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RESEARCH ARTICLE

OPTIMAL CONVERSION OF PADDY BIOMASS INTO RUMINANT FEED PELLET FOR LOCAL MEAT PRODUCTION USING OPTIMIZATION MODELLING

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ABSTRACT

In Malaysia, the rice industry produces a significant amount of byproducts like rice husk and rice straw. However, finding efficient ways to dispose of and utilize these byproducts poses challenges. The paddy biomass has economic potential, but there is a lack of information on the most profitable technology to use in the local rice industry. This limited knowledge hinders the effective utilization of paddy biomass and the ability to maximize its economic value. Therefore, this study focuses on optimizing the profitability of converting paddy biomass into ruminant feed pellets using the General Algebraic Modeling System (GAMS). The research includes stages such as identifying challenges and requirements, constructing simplified models, developing a profit-maximizing model, and conducting sensitivity analysis. The analysis revealed the successful revenue generation and profitability achieved through the production of paddy biomass and the sale of livestock meat. The profit of livestock industry was measured based on the amount of livestock produce and the sale of livestock meat. The annual profit of RM 5,999,900.00 highlights the ability to generate significant returns. Notably, the substantial output of paddy biomass greatly contributed to revenue generation, underscoring the importance and demand for paddy biomass in ruminant feed pellet production. The estimated return on investment (ROI) of approximately 3.14% signifies a positive return on the initial investment, indicating profitability. Additionally, the estimated payback period of approximately 0.24 years suggests a short duration for recovering the initial investment. This case study provides valuable insights into the factors influencing profitability and offers guidance for maintaining and improving financial success in the industry.

KEYWORDS

Paddy Biomass, Optimization Modelling, Mixed-Integer Linear Programming, Circular Economy.

1. INTRODUCTION

Rice is a staple food for Malaysian and most Asian countries and has played a significant aspect in culture and identity. Malaysians consume up to 80 kg of rice per person each year, compared to the global average of 55 kg (Malaysia, J. P., 2018). A plate of rice begins its journey on the farm where seeds were spread across 700,000 hectares of land. According to Jabatan Pertanian Malaysia (JPM) the second-largest agricultural activity in Malaysia after the palm oil sector is rice farming. 2018 is the year that the cultivation of rice spread across 689 810 hectares. JPM also stated that contrarily, the production of rice increased favourably from 2 138 788 tons in 1994 to 3 064 822 tons in 2018. As of these factors, it can be seen that waste from paddy cultivation will also increase significantly along with the increase of paddy cultivation.

Based on Figure 1, rice production in Selangor, Malaysia has shown a slight increase since 2013. Selangor ranks as the second largest rice producer in Malaysia, trailing behind Kedah (Kalvani et al., 2022). The primary rice cultivation regions in Selangor are the Integrated Agricultural Development Area (IADA) Barat Laut Selangor (BLS) and the IADA Kuala Selangor (KS). Average, paddy yield in Selangor reaches approximately 4,500 kilograms per hectare, surpassing the national average yield in Malaysia (Kalvani et al., 2022). This indicates that rice farming in Selangor is relatively productive

There are two types of waste that the paddy industry generated, one is paddy straw and another one is paddy husk. After the rice is harvested, a residue called rice straw is created, consisting of leaves and stems (Muda, L. K., 2011). Traditionally, straws were piled up and ploughed, burned, or pillaged. As stated by Lembaga Kemajuan Pertanian Muda (MADA), straw made up the remaining 45% to 50% of the overall rice production. Rice and rice straw are products of rice farming, and the ratio of rice to straw is estimated to be 0.45: 0.55. Based on this ratio, high-producing areas produce 5.5 tons of rice straw overall per hectare. MADA also affirm that a byproduct of the rice processing process in rice mills is rice husk. A portion of rice known as the husk is dry, scaly, and unpalatable.

To improve this problem, extensive efforts have been done by the farmers to explore the prospect of crop residue usage. One of the efforts that had been made was the rice residues were used to feed ruminant livestock. According to the research, the main obstacle to livestock production is a lack of high-quality and sufficient feed (Du et al., 2019). Grass and agricultural byproducts are the main sources of feed for animals. As a result, low-quality roughage is fed to animals, which lowers production. Therefore, efforts were made to identify appropriate substitute techniques for its application. One of the finest techniques right now is conversion to nutritionally enhanced full-feed pellets (Jeon et al., 2019). Pellets technology and uses, as well as research into the nutritional value and productivity of ruminant livestock, have all been developed to help

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improve feed quality. When turning paddy waste into pellets, an optimization process is employed to maximise the yield of pellets while lowering production costs and environmental impact (Adjorlolo et al., 2020).

In this case, one of the greatest solution that has is to use optimization modelling. Modeling is the process of creating a representation of something to enhance the understanding and predict its behavior. According the modelling can take various forms, such as physical models that use tangible objects or mathematical models that utilize equations (Gianni et al., 2018). Another type is computational modeling, which employs computers to simulate real-world systems. Each modeling approach has its strengths and weaknesses. Physical models offer accuracy but can be costly and time-consuming while mathematical models are flexible but can be challenging to develop and solve (Bolzoni et al., 2021). Computational models are fast and efficient but require careful validation to ensure accuracy (Bolzoni et al., 2021). Despite the limitations, models provide valuable insights into complex systems. It can help comprehend system behavior, predict future outcomes, test policies and strategies, and improve system design (Zarei et al., 2021).

