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Efficiency Improvement Strategy Using Data Envelopment Analysis (Dea) and Linear Programming Methods in a Tofu Factory in Bengkulu City

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Abstract
This study aims to analyze the level of production efficiency and determine the optimal combination of production factors at the Saiful Tofu Factory in Bengkulu City. The analytical methods used were non-pure Data Envelopment Analysis (DEA) to measure technical production efficiency and Linear Programming with the Z-maximum and Z-minimum approaches to determine optimal production conditions. Research data was obtained through observation, interviews, and documentation. Input variables include soybean raw materials, labor, energy, water, and supporting materials, while the output variable is the quantity of tofu produced. The novelty of this study lies in the integration of the non-pure DEA method with the Z-maximum and Z-minimum Linear Programming models in analyzing tofu production efficiency. The non-pure DEA analysis results showed an efficiency index value of 0.773, indicating that tofu production is relatively efficient, but still has room for efficiency improvement. The Linear Programming analysis results indicate that the production cost of Rp13,427,609.77 for producing 72,000 units of tofu is within the minimum operational limit. The maximum total revenue is Rp21,600,000, with a profit of Rp8,172,427.77 in one production period. Efforts to increase efficiency can be achieved through better management of soybean raw materials, increased energy efficiency, improved production processes, and enhanced workforce skills and discipline.

Keywords: *production efficiency, DEA, Linear Programming, tofu industry, production optimizatio*

Introduction

Background

The agribusiness sector has a strategic role in Indonesia's economic development because it is able to integrate agricultural production activities with processing industries, distribution, and marketing in a sustainable manner. According to FAO (2017), agro-industry development is key to increasing the added value of agricultural products, creating employment, and strengthening national food security. This is in line with the opinion of Sjarkowi and Sufri (2018) who stated that agro-industry plays an important role in encouraging the efficiency of agricultural systems and increasing the competitiveness of local products.

One important sub-sector in the agribusiness system is agricultural

product processing agro-industry, including the tofu industry based on soybeans as the main raw material. Tofu is a processed food product that contains high vegetable protein, is relatively affordable, and has a high consumption rate in Indonesian society. According to BPS (2023), consumption of tofu and tempeh is still the main source of protein for most households, especially in urban and rural areas.

Saiful Tofu Factory in Bengkulu City is one of the small-medium scale agro-industries that operates sustainably in processing soybeans into tofu. However, small and medium industries (SMIs) generally still face various obstacles in production management, such as the use of simple technology, limited production management, and the absence of production planning based on quantitative analysis. Wibowo and Hidayat (2019) stated that most small agro-industries still carry out production processes conventionally, thus potentially causing inefficiency in input use.

Based on initial observations at Saiful Tofu Factory, it was found that there was wastage of soybean raw materials, less than optimal use of labor, and relatively high energy and water consumption. This condition indicates that production activities are not yet at an optimal level of technical and economic efficiency. According to Coelli et al. (2017), production inefficiency occurs when the combination of inputs used has not been able to produce maximum output or when production costs have not been reduced to a minimum level.

To overcome these problems, a quantitative analysis approach is needed that is able to provide optimal solutions systematically. Operations Research is an appropriate scientific approach to assist production decision-making through mathematical modeling. Taha (2017) explains that operations research is designed to determine the best (optimal) decision by considering various existing resource constraints.

One of the main methods in operations research is Linear Programming (LP), which allows the formulation of production models with two main orientations, namely maximizing profit or output (Z maximum) and minimizing costs or input use (Z minimum). According to Hillier and Lieberman (2021), Linear Programming is very effective in production planning because it is able to determine the most efficient combination of inputs by considering constraints of raw materials, labor, and production capacity.

In addition, to measure the actual level of technical efficiency of the ongoing production process, the Data Envelopment Analysis (DEA) method is used. DEA is a non-parametric method used to assess the relative efficiency of a production unit based on the relationship between inputs and outputs. Cooper, Seiford, and Tone (2020) state that DEA is very suitable for evaluating the performance of small and medium enterprises because it does not require certain production function assumptions and is able to identify sources of inefficiency specifically.

