第 49 卷 第 11 期
2022 年 11 月

湖南大学学报（自然科学版）
Journal of Hunan University (Natural Sciences)
http://jonuns.com/index.php/journal/index

Vol. 49 No. 11
November 2022

Open Access Article https://doi.org/10.55463/issn.1674-2974.49.11.10

Potential of Biomass from Felled Trees in the Oil Palm Replanting Program as a Raw Material for Ready-to-Eat Cattle Feed

Ardi Novra[1]*, Mairizal[1], David Kusmawan[2], Akmal[1] , Jul Andayani[1]

[1] Faculty of Animal Science, University of Jambi, Indonesia

[2] Faculty of Health and Medical Sciences, University of Jambi, Indonesia

Abstract: This study aims to estimate the potential and develop strategies for using the biomass of old oil palm tree cuttings in the oil palm replanting program in smallholders as a source of feed raw materials for producing ready-to-eat animal feed. This observation research was carried out for three months in the people's oil palm plantation center in the Purnama Kempas area of Jambi Province, Indonesia. Selection of five samples of old oil palm trees that have entered the replanting period using a systematic sampling technique and data analysis of field measurements using a simple mathematical approach carried out in stages. The estimation results show that the potential for fresh biomass of animal feed ingredients for each hectare of old oil palm plantations in the replanting program reaches 56.76 tons of biomass consisting of 41.52 tons of fresh pith (73.15%) and 15.24 tons of green palm fronds (28,85%). The potential of this biomass is more than 4.23 times compared to the ability of a hectare for one year of productive oil palm plantations to provide fresh forage between plants, namely, 13.37 tons/ha, which means that tree biomass because of the replanting program can substitute for the availability of forage between coconut trees, producing palm oil for more than four years. However, because of the simultaneous harvesting process, it must be done under collectively planned management, such as in the form of a village corporation.

Keywords: biomass, cattle feed, fresh pith, fresh palm fronds, old palm trees.

体能对女体育教师职业倦怠及心理健康的影响

摘要：本研究旨在評估在小農的油棕再植計劃中使用老油棕樹插條的生物量作為生產即食動物飼料的飼料原料來源的潛力並製定策略。本次觀察研究在印度尼西亞佔碑省滿月甘拔士地區的人民油棕種植中心進行了三個月。使用系統抽樣技術和使用簡單數學方法分階段進行的實地測量數據分析，選擇五個已進入補種期的老油棕樹樣本。估算結果顯示，在重新種植計劃中，每公頃老油棕種植園的動物飼料成分的新鮮生物量潛力達到 56.76 噸生物量，其中包括 41.52 噸新鮮髓（73.15 百分）和 15.24 噸綠棕櫚葉（28.85 百分）。這種生物量的潛力是一公頃一年的生產性油棕種植園在植物之間提供新鮮草料的能力的 4.23 多倍，即 13.37 噸/公頃，這意味著由於重新種植計劃，樹木生物量可以 替代椰子樹之間的草料，生產棕櫚油超過四年。但是，由於採伐過程是同時進行的，因此必須在集體計劃管理下進行，例如以村社的形式進行。

关键词：生物質、牛飼料、新鮮髓、新鮮棕櫚葉、老棕櫚樹。

1. Introduction

Sustainable development in Indonesia is universal and integrated with government programs through 4 pillars, namely, economic, environmental, social, and

Received: July 10, 2022 / Revised: September 5, 2022 / Accepted: October 3, 2022 / Published: November 30, 2022

About the authors: Ardi Novra, Mairizal, Faculty of Animal Science, University of Jambi, Indonesia; David Kurniawan, Faculty of Health and Medical Sciences, University of Jambi, Indonesia

Corresponding author Ardi Novra, ardinovra@unja.ac.id

legal and governance [19]. The Smallholder Palm Oil Replanting (SPR) program to maintain the sustainability of plantation development by replacing old/unproductive plants with new plants, both comprehensively and gradually [22], has become a new basis for smallholder oil palm plantations because it not only replants but also fixes many sectors that have been supporting the regional economy to be more sustainable [20]. However, as long as the SPR program causes plantation income to be cut off, mill continuity cannot be maintained due to reduced FFB supply, and the potential for land looting [27]. The key indicators of the success of the SPR program are the participation of households as the main actors who are threatened with loss of income and process uncertainty [4], access to information and capital, income and experience [17].