The best planning in terms of cost and economy for pelletizing paddy waste into animal pellets has not yet been developed in Malaysia, even though various research on the possibility of transforming paddy waste into livestock pellets have been undertaken. Using a mathematical optimization model, the current work aims to create and construct the best operational plan to turn paddy waste into animal pellets. With the aid of this model, planners may develop and assess ideal pelletizing designs that cut costs while boosting prospective profits. In this study, mixed-integer linear programming (MILP) of GAMS modelling is utilized to apply mathematical methodologies to situations with specific features.

2. Materials And Methods

2.1 Research Methodology

The objective of the research methodology is to identify the most efficient process for turning paddy waste into ruminant livestock pellets, which requires several steps. The methodology's flowchart may be seen in Figure 3 and includes the following steps: problem definition, superstructure development, model formulation, data input, GAMS coding, result generation, and result analysis.

The conversion of paddy waste into ruminant livestock pellets that is relevant to the problem is defined in the earlier step of stage 1 (problem analysis). To tackle the issue, the number of crucial questions was determined. A case study was created and presented relating the paddy waste and ruminant livestock pellets. Superstructure diagrams are then created in step 2 (Superstructure development) based on various case studies. For the indicated model, the resulting superstructure is streamlined.

The model formulation is developed in step 3 (Model formulation). The analytical model is chosen in this step to finish the optimization model. The goal of the developed mathematical model was to maximize profitability. The objective function and equality constraint were divided by two in the model that was created. While the equality constraint places restrictions on the optimization model, the objective function describes the optimization's purpose. In stage 4 (result analysis), the outcome was examined using sensitivity analysis to determine the optimization model's degree of accuracy.

The problem at hand is the lack of comprehensive information and analysis on the most profitable technology for the utilization of paddy biomass in the Malaysian paddy industry. The paddy industry generates a significant amount of biomass in the form of rice husk and paddy straw, but there is limited knowledge about the optimal technology that can effectively utilize this biomass and provide economic benefits to the industry. Several key questions should be answered throughout the decision-making process,

- Is it feasible to convert paddy biomass into ruminant pellets?
- Is it economical to convert paddy biomass into ruminant pellets?
- What is the revenue from the ruminant pellet sales in the industry?

The problem that has been identified in this study is the possibility and feasibility for the conversion of paddy biomass into the ruminant pellet. Paddy biomass which is the rice straw is selected to be processed into the ruminant pellets. The optimization in GAMS modelling was used to identify whether it is profitable to use paddy biomass on the production of ruminent pellets in feed mill.

2.2 Superstructure Development

A superstructure was develop to consider all possible solution in order to solve the problem in problem definition step which is to find maximum profit in conversion of paddy biomass into the ruminent pellet. Superstructure development of optimization model is shown in Figure 2. The superstructure is divided into 4 major element which are type of resources, processing technology, demand of pellet and production of meat. Each element is represented by each set in simplified superstructure model shown in Figure 3. The character i represent type of resources, j represent processing technology, k represent demand of pellet and m represent production of meat.

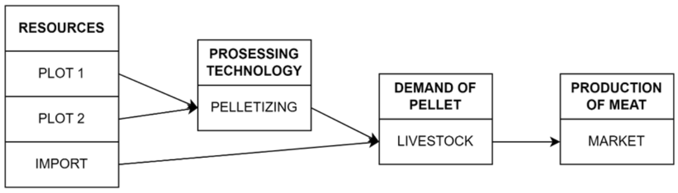

Figure 1 : The superstructure of of paddy feed pellet conversion

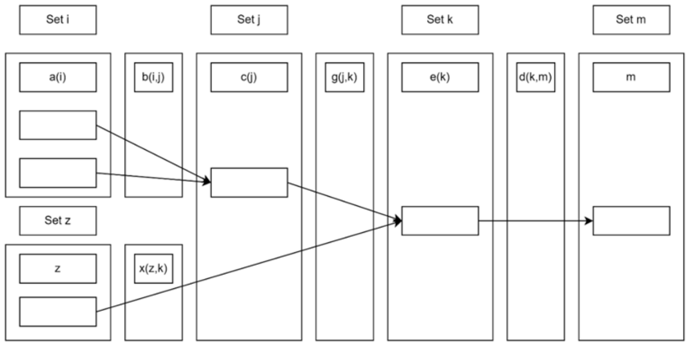

Figure 2 : The simplified superstructure of paddy feed pellet conversion

2.3 Model Formulation

The analytical model was developed based on a simplified superstructure of optimization model presented in superstructure development. Significant key variables such as the profit, production cost, sale, transportation cost, and imported pellet are being addressed using model equations (Table 3). Type of model used in GAMS modeling is linear programming model (LP). Linear programming (LP) is a mathematical optimization technique used to find the best possible outcome in a given mathematical model with linear relationships. The General Algebraic Modeling System (GAMS) is a high-level modeling and optimization language widely used for mathematical programming. In GAMS, a linear programming model is represented using variables, constraints, and an objective function.The main function of a linear programming model in GAMS is to optimize a given objective while satisfying a set of linear constraints. It used to represent and solve optimization problems with linear relationships efficiently. It helps find the best possible solution given the objective and constraints, supports decision making, and provides insights into the trade-offs and sensitivities of the model.

