *1*(1), 1–11. https://journal.lajagoe.com/index.php/lajumen/article/view/9

Nebansi, S., Moita, S., & Supiah, R. (2025). Kontribusi hasil usaha pengolahan nira terhadap kebutuhan ekonomi keluarga. *Jurnal Pemikiran dan Penelitian Sosiologi*, *2*(1), 65–74. https://doi.org/10.52423/societal.v2i1.8

Ntakirutimana, J. M., Otieno, G. O., Ngigi, M., & Majiwa, E. (2025). Optimizing sugarcane production in Rwanda : a stochastic frontier analysis of smallholder farmers. *BMC Agriculture*, *1*(22), 1–19. https://doi.org/10.1186/s44399-025-00021-x

Nugraheni, S. S., Tinaprilla, N., & Rachmina, D. (2022). Pengaruh penggunaan benih bersertifikat terhadap produksi dan efisiensi teknis usahatani kentang di Kecamatan Pangalengan. *Jurnal Agribisnis Indonesia*, *10*(2), 389–401. https://doi.org/10.29244/jai.2022.10.2.389-401

Nursan, M., & Wathoni, N. (2021). Efisiensi teknis usahatani bawang merah di Kabupaten Bima Provinsi Nusa Tenggara Barat. *Jurnal Agribisnis Lahan Kering*, *6*(2502), 155–162. https://doi.org/10.32938/ag.v6i4.1439

Peter, W., & Orser, B. (2024). Women entrepreneurs in rural Nigeria : Formal versus informal credit schemes. *Emerald Insight*, *16*(4). https://doi.org/10.1108/IJGE-03-2023-0053

Prananjaya, I. G. N. Y. I., & Wenagama, I. W. (2023). Analisis beberapa faktor yang mempengaruhi produksi dan pendapatan pengrajin sanggah di Desa Taro Kecamatan Tegallalang Kabupaten Gianyar. *E-Jurnal EP Unud*, *12*(11), 759–770. https://doi.org/10.24843/EEP.2023.v12.i11.p04

Purwanto, A. (2025). Mengintip tren dan geliat bisnis makanan sehat makanan sehat. *Kompas ID*. https://www.kompas.id/artikel/mengintip-tren-dan-geliat-bisnis-makanan-sehat

Puspitasari, S. I. Dela, & Sudharma, I. W. P. A. (2025). Pengaruh sektor basis non pariwisata, pendidikan dan umk terhadap penyerapan tenaga kerja di Provinsi Bali. *E-Jurnal Ekonomi dan Bisnis Universitas Udayana*, *14*(10), 1475–1492. https://doi.org/10.24843/EEB.2025.v14.i10.p07

Putra, I. G. A. M., Luh Putu Wrasiati, & Yuarini, D. A. A. (2023). Effect of adding lemongrass stalks on characteristics of herbal drink lemongrass - palm sugar as a functional food. *Journal of Functional Food and Nutraceutical*, *4*(2), 103–110. https://doi.org/10.33555/jffn.v4i2.102

Putri, N. A., Hakiki, R., Purwadi, J., & Budiarjo. (2025). Analisis efisiensi proses produksi dalam meningkatkan produktivitas perusahaan manufaktur. *Jurnal Sains dan Teknologi*, *2*(2), 97–102. https://jurnal.globalscients.com/index.php/jsit/article/view/913

Rahayu, S., & Sari, C. M. (2022). Pengaruh kualitas bahan baku, tenaga kerja dan modal terhadap tingkat produksi industri Kerupuk Rejo Tulungagung. *ULIL ALBAB : Jurnal Ilmiah Multidisiplin*, *1*(8), 2560–2570. https://al-haramjournal.com/index.php/JIM/article/view/599

Rayappa, M. K. (2023). Palmyrah palm (Borassus flabellifer) non-centrifugal sugar - Current production practices as a natural sugar and a promising functional food / additive. *Journal of Agriculture and Food Research*, *14*(October). https://doi.org/10.1016/j.jafr.2023.100829

Rivai, Z., Halid, A., & Wibowo, L. S. (2023). Faktor modal dan tenaga kerja pengaruhnya terhadap produksi usahatani padi sawah Desa Sidodadi Kecamatan Boliyohuto. *Jurnal: Agricultural Review*, *2*(2), 3–12. https://doi.org/10.37195/arview.v2i2.696

Sadewo, I., Zain, S. A., Fauzan, A., & Mashuri, M. J. (2023). Pemberdayaan masyarakat melalui pengolahan siwalan (tribung) di Dusun Lembana Desa Bancamara Kecamatan Dungkek Kabupaten Sumenep. *Al Busyro : Jurnal Pengabdian Kepada Masyarakat*, *1*(1), 49–59. https://doi.org/10.52491/busyro.v1i1.51