Sources of forage fodder in oil palm plantations include intercrop forage (IF) including natural grasses, weeds and introduced forage [39], which vary according to soil type, climate, shade, types of cultivated plants, technical culture and history land use before planting [10]. The dominant forage types vary, including Axonopus compressus (Sw.) [37], Beauv or papaitan [3], Ludwigia perennis L or cacabean [15], Ottochloa nodosa (Kunth) Dandy or wire grass [15, 38], and Cyperus kyllingia Endl or riddle [40]. The estimated production of HAT for oil palm plantations in the form of field grass is 5,282.74 kg/ha/year of dry matter [2]. Another potential source of forage is palm leaves, which are taken every harvesting and are capable of producing 0.66 tons/ha/year [7], and palm fronds as the main source of energy [11] and fiber for animals. Livestock [23] with a potential of 20 tons of fresh midrib/ha or in the form of dry matter 5,214 tons/ha/year [24]. Usage of by-products from plantations and palm oil processing industries as feed is predicted to be able to provide a higher carrying capacity of 1.3 million head of cattle (108.25%) compared to using interplant forage, and palm leaves which is 428,786 heads [16]. Through technology, added value and an increase in cattle productivity of 72% can be achieved in an integrated cattle business model with the palm oil industry [32].

SISKA generally involves cattle that are directly grazed in natural pastures and cover crops under established oil palm trees [18]. Livestock industrialization requires a change in the perspective of the livestock production system, especially mix farming such as SISKA, which has been oriented to the potential of land resources to become more oriented to the potential of biomass. Building a resilient livestock industry requires adaptive livestock and responsive to changes in the external environment so that the shock of external factors does not cause the integration system to stop operating and continue to run by transforming threats into opportunities. The program of community oil palm rejuvenation or *Peremajaan Sawit Rakyat* (PSR) is a good program although it can cause double disruption to the household economy of SISKA actors in the form of loss of income due to the cessation of oil palm fruit bunches (FFB) production and the supply of forage between crops for grazing and grazing. Even though this loss is temporary, it is estimated that it will last 4–5 years; so it is necessary to find alternative feed supply solutions through technological innovations by using biomass from the PSR program, such as palm tree pulp.

Based on the previous description, research was carried out to estimate the potential and strategy for using biomass derived from felled trees from the oil palm replanting program as raw material for preparing ready-to-eat cattle feed.

2. Materials and Methods

Field observation research was conducted for 1 month using 5 samples of oil palm trees that had entered the replanting period. The measurement of the potential of oil palm tree biomass felled by the replanting program as animal feed material is carried out in stages, as shown in Fig. 1.

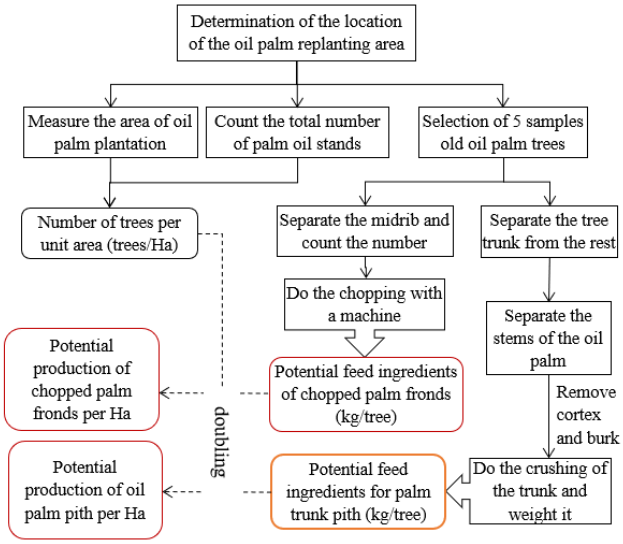

Fig. 1 Stages of field measurement of biomass potential

The selection of trees in the plantation area was carried by the selection of the first tree at random and for the next tree, 4 trees were selected systematically with a distance of 10 trees to the left, right, front and back (Fig. 2).