2.4 Objective Function

Sales and production costs have a simultaneous effect on profit (Suzan and R, 2020). The objective function was presented to maximize the total profit in conversion of paddy biomass into the ruminent pellets by correlation of variables and constraints based on the study of Effect of production Costs and Sales on the Company's Net Profit that was conducted by (Suzan and R 2020). The maximum profit equation are shown in the Equation 1. The objective functions are determined with the summation of pellet sale differences with raw and operating cost of pellets.

$$Profit = \sum sale - \sum productioncost - \sum transportationcost - \sum importedpelletcost \quad (1)$$

he abbreviation Profit stands for total profit, sale represent the revenue generated from sales, productioncost represent the capitol cost and maintenance cost, transportationcost represent the cost of delivery, whereas importedpelletcost stand for amount of pellet imported. Equation

2 is to calculate the revenue by multiplying meat produce with the price of meat per kg.

2.5 Equality Constraints

Equality constraints will consider distinguishing factors of raw materials, technology conversion and product. Equation 2 is to calculate the revenue by multiplying meat produce with the price of meat per kg.

$$sale = \sum((k,m), d(k,m) * price(m)) \quad (2)$$

The abbreviation (k,m) stands for the conversion from livestock to meat produce, d(k,m) represent quantity of meat produce (product), whereas price(m) stand for market price of meat per kg. Equation 3 is to calculate the transportation cost by multiplying the distance value in km with cost for delivery in RM per km.

$$transportationcost = ((i,j), transportation\_value(i,j) * R * b(i,j)/1000) \quad (3)$$

The abbreviation (i,j) is the distance value in km, R represent the unit cost for delivery in RM per km and b(i,j) stand for amount of straw from i transport to pelletizing facilities j in kg per year. Equation 4 is to calculate the production cost by summation of capitol cost and maintenance cost.

$$productioncost = \sum (j, capcost(j) + maincost(j)) \quad (4)$$

The abbreviation j is the processing technology, capcost(j) represent the capitol cost for pelletizing technology conversion whereas maincost(j) stands for maintenance for pelletizing technology. Equation 5 is to calculate the imported pallet by multiplaying the price import and the amount of pellet imported.

$$importedpellet = \sum ((z,k), priceimp(z) * x(z,k)) \quad (5)$$

The abbreviation priceimp(z) the price of pellet imported per kg in RM, whereas x(z,k) stands for amount of pellet imported in kg per year. Equation 6 is to determine the summation of paddy biomass in plot 1 and plot 2 and the distance of the 2 plot to the pelletizing technology

$$c(j) = \sum(i, b(i,j)) \quad (6)$$

The abbreviation c(j) is the amount of paddy biomass at pelletizing facilities j in kg per year, i stands for type of resources whereas b(i,j) is distance between the type of resources and pelletizing technology. Equation 7 is to determine the quantity of pellet produce after the pelletizing.

$$g(j,k) = c(j) * conversion\_a(j,k) \quad (7)$$

The abbreviation g(j,k) is the amount of pellet produce from pelletizing facilities j, whereas conversion_a(j,k) is the ratio of the pellet produce based on the paddy biomass received. Equation 8 is to determine the summation of the pellet produce and the pellet imported

$$e(k) = \sum(j, g(j,k)) + \sum(z, x(z,k)) \quad (8)$$

The abbreviation e(k) is the amount of pellet supply at livestock, g(j,k) is the amount of pellet produce from pelletizing facilities j, whereas x(z,k) is the amount of pellet imported in kg per year. Equation 9 is to calculate the quantity meat are produce.

$$d(k,m) = e(k) * conversion\_b(k,m) \quad (9)$$

The abbreviation d(k,m) is the amount of meat produce in kg per year, e(k) is the amount of pellet supply at livestock and conversion_b(k,m) is the ratio of meat produce based on the pellet received at the livestock facilities.

2.6 Inequality Constraints

Equation 10 shows that the quantity of paddy biomass received at facilities j not exceed the quantity paddy biomass produce.

$$a(i) \geq \sum(j, b(i,j)) \quad (10)$$

The abbreviation a(i) is the amount paddy biomass produce yearly, j is the peletizing facilities whereas b(i,j) is amount of paddy biomass from i transport to pelletizing facilities j. Equation 11 shows that the quantity of pellet imported received at facilities k not exceed the quantity of pellet imported that were produce

$$eqpcapacity_p \geq \sum_i b_{i,p} \quad \forall\, p \quad (11)$$

The abbreviation ampimport(z) is the amount of pellet imported in kg, k is the livestock facilites whereas x(z,k) is the amount of pellet imported in kg per year that were received at the facilities k. Equation 12 shows that the supply quantity of pellet supply at facilities k must exceed the demand of livestock in facilities k

$$e(k) \geq demand(k) \quad (12)$$

The abbreviation e(k) is the amount of pellet supply at livestock facilites k whereas demand(k) is the demand of pellet needed in the facilities k.

2.7 Analytical Method and Calculation

The results undergo thorough analysis to evaluate the functionality of the model by assessing the individual profit generated for each bio-product. In this analytical phase, an economic evaluation is conducted to scrutinize the rationality of the outcomes derived from the developed model. This evaluation encompasses the scrutiny of return on investment (ROI) and the payback period, categorized and compared based on the optimized mass balance. This approach provides a nuanced perspective on the industry, considering the outlined factors and constraints within the selected case study. Moreover, it furnishes an overview of the industry operating at maximum capacity for comparative purposes.