By combining the Operations Research approach through the Z maximum and Z minimum models as well as Data Envelopment Analysis (DEA), this study is expected to provide a comprehensive picture of production efficiency while producing recommendations for optimal input combinations for Saiful Tofu Factory, Bengkulu City.

Problem Formulation

Based on the background, the problem formulation of this research is:

What is the level of technical efficiency of tofu production at Saiful Tofu Factory based on the DEA method?

How is the tofu production optimization model based on Linear Programming with the Z maximum and Z minimum approaches in producing the most

efficient combination of production inputs at Saiful Tofu Factory?
What strategies can be implemented to improve the efficiency of tofu production at Saiful Tofu Factory?

Research Objectives

To analyze the level of technical efficiency of tofu production using the Data Envelopment Analysis (DEA) method
To develop a production optimization model with the objective functions of Z maximum and Z minimum to determine the optimal solution for the use of production inputs at Saiful Tofu Factory
To provide strategic suggestions that can be implemented to improve production efficiency at Saiful Tofu Factory

Benefits of Research Theoretical Benefits:

This research is expected to contribute to the development of agribusiness science and production management, particularly in the application of Operations Research methods (Linear Programming with Z maximum and Z minimum approaches) and Data Envelopment Analysis (DEA) to analyze the production efficiency of small-medium scale food agro-industry.

Practical Benefits:

Practically, this research is expected to provide applicable recommendations for Saiful Tofu Factory, Bengkulu City in determining the optimal combination of production inputs, including the use of soybean raw materials, labor, energy, and water.

Research Methods

Research Location and Time

This research was conducted at Saiful Tofu Factory located on Jalan Tribrata, Cempaka Permai Village, Gading Cempaka District, Bengkulu City. The research was conducted from December 2025 to January 2026.

Data Collection Methods

This study uses two types of data:

a. Primary Data

Primary data were obtained directly from the field through interaction with parties involved in the tofu production process, including:
Owner or manager of Saiful Tofu Factory
Production workers
Primary data collection methods include:
Structured interviews
Direct observation
Questionnaires

b. Secondary Data

Secondary data were obtained from:
Department of Industry and Trade of Bengkulu City
Central Bureau of Statistics (BPS)
Scientific literature and previous research results
Internal documents of Saiful Tofu Factory

Respondent Determination Method

Respondents were determined using purposive sampling method with criteria of respondents who directly understand the production process. The respondents in this study consisted of:
Owner/manager of Saiful Tofu Factory (1 person)
Head of production section or foreman (1 person)
Production workers (11 people)
Total respondents were 13 people.

Data Analysis Methods

Efficiency Analysis with Non-Pure Data Envelopment Analysis (DEA)

Since the study only involved one business unit (1 DMU), a non-pure DEA approach was used with the formula:

$$\textbf{Efficiency} = Y / \sum X_i$$

Where:
Y = amount of tofu output
X_i = i-th production input
For easier interpretation, the efficiency value is transformed into an efficiency index (0–1):

Efficiency Index = Y / (Y + $\sum X_i$)
Assessment criteria:
Value close to 1: business is more efficient
Value close to 0: business is less efficient

Optimization Analysis with Linear Programming
Z Maximum Model (maximizing output):
Objective function: Z max = $c_1X_1 + c_2X_2 + c_3X_3 + c_4X_4$
Constraints: limitations of raw materials, labor, energy, and water
$X_j \geq 0$

Z Minimum Model (minimizing costs):
Objective function: Z min = $c_1X_1 + c_2X_2 + c_3X_3 + c_4X_4$
Constraints: Output ≥ production target
$X_j \geq 0$
Optimization analysis used Microsoft Excel Solver.

Results and Discussion
General Conditions of Research Location
This research was conducted at Saiful Tofu Factory located on Jalan Tribrata, Cempaka Permai Village, Gading Cempaka District, Bengkulu City. The location is a residential area that develops with small and medium-scale economic activities, including household businesses and food processing industries.
Geographically, Cempaka Permai Village is located in the urban area of Bengkulu City with relatively good accessibility. Around the factory location, there is a river that plays an important role in supporting tofu production activities, particularly in meeting water needs for the soaking, washing, and soybean processing.