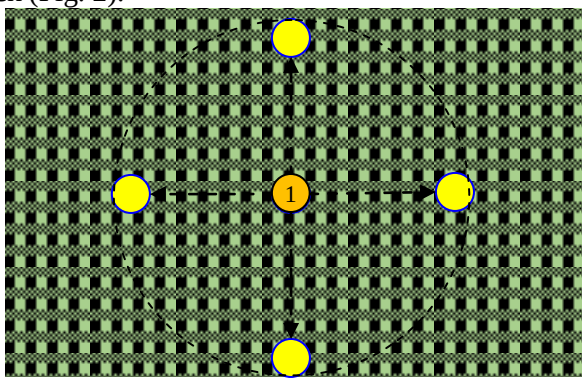

Fig. 2 Old oil palm tree sampling technique

The height of felling of old oil palm trees from the land surface is adjusted to field conditions, which are then measured and separated between parts of potential food sources (trees and midrib). Separation and chopping of the pith from the stem and midrib of the palm with the leaves using a modified crusher machine with the main ingredient of the blade using a used motor disc. The variables measured directly in the process or field activities or database are presented in Table 1.

Table 1 Types, units of measurement and symbolization of basic data measured in research activities

No	Variable	Unit	Symbol
1	Height of cutting (stump)	cm	A
2	Cutting stem height	cm	B
3	Tree Diameter	cm	C
3	Pith weight	kg	D
4	Non-pith weight	kg	E
5	Crushed fresh pith weight	kg	F
6	Number of oil palm fronds	sheet	G
7	Weight of oil palm fronds	kg	H
8	Weight of leaf oil palm fronds	kg	I
9	Weight of fresh chopped	kg	J
10	Proportion of used as feed raw	%	K
11	Number of oil palm tree	tree/ha	L
12	Mass weight (conversion)	kg/m^3	M

In summary, a simple mathematical formulation of the stages in the analysis of the potential for biomass sources of raw materials for making ready-to-eat cattle feed is provided in Appendix 1.

3. Results and Discussion

3.1. Scoping a Biomass Feed Source for Cattle Oil Palm Tree Replanting

The recent rapid expansion of OP plantations across managed tropical results in net carbon emissions and is associated with this land use change [21]. The oil palm is monoecious; that is, male and female flowers occur separately on the same plant, usually in distinct male and female inflorescences, thus minimizing the chance of self-pollination [6]. During its lifetime, the oil palm may grow up to sixty feet and more in height and live up to 100 years or more. Due to economic reasons, the oil palm is normally replanted with a newer breed for every 25–30 years [26].

The oil palm was separated into 11 parts: trunk (without bark and cortex), bark, petiole, rachis, leaves, empty fruit bunch (EFB) fiber, midrib spine leaflets, the stalk of fruit bunch, flesh, kernel shell, and albumen [6].

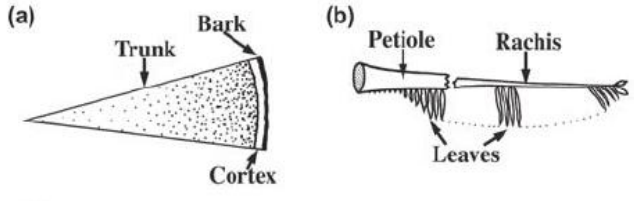

Fig. 3 Parts of the stem and midrib of the oil palm tree

In the research context, the biomass of potential animal feed sources from replanted oil palm trees consists of stem pith as the main product and palm frond (without leaves) as a by-product. The trunks of young, mature trees are wrapped in fronds, which give them a rather rough appearance. The older trees have smoother trunks apart from the scars left by the fronds that have withered and fallen off [26]. The trunk is the main part (70%) of the oil palm tree with the outer potential being used for making plywood, while the inner part is not strong enough to be used as wood to be discarded in large quantities [31]. The substance that can be extracted from the stems has sugar content comparable to that of cane sugar. The inner part produced and has low economic value and causes a big problem in the form of waste, so it is critical to increase the use of oil palm stem pith, one of which is as animal feed.

The use of grated pith has limitations, including having a low nutrient content so that it cannot be used directly and as a single feed for cattle. Oil palm pith contains high enough cellulose as an energy source for livestock, but includes low-quality feed [1] with fresh nutrient content of 25.17% water, 74.83% dry matter, 1.83% ash. crude fiber 38.26%, crude protein 2.48%, crude fat 0.34%, BETN 58.02%, NDF 74.33%, ADF 66.45, Cellulose 32.09%, Hemicellulose 7.88%, and Lignin 18.27%, and Silica 1.3% [35]. The average dry weight of oil palm wood is 394.11 kg/tree or equivalent to a dry weight of 50.45 tons/ha with biomass carbon content of 223.68 kg C/tree or equivalent to 28.63 tons C/ha (equivalent to carbon dioxide). of 104.97 tons CO_2/ha) [36].