Sensitivity analysis is employed to further substantiate the model's functionality and to identify the weightage of constraints. Subsequently, data is extracted for the calculation of return on investment and payback period for each factor, incorporated into GAMS software version 40.1. The sensitivity analysis entails adjusting the multiplication factor (-45%, -30%, -15%, 15%, 30%, and 45%) to verify the coding and compare the results with manual calculations. For instance, the developed model is deemed logically sound if the total profit generated by the model decreases as the cost of biomass material increases. Once the model is established as reliable, additional factors and constraints can be incorporated. Finally, after all factors are included, an overarching sensitivity analysis is conducted to ascertain the weightage of constraints. This analysis aims to pinpoint the significant factors impacting the profitability of the biomass industry.

2.8 Data Input Case Study - Sekinchan, State of Selangor (Malaysia)

The case study area, PKPK Sekinchan within the Kawasan Pembangunan Pertanian Bersepadu (IADA), Barat Laut Selangor region, was chosen to demonstrate the developed model due to the increasing production of paddy biomass. Additionally, Malaysia's annual production of 2.6 million tons of paddy grain valued at RM 2 billion, with an average growth rate of 3.7% per year over the last five years, highlights the significance of the agricultural sector in the region (Siwar et al., 2014).

The limited utilization of rice straw for ruminant feeding in Malaysia, despite the availability of well-established processing technologies, further emphasizes the need to address this issue (Zahari and Wong, 2009). By focusing on the PKPK Sekinchan area and involving the Kawasan Pembangunan Pertanian Bersepadu (IADA), the case study aims to showcase how the developed model can be implemented to maximize the potential of paddy biomass, specifically rice straw, in livestock feeding or other value-added applications.

The production of rice grain in Selangor, Malaysia was 733,992 kg and 134,196 kg in two different places. Typical values for straw: grain ratios for rice, which range from 0.7 to 1.5 (Bakker et al., 2013). This means that for every ton of rice grain produced, approximately 700 to 1,500 kg of rice straw is generated. Applying these ratios, the estimation of the production of rice straw in each location. For the first place with a rice grain production of 733,992 kg, the lower bound of the straw: grain ratio yields approximately 513,794 kg of rice straw, while the upper bound indicates around 1,100,988 kg of rice straw. In the second place, with a rice grain production of 134,196 kg, the lower bound of the ratio results in approximately 93,937 kg of rice straw, and the upper bound suggests around 201,294 kg of rice straw. Therefore, the approximate production of rice straw in the first place ranges from 513,794 kg to 1,100,988 kg, while in the second place, it ranges from 93,937 kg to 201,294 kg. These estimations as shown in Table 1 provide an understanding of the expected amounts of rice straw generated based on the given rice grain production figures and the typical straw: grain ratios (Bakker et al., 2013).

Based on the given information, the most significant variables in cost computation for project assessment and analysis are capital and maintenance costs. These costs are estimated based on existing or planned projects, considering factors such as system design, configuration, and construction. To provide a comprehensive estimate of costs, a table is provided that includes the capital and maintenance costs of pelletizing technology, as well as the transportation cost for paddy straw to the pelletizing place. The total cost production of pelletizing technology is obtained from the Feed Manufacturing Costs and capital requirements as shown in the Table 2. It's important to note that the transportation cost of paddy straw to the pelletizing place is estimated based on the distance between the production location of paddy straw and the pelletizing place (Table 3). The costs outlined in the table are determined based on the capacity of equipment and pelletizing technology in a feed mill. This cost estimation table serves as a valuable tool for project assessment and analysis, allowing stakeholders to consider the capital and maintenance costs associated with pelletizing technology, as well as the transportation costs for paddy straw.

Table 1: Rice Grain and Paddy Straw Produced in a year.

	Plot 1	**Plot 2**
Rice grain produced (kg/year)	733992	134196
Paddy straw produced (kg/year)	513,794 - 1,100,988	93,937 - 201,294

Table 2: Capital and Maintenance Cost

Annual owning cost (cost)	Total (RM)
Capital Cost	1,113,860.00
Maintenance Cost	335,420.00

Table 3: Transportation Cost to Pelletizing Place

	RM/km	Distance(km)	Amount of paddy straw (kg/year)	Total (RM)
Plot 1	0.25	20	1,100,988	5504940
Plot 2		85	201,294	4277497.5

The daily pellet feed requirement for a cow is influenced by various factors including body weight, age, stage of production, activity level, and the nutritional composition of the pellets. These factors must be taken into account when determining the appropriate feed amount for a cow. Feeding an animal an incorrect amount of feed, whether it is pellets or any other type, can have negative consequences on their health and digestion. Overfeeding dehydrated pellets can lead to digestive upsets and may cause cows to reduce their feed intake, To ensure proper feeding, it is essential to consider the specific needs of the cow and calculate the average daily intake based on factors such as body weight, nutritional requirements, and the quality of the feed. Dairy cows typically consume around 1.8% to 2.5% of their body weight in dry matter feed per day. This includes forage (such as hay or pasture) and concentrates (such as pellets or grain). Of that total, concentrate feeds like pellets generally make up a smaller portion, typically ranging from 0.5% to 1% of their body weight ("Feeding Dairy Cows," 1900b). According to ("Feeding Dairy Cows," 1900b), to calculate the daily pellet feed requirement for a cow, the following factors are needed to consider:

- Body weight (BW): Determine the weight of the cow in kilograms (kg).
- Dry matter intake (DMI): Estimate the dry matter intake as a percentage of the cow's body weight. This value depends on various factors, such as the cow's physiological stage, production level, and feed quality. It typically ranges from 2% to 3% for lactating cows and 1.5% to 2.5% for dry cows. Assume a dry matter intake of 2%.