Sarlan, M. (2020). Analisis efisiensi penggunaan faktor-faktor produksi pada usaha tani bawang merah di Kecamatan Pringgabaya Kabupaten Lombok Timur. *Journal Ilmiah Rinjani (JIR)*, *8*(2), 132–142. https://doi.org/10.53952/jir.v8i2.286

Setiyani, R., & Sepfrian, B. (2025). Analisis tipe perilaku konsumen dalam pembelian salad buah. *Journal Science Innovation and Technology (SINTECH)*, *5*(2), 19–26. https://doi.org/10.47701/sintech.v5i2.5010

Sinabang, L., Anggraeni, D., & Aliudin. (2021). Elastisitas produksi dan efisiensi penggunaan faktor produksi padi sawah pada berbagai tingkat luas lahan garapan di Kabupaten Tangerang. *Jurnal Ilmu Pertanian Tirtayasa*, *3*(2), 311–326. https://doi.org/10.33512/jipt.v3i2.13738

Sintia Ratusehaka, S. E. M. (2024). Strategi pemanfaatan pohon lontar (Borassus flebellifer) sebagai bahan baku gula merah dalam meningkatkan ekonomi keluarga Desa Oirata Timur Kecamatan Kisar Selatan. *GEOFORUM: Jurnal Geografi dan Pendidikan Geografi*, *3*(1), 35–45. https://doi.org/10.30598/geoforumvol3iss1pp35-45

Sisdiyantoro, K., & Lestari, E. D. (2022). Pengaruh modal, tenaga kerja, dan bahan baku terhadap hasil produksi industri konveksi SMB Tulungagung. *Business, Entrepreneurship, and Management Journal*, *1*(1), 24–33. https://doi.org/10.36563/bemj.v1i1.575

Sithole, K., Bulagi, M., & Belete, A. (2025). Improving sugarcane productivity and water use efficiency in nkomazi municipality through technology and resource optimisation. *African Journal of Innovation and Entrepreneurship*, *4*(1), 137–155. https://doi.org/10.31920/2753-314X/2025/v4n1a6

Suek, J., Nurwiana, I., & Wayan Nampa, I. (2025). Comparative study of lontar palm sap products for supporting access to food sustainability during the scarcity season on Rote Island. *IOP Conference Series: Earth and Environmental Science*, *1518*(1). https://doi.org/10.1088/1755-1315/1518/1/012006

Sukasih, E., & Sasmitaloka, K. S. (2024). Kajian perbaikan proses produksi gula lontar mendukung mutu dan kesesuaian standar. *Balai Besar Litbang Pascapanen Pertanian*, 235–244. https://repository.pertanian.go.id/server/api/core/bitstreams/b714575d-4b95-4fb4-b057-

0d0a4e006f4b/content

Suwatiningsih, D., Elinda Nurqomariah, D., Syifa Al, A., Novey Pertiwi, C., Rinda Ashima, A., & Saiful Anam, M. (2024). Analisis prospek pengembangan usaha pengolahan gula merah lontar dengan metode Profitability Ratio di Kabupaten Tuban. *Ekoma : Jurnal Ekonomi*, *3*(5), 1252–1258. https://al-haramjournal.id/EKOMA/article/view/4330

Syamita, I. A., Nurhapsah, & Nurhaedah. (2021). Analisis kelayakan usaha pembuatan gula merah di Kelurahan Kassa Kecamatan Batulappa Kabupaten Pinrang. *Jurnal Ilmiah Ecosystem*, *21*(3), 516–525. https://doi.org/10.35965/eco.v21i3.1143

Ubaddilah. (2024). Analisis saluran pemasaran dan struktur pasar gula siwalan di Desa Karduluk Kecamatan Pragaan Kabupaten Sumenep. *Prosiding : Seminar Nasional Ekonomi Dan Teknologi*, *3*(1), 123–133. https://ejournalwiraraja.com/index.php/PROSD/article/view/3975

Uche, Umar, Girei, & Ibrahim. (2021). Performance of Translog And Cobb-Douglas Models in the estimation of technical efficiency of irish potato production in Plateau State, Nigeria. *Journal of Tropical Agriculture, Food, Environment and Extension*, *20*(2), 62–67. https://doi.org/10.4314/as.v20i2.10

Widyawati, A. T. (2025). Siwalan pohon kehidupan berjuta manfaat. *Buletin Teknologi & Inovasi Pertanian*, 25–30. https://epublikasi.pertanian.go.id/berkala/btip/article/view/4077

Winangun, I. G. A. R. P., & Wenagama, I. W. (2024). Pengaruh modal, bahan baku, dan tenaga kerja terhadap produksi kerajinan kayu di Kabupaten Tabanan. *E-Jurnal Ekonomi Dan Bisnis Universitas Udayana*, *13*(3), 615–625. https://doi.org/10.24843/EEB.2024.v13.i03.p19