3.2. Composition of Feed Sources from Replanting Palm Trees

During the SPR program process, biomass is produced as a by-product in the form of logged-over trees consisting of trees and palm fronds with countless volumes and potential as a source of substitute feed raw materials. As previously explained, the parts of old oil palm trees that are potential sources of feed for cattle are the stems and midrib. The felling of old palm trees from the SPR program was carried out manually using a saw at an average height of 33,20 cm above the ground, resulting in variables as shown in Table 2.

Table 2 Average size of stem sections and number of midrib from logged old oil palm trees (Data processing, 2022)

No.	Variable	Value
2	Cutting stem height (cm)	540.00
3	Tree Diameter (cm)	
	a. Lower	40.40
	b. Middle	33.40
	c. Highest	27.80
4	Number of fronds	38.00

Using a mathematical approach formula with an average tree trunk diameter of 33.87 cm or 0.3387

meters and a height of 5.4 meters), the average volume of felled palm trees is around 0.49 m^3. The density of oil palm trees ranged from 0.46 – 0.62 g/cm^3, the highest at the base and the lowest at the tip [9]. The wood at the base of the trunk has thicker walls and the proportion of lignin and an extractive percentage is greater than the wood at the ends, considering its function as a support for the trunk and crown above it [8]. The conversion from volume to the weight of oil palm trunks with a volume of 0.49 m^3 and an average density of 0.62 g/m^3 resulted in the weight of each oil palm stem being cut at 784.18 kg. Splitting and crushing tree trunks using a machine produce a sequence of data, as shown in Table 3.

Table 3 Proportion of the source of cattle feed ingredients and weight loss while producing a fresh shell of oil palm trees (Data processing, 2022)

No.	Indicators	Value
1	Palm trunk weight (kg)	784.18
2	Weight of parts used (kg)	392.80
3	Weight of unused parts (kg)	391.38
4	The proportion of parts used (%)	50.09
5	Crushed fresh pith weight (kg)	345.97
6	Weight loss during crushing (%)	11.92

The low proportion of the chart used (50.59%) as a source of cattle feed is due to the separation of the stems done manually using a saw. Cutting along the trunk must be made thicker and straighter, causing some of the trunk to be carried away and become unused parts. The proportion of this used part will be greater if using a tree bark peeler machine so that more fresh pith will be produced. Another weight loss occurred during machine crushing, which was about 11.92%. Although there was a loss of weight during the production process, the weight of the fresh eggshell produced for cattle feed was quite large, namely, 345.97 kg/stem.

Besides the pith, there is another by-product of biomass that can be used as a substitute for feed, namely, palm fronds. This plant waste feed material is commonly used because it is available as long as oil palm plants live, especially in productive age plants. Pruning is a activity that is required in the maintenance or management of oil palm plants. Cutting the midrib in oil palm will reduce the risk of losses to increase production [13]. The benefits of pruning include the residue from pruning that accumulates on the land that is useful as mulch, inhibits weed growth, and is a source of organic matter for the soil [33]. If pruning is not carried out, it will disrupt the vegetative and generative growth periods of oil palm plants and will cause fruit rot in plants because harvesters are not visible [41]. The estimated fresh weight of chopped palm fronds as a source of animal feed is presented in Table 4.

Table 4 Estimated weight of chopped fresh palm fronds because of felling trees from the replanting program (Data processing, 2022)

No.	Variable	Value
1	Number of fronds (sheet)	38.00
2	Midrib Weight (kg)	147.00
3	Leaf Weight (kg)	54.00
4	Chopped fresh weight (kg)	127.00
5	Weight loss during chopped (%)	13.61

The yield of chopped fresh midrib after the leaves were separated for each oil palm tree trunk in the replanting program was lower than that of fresh pith. The comparison of the weights of the two fresh feed sources, namely, pith and palm midrib, is about 2.91. The higher midrib moisture content was thought to be a factor causing the higher rate of loss during the chopping process, namely, 13.61%. The above potential is the potential for fresh pith produced by each replanted oil palm tree, while to estimate the potential per unit area (Ha) data on the number of trees are needed for each hectare of replanted oil palm plantation land, as presented in Table 5.