Percentage of pellet feed in the diet: Determine the percentage of the cow's diet that should consist of pellet feed. This value can vary depending on the cow's nutritional requirements and the composition of the pellet feed.

To calculate the daily pellet feed requirement:

$$Daily\ pellet\ feed\ requirement\ (in\ kg) = BW\ (in\ kg) \times DMI\ (\%) \times Percentage\ of\ pellet\ feed\ in\ the\ diet\ (\%) \quad (13)$$

The following Table 4 is the estimation of pellet feed that were needed in a cattle farm in Selangor.

Table 4: Feed Pellet Requirement for a cow

Approximately Body Weight (kg)	Percentage of pellet feed (%)	DMI (%)	Daily pellet feed requirement (kg)	Total pellet feed requirement in a year (kg)	Feed Pellet Requirement for:
600	50	2	6	2190	1 cow
600	50	2	1800	657000	300 cows

3. Results

The feature of the developed model with Mixed Integer linear programming (MILP) functions in this case study is to optimize the production and profitability of Paddy biomass-feed pellet conversion in the ruminant feed industry. The model aims to eliminate unprofitable or low-profit production processes and identify optimal operations. By formulating a mathematical model within the GAMS modelling environment, the developed model can calculate and optimize various financial metrics such as annual profit, return on investment, and payback period (He et al., 2020). These calculations provide valuable insights for decision-making in the feed mill industry.

Furthermore, the model incorporates additional functions to display the optimal quantity of paddy straw required to meet livestock demand, the maximum sales of meat produced, and the resulting annual profit for the industry. These factors are crucial considerations for the feed mill industry as they affect overall profitability. To analyze the impact of various factors and constraints on the total profit of the industry, a sensitivity analysis is conducted. This analysis allows for the examination of the relationship between specific dependent variables and different values of independent variables under certain conditions. The results of the sensitivity analysis can provide insights into the industry's performance and guide decision-making processes and viable to infer that a sustainable production performance can achieve more revenue and profit (Tseng et al., 2021).

Overall, the developed model with MILP functions, mathematical formulation, financial analysis capabilities, and sensitivity analysis contributes to optimizing operations, maximizing profitability, and facilitating informed decision-making in the Paddy biomass-feed pellet conversion and ruminant feed industry.

3.1 Optimal Mass Balance and Economic Value

The quantities of paddy straw that was produced from two plots, are Plot 1 yielding 1,101,000 kg and Plot 2 yielding 13,012 kg. These figures give an insight into the scale and distribution of straw production. To produced 1 kg of ruminant feed pellet, nearly 50% of the ingredient is paddy straw (Wadhwa et al., 2021),. Based on the demand of the livestock, the yielding

Table 5: The profit and results analysis on the case study

	Plot 1 (1101000 kg)	Plot 2 (13012 kg)	Imported cost (100,000kg)
Annual Profit	RM 5,999,900.00		RM 170,000.00
Production cost (Capital and maintenance cost)	RM 1,449,300.00		
Sale	RM 7,629,000.00		
Transporttion Cost	RM 9,782.44		
ROI (%)	3.14% (approx.)		
Payback Period	0.24 years (approx.)		

of paddy straw from both plot is the exact amount of paddy straw needed to produce the feed pellet. Utilizing paddy straw in combination with complete feed and biological agents is essential at present to maximize the benefits of available feeds in animal production systems. This approach allows for optimizing the nutritional value and digestibility of paddy straw, which is abundant but otherwise limited in direct use as animal feed (Li et al., 2021). This strategy not only improves the efficiency of animal production systems but also promotes sustainable agriculture by utilizing agricultural by-products effectively. Customized approaches should be developed in consultation with experts considering factors like animal species, nutritional requirements, and local conditions. (Sheikh et al., 2018)

Based on the table below. the significant annual profit of RM 5,999,900.00 highlights the successful revenue generation, which can be attributed to the combined output of paddy biomass in Plot 1 with 1,101,000 kg and Plot 2 with 13,012 kg. The demand for paddy biomass, particularly for producing ruminant feed pellets, appears to be significant, contributing to the overall profit. The production costs of RM 1,449,300.00 encompass both capital and maintenance expenses. It is crucial to analyze these costs to determine the impact on the overall profitability. Assessing the production processes, equipment efficiency, and maintenance strategies can help identify areas for cost optimization and further enhance the financial stated that any cost of resources used in the production process, and their management is essential for assessing the effectiveness of management actions (Trofimova et al., 2021).

Next, the sales revenue of RM 7,629,000.00 played a significant role in generating the annual profit (Table 5). Analyzing the sales performance and market demand reveals the revenue generated from selling the meat of the livestock. Lastly, The transportation cost of RM 9,782.44 represents the expenses incurred in transporting the harvested products. Although relatively low compared to other figures, it is still important to optimize transportation to minimize costs and maximize profitability.