Respondent Characteristics
The respondents in this study consisted of:
1. Business Owner/Manager
The owner and manager of Saiful Tofu Factory has a high school education level. This tofu business has been operating since 2009, so the owner has more than a decade of business experience.
2. Production Workers
The number of workers is 11 people, with the following education levels:
2 people with junior high school education
9 people with high school education
All workers acquire skills through direct experience (learning by doing).

3.3 Efficiency Calculation Results with Non-Pure DEA Method
Input and output production data of Saiful Tofu Factory in one production period are presented in Table 1.

Table 1. Production Input and Output Data of Saiful Tofu Factory

Variable	Value	Unit
Soybeans (X_1)	1000	kg
Labor (X_2)	11	people
Electricity (X_3)	69.252	kWh
Wood (X_4)	2	m^3
Diesel Fuel (X_5)	10	liters
Water (X_6)	20000	liters
Cooking Oil (X_7)	20	liters
Vinegar (X_8)	3	liters
Salt (X_9)	1	kg
Tofu Output (Y)	72000	units

Source: Primary data 2026

Total input calculation:
Total Input = 1,000 + 11 + 69.252 + 2 + 10 + 20,000 + 20 + 3 + 1 = 21,116.252
Efficiency value calculation:
Efficiency Value = 72,000 / 21,116.252 = 3.41
This means that each unit of production input used is able to produce an output of 3.41 units.
Efficiency index calculation:

Efficiency Index = 72,000 / (72,000 + 21,116.252) = 0.773 or 77.3%
The efficiency index value of 0.773 or 77.3% indicates that tofu production at Saiful Tofu Factory is classified as efficient. However, there is still a potential efficiency increase of 22.7% that can be achieved through improvements in production management, input usage efficiency, improvement of worker skills, and application of more efficient production technology.
This result is in line with research by Ristiani et al. (2024) which stated that small and medium-scale tofu industries are generally quite efficient, but not yet fully optimal from a technical perspective.
Factors affecting efficiency include:
Less than optimal soybean soaking process (less than 30 minutes)
Less than effective worker performance
Need to improve management of imported soybean raw materials

3.4 Production Cost Optimization Results (Z Minimum) and Revenue (Z Maximum)

3.4.1 Production Costs Before Optimization

Based on initial calculations, the total production cost incurred to produce 72,000 units of tofu was Rp13,427,609.77. This value reflects the actual production cost conditions in the field before the optimization process.

Table 2. Production Cost Components Before Solver

Component	Amount	Unit Price (Rp)	Total Cost (Rp)
Soybeans	1000 kg	10,000	10,000,000
Labor	11 people	120,000	1,320,000
Electricity	69.252 kWh	1,444	100,000
Wood	2 m³	700,000	1,400,000
Diesel Fuel	10 liters	10,000	100,000
Water	20,000 liters	0	0
Cooking Oil	20 liters	15,000	300,000
Vinegar	3 liters	33,000	99,000
Salt	1 kg	19,000	19,000
Depreciation Cost	-	-	48,513.88
Land & Building Rent	-	-	41,095.89
Total			**13,427,609.77**

Source: Primary data processed 2026

3.4.2 Z Minimum Optimization Results

After optimization with Excel Solver, all decision variables were mathematically zero because the cost optimization model without minimum production constraints would choose the lowest cost, which is zero. However, this result does not reflect actual production conditions because the production process cannot run without inputs.

By comparing production cost conditions before and after optimization, it can be concluded that the actual production cost of Rp13,427,609.77 is the **minimum operational cost** that must be incurred to produce an output of 72,000 units of tofu. This shows that operationally:
The business has been cost-efficient
There are no production inputs that can be reduced without decreasing the amount of production
Production cost savings cannot be achieved through reducing input quantities

This finding is in line with Heizer and Render (2017) who stated that optimization results do not always result in cost reduction, but can function to confirm that the production system is at optimal condition.

3.4.3 Z Maximum Optimization Results (Revenue)

Based on production data, the amount of tofu output produced in one production period is 72,000 units, with a selling price of Rp300 per unit.