Table 5 The results of the estimated pith and midrib weights for each hectare of oil palm trees in the replanting program (Data processing, 2022)

No.	Indicators		Value
1	Fresh production per palm tree (kg/stem)		
	a.	Fresh pith of oil palm tree	345.97
	b.	Chopped fresh palm fronds	127.00
2	Number of trees (trees/Ha)		120.00
3	Fresh production per hectare of oil palm plantations (tones/Ha)		
	a.	Fresh pith of oil palm tree ith	41.52
	b.	Chopped fresh palm fronds	15.24
	Total (kg/Ha)		56.76
4	Level used on cattle feed (%)		40,00
5	Potential feed production (tones)		141.89

The number of trees in the area of replanting oil palm plantations in the sample garden reached 120 stems, so the total potential sources of fresh cattle feed ingredients were around 56.76 tones/ha. The total production of fresh feed ingredients was contributed by 73.15% by the main product in the form of fresh pith and the remaining 26.85% by by-products in the form of chopped fresh palm fronds. If its use in cattle feed is limited to 40%, the availability of this feed raw material can be used for the production of around 141.89 tons.

3.3. Potential Feed Ingredients from Felling Oil Palm Trees in the SPR Program in the Development of Village Corporations

The challenge in the livestock industry is securing the supply of high-quality animal protein to meet the needs of a growing global population while minimizing impacts on natural resources, optimizing land use, and increasing production with low pollution and ecological pollution [29]. Farmers still rely on natural grass as a source of feed, and meeting local feed supplies is a major challenge [30]. The lack of feed is a

critical factor that limits the ability of farmers to increase their business scale so that opportunity to enter the market are very limited [5]. In line with the Regulation of the Minister of Agriculture Number 18/Ministry of Agriculture/RC.040/4/2018 concerning Guidelines for the Development of Agricultural Areas Based on Farmers' Corporations (FC). This regulation is a follow-up to the direction of the President of the Republic of Indonesia, who asked government officials to focus on improving the welfare of farmers [25].

Changes in the work pattern of farmers to become more modern through the concept of FC to create large groups of farmers and equip these farmer groups with management, application, and modern production and processing methods. The development of corporate-based agricultural areas aimed at increasing development efficiency and increasing the competitiveness of farmers through strengthening from upstream to downstream is expected to gain greater profits for farmers. FC are an effort to manage resources to be more optimal because they are carried out in a more integrated, consistent, and sustainable manner to form businesses that are more efficient, effective and have high-quality standards to encourage economic growth in rural areas [28]. The farmer corporation developed by the Ministry of Agriculture in 2019 is a program that focuses on encouraging collective (corporate) agricultural business management for more advanced and competitive agriculture.

Farmer corporation-based agricultural areas as part of national agricultural development are carried out on the basis of the Unitary State of the Republic of Indonesia and the 1945 Constitution. FCs agree with the mutual cooperation economy or dynamic family system as mandated by Pancasila and it the government's obligation to prioritize the protection and empowerment of society is weak in various aspects including the economy. The FC development increases welfare as much as possible as part of the affirmation of a prosperous, dignified, advanced, fair and equitable life for all the Indonesians [34] with the basic principles of *gotong rodong*, people's justice, and independence. FC development is carried out in a planned and programmed manner with a good governance system to increase farmers' access to productive resources, provide added value and competitiveness for agricultural products, strengthen farmer institutions, and increase farmers' capacity and bargaining position, which leads to increased income and welfare of farmers [14].

The FCs will be an effective tool if they can support agricultural businesses, are based on local resources, can be a solution to solve problems faced by farmers and have a clear market share with guaranteed availability of cheap, easily obtained and sustainable inputs. The use of pith and chopped fronds of oil palm fronds from the SPR program as low-cost inputs can be seen from the structure and average production costs (Table 6).

Table 6 Structure and average cost of production feed ingredients from logged oil palm trees in the SPR program (Data processing, 2022)

No.	Cost and production components	Value
1	Labor wages (IDR)	
	a. Logging and splitting	1.000.000
	b. Chopping and crushing	1.800.000
2	Fuel supply (IDR)	
	a. Solar crusher machine	210.000
	b. Vehicle gasoline	50.000
4	Total input production costs (IDR)	3.060.000
5	Production of feed raw materials (kg)	
	a. Fresh pith	1,729.86
	b. Chopped palm midrib	635.00
6	Total number of inputs (kg)	2,364.86
7	Cost per unit (IDR/kg)	1,293.95

The average cost of production (not including fixed costs from investment) of fresh feed raw materials sourced from palm trees felled by the PSR program is relatively low at IDR 1,293.95/kg. If we include the investment depreciation cost, it is estimated that it will not exceed IDR 2,000/kg and is cheaper than the price of inputs for other similar cattle feed ingredients such as rice bran, palm kernel cake and polar wheat. Generally, it can be stated that the biomass of animal feed ingredients is a competitive and low-priced cattle feed input so that it is expected to be able to produce low-priced feed output.