Return on Investment (ROI) is a crucial metric for assessing the profitability of an investment. In this case study, the calculated ROI is approximately 3.14%. This indicates that for every RM invested, the business generated a return of 3.14%. The positive ROI suggests that the case study generated profits that exceeded the initial investment cost. A higher ROI indicates a more favorable return on investment (Batra and Kalia, 2016). The payback period is estimated to be approximately 0.24 years, which is equivalent to around 3 months. This means that it would take approximately 0.24 years to recoup the initial investment. A shorter payback period is generally desirable as it indicates a faster recovery of the invested capital.

These financial metrics, the ROI and payback period, provide valuable insights into the financial performance and viability of the farming business. The ROI indicates the profitability of the investment, while the payback period highlights the time it takes to recover the initial investment. These metrics help assess the efficiency and effectiveness of the business in generating returns and managing its financial resources (Salkova et al., 2021). Overall, based on the table, the case study has achieved an estimated ROI of approximately 3.14% and a payback period of around 0.24 years. These metrics suggest positive financial performance and a relatively quick recovery of the initial investment.

3.1.1 Sensitivity Analysis on on Price of Meat per kg

A sensitivity analysis was conducted to evaluate the implications of fluctuations in price of meat per kg on overall profit. The price of meat was changed by ± 10 percent, ± 20 percent, and ± 30 percent and their effects are stated in the Table 6 below. The "Changes in Profit" column represents the percentage change in profit relative to the actual profit. When the price of meat increases by 30%, the profit experiences a significant change. The profit value rises to RM8,288,600.00. reflecting a percentage change of approximately 38% compared to the actual profit. Similarly, with a 20% increase in the price of meat, the profit increases to RM7,525,700.00, resulting in a percentage change of approximately 25%. A 10% increase in the price of meat leads to a smaller positive change in profit. The profit decreases slightly to RM6,762,800.00, indicating a loss. representing a percentage change of approximately 92% compared to the actual profit.

However, when the price of meat decreases, the profit experiences negative changes. A 10% decrease in the price leads to a profit of RM5,237,000.00, corresponding to a percentage change of approximately -13% compared to the actual profit. With a 20% decrease in the price of meat, the profit decreases further to RM 4,474,100.00, resulting in a percentage change of approximately -25%. The most significant negative change in profit occurs when the price of meat decreases by 30%. The profit reaches RM3,711,200.00, representing a percentage change of approximately -38% compared to the actual profit..

Table 6: Sensitivity Analysis on Price of Meat per kg (RM)

Percentage	30%	20%	10%	0%	-10%	-20%	-30%
Profit	8288600	7525700	6762800	5999900	5237000	4474100	3711200
Changes in Profit	38%	25%	13%	0%	-13%	-25%	-38%

3.1.2 Sensitivity Analysis on Demand of Pellet to Livestock

In Table 7, a sensitivity analysis is conducted on the demand for pellets in the livestock industry, exploring various percentage changes. The table presents the corresponding profit values for each percentage change. When the demand for pellets increases by 30 the profit experiences a significant negative change. The profit value decreases to RM102,960, reflecting a percentage change of approximately -98% compared to the actual profit. Similarly, with a 20% increase in the demand of pellet to livestock, the profit decreases further to 37,259 RM, resulting in a percentage change of approximately -99%. However, A 10% increase in the demand of pellet to livestock leads to no change in profit. The profit remains at RM5,999,900.00, resulting in a 0% change in profit compared to the actual profit.

Interestingly, even when the demand of pellet to livestock decreases by 10%, 20%, or 30%, the profit remains unchanged at RM5,999,900.00. There is no change in profit compared to the baseline for these percentage decreases in demand.The percentages in the "Changes in Profit" column represent the relative change in profit compared to the actual profit for each corresponding percentage change in the demand of pellet.

Table 7: Sensitivity Analysis on the Demand of Pellet to Livestock (RM)

Percentage	30%	20%	10%	0%	-10%	-20%	-30%
Profit	102960	37259	5999900	5999900	5999900	5999900	5999900
Changes in Profit	-98%	-99%	0%	0%	0%	0%	0%

3.1.3 Sensitivity Analysis on on the Capital Cost.

In Table 8, a sensitivity analysis is conducted on the capital cost, exploring different percentage changes. The table presents the corresponding profit values for each percentage change. When the capital cost increases by 30%, the profit value decreases to RM5,899,300.00, reflecting a percentage change of approximately -2% compared to the actual profit. Similarly, with a 20% increase in the capital cost, the profit decreases slightly to RM5,932,800.00, resulting in a percentage change of approximately -1%. While a 10% increase in the capital cost leads to a similar small negative change in profit. The profit decreases to RM5,966,400.00, representing a percentage change of approximately -1% compared to the actual profit.

On the other hand, when the capital cost decreases, the profit experiences positive changes. A 10% decrease in the capital cost leads to a profit of RM6,033,400.00, corresponding to a percentage change of approximately 1% compared to the actual profit. Moreover, with a 20% decrease in the capital cost, the profit increases further to RM6,067,000.00, resulting in a percentage change of approximately 1% . The most significant positive change in profit occurs when the capital cost decreases by 30%. The profit reaches RM6,100,500.00, representing a percentage change of approximately 2% compared to the actual profit. These percentages indicate the relative change in profit compared to the baseline profit for each corresponding percentage change in the capital cost.