Table 3. Total Revenue

Component	Amount (units)	Selling Price (Rp)	Total (Rp)
White Tofu	36,000	300	10,800,000
Fried Tofu	28,800	300	8,640,000
Pong Fried Tofu	7,200	300	2,160,000
Total	**72,000**		**21,600,000**

Source: Primary data processed 2026

Production is dominated by white tofu (50%) due to high market demand and simpler production process, followed by fried tofu (40%) and pong fried tofu (10%).

3.4.4 Business Profit

Profit = Z Maximum – Z Minimum
= Rp21,600,000 – Rp13,427,609.77
= **Rp8,172,427.77** per production period
This profit value indicates that Saiful Tofu Factory is able to generate significant economic added value in one production period. According to Fauzi et al. (2024), the greater the difference between revenue and production costs, the higher the level of business efficiency.

3.5 Production Efficiency Improvement Strategies

Based on the results of efficiency analysis using the non-pure Data Envelopment Analysis (DEA) method and the results of production cost and revenue optimization, the following strategies can be implemented to improve production efficiency:

1. **Soybean Raw Material Management**
Soybean raw material is the largest cost component in the tofu production cost structure. In addition, most of the soybeans used are imported so their availability and prices are greatly influenced by international market conditions and exchange rates. Strategies that can be implemented:
Choose trusted suppliers to maintain supply stability
Ensure good soybean quality during storage
Control the use of raw materials to prevent wastage during the production process

2. Energy Efficiency Improvement
Uncontrolled energy use can cause cost wastage in the long term. Strategies that can be implemented:

Plan production time more systematically
Perform regular equipment maintenance to make fuel use more efficient
Consider using alternative energy such as palm kernel shells as a substitute for wood fuel

3. Production Process Improvement
More effective workflow arrangement can reduce waiting time between processes.
Strategies that can be implemented:
Apply standard soybean soaking time (±30 minutes) so that soybeans become softer and easier to grind
Standardize each production stage (soaking, grinding, boiling)
Maintain consistent tofu quality

4. Improvement of Worker Skills and Discipline
Workers who have good skills and understanding of the production process will be able to work faster and more efficiently. Strategies that can be implemented:
Conduct continuous skills training
Improve work time discipline
Avoid habits that can hinder the production process (too frequent breaks, smoking during working hours)

4. Conclusions and Suggestions
4.1 Conclusions
Based on the results of analysis and discussion, it can be concluded as follows:

Technical Efficiency Level (DEA Method)
The results of efficiency calculation using the non-pure Data Envelopment Analysis (DEA) method showed an efficiency index value of 0.773 or 77.3%. This means that tofu production at Saiful Tofu Factory is classified as efficient, but still has a potential efficiency increase of 22.7% through improvements in input management and production processes.

Production Optimization Model (Linear Programming)
Based on the results of analysis using the Linear Programming method, the actual production cost of Saiful Tofu Factory of Rp13,427,609.77 to produce 72,000 units of tofu has been at the minimum operational limit. The maximum total revenue obtained was Rp21,600,000, so the business profit reached Rp8,172,427.77 in one production period. Production is dominated by white tofu (50%), followed by fried tofu (40%) and pong fried tofu (10%), in accordance with the level of market demand.

Production Efficiency Improvement Strategies
Efforts to improve efficiency cannot be done through reducing production inputs, but through improving the production system, including:
Better management of soybean raw materials
Increasing energy efficiency through more economical fuel use or alternative energy
Improving production processes with clear work standards
Improving worker skills and discipline

4.2 Suggestions
Based on the research results, the suggestions that can be given are as follows:
Saiful Tofu Factory is advised to improve production efficiency through improving work processes and controlling input use, especially soybean raw materials which are the largest cost component.
Energy savings and management need to be done in a more planned manner, including considering the use of alternative energy such as palm kernel shells as a substitute for firewood, so that production efficiency can be improved in the long term.

Improvement of worker skills through continuous training and work experience needs to be done to support productivity and production quality. Workers are expected to work diligently and avoid habits that can hinder the production process.

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