Table 8: Sensitivity Analysis on the Capital Cost (RM)

Percentage	30%	20%	10%	0%	-10%	-20%	-30%
Profit	5899300	5932800	5966400	5999900	6033400	6067000	6100500
Changes in Profit	-2%	-1%	-1%	0%	1%	1%	2%

3.1.4 Sensitivity Analysis on the Maintenance Cost.

In Table 9, a sensitivity analysis is performed on the maintenance cost, considering various percentage changes. The table presents the corresponding profit values for each percentage change. When the maintenance cost increases by 30%, the profit experiences a significant negative change of RM5,899,300.00, reflecting a percentage change of approximately -2% compared to the actual profit. Similarly, with a 20% increase in the maintenance cost, the profit decreases to RM 5,932,800.00, resulting in a percentage change of approximately -1%. A 10% increase in the maintenance cost leads to a smaller negative change in profit. The profit decreases to RM 5,966,400.00, representing a percentage change of approximately -1% compared to the actual profit.

On the other hand, when the maintenance cost decreases, the profit experiences positive changes. A 10% decrease in maintenance cost results in a profit of RM6,033,400.00, corresponding to a percentage change of approximately 1% compared to the actual profit. With a 20% decrease in the maintenance cost, the profit increases further to RM6,067,000.00, resulting in a percentage change of approximately 1%. The most significant positive change in profit occurs when the maintenance cost decreases by 30%. The profit reaches RM6,100,500.00, representing a percentage change of approximately 2% compared to the actual profit. These percentages indicate the relative change in profit compared to the baseline profit for each corresponding percentage change in the maintenance cost.

Table 9: Sensitivity Analysis on the Capital Cost (RM)

Percentage	30%	20%	10%	0%	-10%	-20%	-30%
Profit	5899300	5932800	5966400	5999900	6033400	6067000	6100500
Changes in Profit	-2%	-1%	-1%	0%	1%	1%	2%

3.1.5 Overall Sensitivity Analysis.

The price increase of meat reflects a percentage change of approximately 38%, while the increase in demand for pellet leads to a significant decrease in profit, representing a percentage change of approximately -99% compared to the actual profit. As shown in Figure 3, when the price of meat increases by 30%, it results in a higher revenue per unit sold. This change, if accurately reflecting a percentage change of approximately 38%, suggests that the cost of production either remained relatively stable or increased at a lower rate than the price of meat. As a result, the profit margin on each unit of meat sold has significantly improved, leading to a higher overall profit.

On the other hand, the increase in demand for pellet to livestock by 20% has a negative impact on profit. This is because meeting the increased demand requires importing more pellets, which increases the cost of production. The higher production costs reduce the profit margin, resulting in a significant decrease in profit. If this decrease is accurately represented as a percentage change of approximately -99% compared to the actual profit, it indicates that the increased production costs outweigh the additional revenue generated from meeting the higher demand. To improve profits, it is beneficial to raise prices and reduce production costs. However, it is crucial to analyze the market, competitor prices, and cost structures to ensure that any adjustments made are sustainable and meet market demand (Dietz et al., 2019).

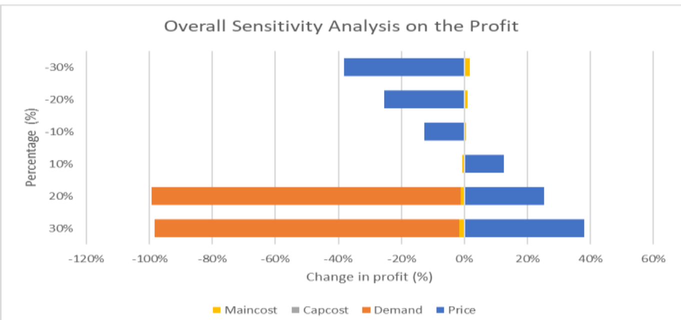

Figure 3 : Overall sensitivity analysis of paddy feed pellet conversion

4. Conclusion

In conclusion, the production of paddy biomass and sale of livestock meat, has demonstrated successful revenue generation and profitability. The annual profit of RM 5,999,900.00 indicates the business's ability to generate substantial returns. The output of paddy biomass from Plot 1 (1,101,000 kg) and Plot 2 (13,012 kg) has contributed significantly to the case study's revenue generation. This highlights the importance and demand for paddy biomass in the production of ruminant feed pellets. The estimated ROI of approximately 3.14% suggests a positive return on investment. This indicates that this case study has generated profits that exceed the initial investment cost. The estimated payback period of approximately 0.24 years indicates a relatively short duration for recovering the initial investment. By analyzing and optimizing production costs, monitoring sales performance, and minimizing transportation expenses, the financial success can be maintain and further enhance profitability.

In optimization modeling, a mathematical algorithm can be employed to calculate the best amount of paddy biomass needed for pelletizing technology, determine the optimal capacity for ruminant pellets, find the maximum number of pellets that can be sold, and estimate the annual profit using a mixed-linear programming model (MILP) implemented through the General Algebraic Modeling System (GAMS). The results of this research offer valuable understanding into the possible uses of paddy biomass in the feed mill industry. Overall, a comprehensive assessment of profitability, production efficiency, sales strategies, and transportation optimization is essential. It is crucial to explore long-term strategies, diversification opportunities, and cost-saving measures to improve future financial outcomes and ensure the sustainability of the business..

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Conflict Of Interest

All authors declare that they have no conflict of interest.

REFERENCES

Adjorlolo, L., Nsoh, M., Mensah-Bonsu, A., and Obese, F. 2020. Effect of pelleted browse-based feed with a basal diet of Andropogon gayanus for sheep on intake, nutrient digestibility and some haematological and blood biochemical parameters. Journal of World's Poultry Research, 10(3), Pp. 76–84. https://doi.org/10.36380/scil.2020.ojafr11

Bakker, R. R., Elbersen, H., Poppens, R., and Lesschen, J. P. 2013. Rice straw and wheat straw – Potential feedstocks for the biobased economy. ResearchGate. https://www.researchgate.net/publication/283416921_Rice_Straw_and_Wheat_Straw_-_Potential_feedstocks_for_the_Biobased_Economy

Batra, R., and Kalia, A. 2016. Rethinking and redefining the determinants of corporate profitability. Global Business Review, 17, Pp. 921–933.

Bolzoni, L., Carson, J. A., and Yang, F. 2021. Combinatorial structural-analytical models for the prediction of the mechanical behaviour of isotropic porous pure metals. Acta Materialia, 207, 116664. https://doi.org/10.1016/j.actamat.2021.116664

Dietz, T., Chong, A. E., Grabs, J., and Kilian, B. 2019. How effective is multiple certification in improving the economic conditions of smallholder farmers? Evidence from an impact evaluation in Colombia's coffee belt. Journal of Development Studies, 56(6), Pp. 1141–1160. https://doi.org/10.1080/00220388.2019.1632433

Du, S., You, S., Bao, J., Gegentu, Jia, Y., and Cai, Y. 2019. Evaluation of the growth performance and meat quality of Mongolian lamb fed grass, hay or pellets of Inner Mongolian native grass. Small Ruminant Research, 181, Pp. 34–38. https://doi.org/10.1016/j.smallrumres.2019.10.008

Gianni, D., D'Ambrogio, A., and Tolk, A. 2018. Modeling and simulation-based systems engineering handbook. CRC Press. https://doi.org/10.1201/b17902

He, S., Gao, H., Wang, L., Xiang, Y., and Liu, J. 2020. Distributionally robust planning for integrated energy systems incorporating electric-thermal demand response. Energy, 213, 118783. https://doi.org/10.1016/j.energy.2020.118783

Jeon, S., Jeong, S., Lee, M., Seo, J., Kam, D., Kim, J. H., Park, J., and Seo, S. 2019. Effects of reducing inclusion rate of roughages by changing roughage sources and concentrate types on intake, growth, rumen fermentation characteristics, and blood parameters of Hanwoo growing cattle (Bos taurus coreanae). Asian-Australasian Journal of Animal Sciences, 32(11), Pp. 1705–1714. https://doi.org/10.5713/ajas.19.0269

Kalvani, S. R., Sharaai, A. H., Masri, M. N., Yunus, N. A. M., Afendi, M., and Uchechukwu, O. B. 2022. Social impact and social performance of paddy rice production in Iran and Malaysia. The International Journal of Life Cycle Assessment, 27(8), Pp. 1092–1105. https://doi.org/10.1007/s11367-022-02083-4

Li, J., Gan, G., Chen, X., and Zou, J. 2021. Effects of long-term straw management and potassium fertilization on crop yield, soil properties, and microbial community in a rice–oilseed rape rotation. Agriculture, 11(12), 1233. https://doi.org/10.3390/agriculture11121233

Malaysia, J. P. 2018. Statistik tanaman – Sub sektor tanaman makanan 2018. Unit Perangkaan, Bahagian Perancangan, Teknologi Maklumat dan Komunikasi, Jabatan Pertanian Semenanjung Malaysia.

Salkova, I., Polishchuk, N. V., Broyaka, A., and Kucher, A. 2021. Cost effectiveness and attracting investments in crop sector. Fìnansovo-kreditna Dìâl'nìst': Problemi Teorìï Ta Praktiki, 1(32), Pp. 176–186. https://doi.org/10.18371/fcaptp.v1i32.200355

Sheikh, G., Ganai, A. M., Reshi, P., Bilal, S., Mir, S. A., and Masood, D. 2018. Improved paddy straw as ruminant feed: A review. Agricultural Reviews, 39(2). https://doi.org/10.18805/ag.r-1667

Siwar, C., Idris, N. A., Yasar, M., and Morshed, G. 2014. Issues and challenges facing rice production and food security in the granary areas in the East Coast Economic Region (ECER), Malaysia. Research Journal of Applied Sciences, Engineering and Technology, 7(4), Pp. 711–722. https://doi.org/10.19026/rjaset.7.307

Tseng, M., Jeng, S., Lin, C., and Lim, M. K. 2021. Recycled construction and demolition waste material: A cost–benefit analysis under uncertainty. Management of Environmental Quality: An International Journal, 32(3), Pp. 665–680. https://doi.org/10.1108/meq-08-2020-0175

Zahari, M. W., and Wong, H. 2009. Research and development on animal feed in Malaysia. WARTAZOA: Indonesian Bulletin of Animal and Veterinary Sciences, 19(4), Pp. 172–179. https://doi.org/10.14334/wartazoa.v19i4.913

Zarei, E., Ramavandi, B., Darabi, A., and Omidvar, M. E. 2021. A framework for resilience assessment in process systems using a fuzzy hybrid MCDM model. Journal of Loss Prevention in the Process Industries, 69, 104375. https://doi.org/10.1016/j.jlp.2020.104375