Worrying about the continuity of the availability of old oil palm trees (SPR program) to be processed into one of the raw materials for cattle feed is not a problem. The SPR program is incidental and only once in the life of the oil palm plant, but with the land area and variations in the age of the oil palm plant, it can be overcome. The replanting process will continue throughout the year even though it moves from one region to another. Procurement of palm trees can be done from other areas that are implementing the PSR program although it will have implications for increasing input production costs due to transportation costs and procurement of palm trees from other parties. Potential sources of raw materials can be estimated from the development of old oil palm plantations in Jambi Province, as presented in Table 7.

Table 7 The development of the area and proportion of old (unproductive) oil palm plantations in Jambi Province during the period 2015–2019 (Jambi Province Plantation Service, 2021)

No.	Year	Area (Ha)		Proportion (%)
		Total	Old years	
1	2015	714.399	18.709	2.62
2	2016	736.095	30.345	4.12
3	2017	755.522	34.185	4.52
4	2018	898.475	18.828	2.10
5	2019	1,070.723	40.792	3.81
Growth (%)		42.67	77.29	34.68

The area and proportion of old (non-productive) oil palm plantations have increased from year to year,

which means that the potential for felled trees as raw materials will be available. Crop age rotation will occur continuously from one area to another and for that, it is necessary to build an effective and efficient supply chain to reduce supply costs. The development of a network of cooperation between parties is an important key factor to maintain the sustainability of the availability of raw materials for the cattle feed industry, which is managed through the farmer corporation.

Finally, an effective FC is the support of innovative technology that can be absorbed and applied to rural businesses and a solution to solving problems for farmers. The direction of developing simple feed production technologies is already available and is starting to be widely applied in the community. The 2 main types of technologies exist that can be applied because they are easy, cheap and can be a solution to problems, namely fermentation technology to improve the quality of feed ingredients and the development of complete animal feed that is ready to be consumed directly by cattle or called ready-to-eat cattle feed (abbreviation in Indonesian is called PAT3S).

4. Conclusion

The estimation results show that each hectare of the old oil palm plantation area in the replanting program can produce 56.76 tones of biomass as raw material for animal feed consisting of 41.52 tones of fresh pith (73.15%) and 15.24 tones of chopped fresh palm fronds (28.85%). The potential for these two biomasses is higher than the potential for fresh forage biomass production between oil palm plants, which only reached 13.37 tons/ha or dry matter was 3.19 tons/ha [12]. Based on the ratio or comparison of the potential for biomass production of these two types of animal feed sources, it can be concluded that the residual biomass from the replanting program can substitute for more than 4 years of forage availability between trees in productive oil palm plantation areas.

However, due to the harvesting process that must be carried out all at once, its usage must be carried out with collectively planned management such as in the form of a village corporation. Support for innovation technologies is needed, including fermentation technology to improve the quality of the two sources of feed raw materials, while to increase storage time and use as well as distribution and marketing effectiveness, the development of complete animal feed innovation products is an alternative. The development of village corporations in the rural industry of ready-to-eat cattle feed is expected to be a solution to the problem of solving the dual impact of the oil palm replanting program, namely, temporary loss of income due to the cessation of fresh fruit bunch production and disruption of supply of fresh forage supplies between oil palm trees for cattle feed.

For this reason, in the future, to build a village corporation, it will be necessary to follow up with further research such as technological engineering in the production process of ready-to-eat cattle feed and sustainable supply chain management modeling and partnership patterns in building a ready-to-eat cattle feed village corporation.

References

[1] ABE H., MURATA Y., KUBO S., WATANABE K., and TANAKA R. Estimation of the ratio of vascular bundles to parenchyma tissue in oil plam trunks using NIR Spectroscopy. *Bio Resources*, 1998, 8: 1573-1581.

[2] AFRIZAL, R. SUTRISNA, and MUHTARUDIN. Potential forage as ruminant feed in Bumi Agung District, East Lampung Regency. *Integrated Livestock Scientific Journal*, 2014, 2(2): 93-100.

[3] ALFAIDA, S.M. SULEMAN S.M., and NURDIN H.M. The types of coastal plants in Pelawa Baru Village, Central Parigi District, Parigi Moutong Regency, and their use as a pocketbook. *e-Jipbiol*, 2013, 1: 19-32.

[4] ANGGREANY S., and DWI S. Farmer participation in oil palm replanting in Jambi Province. *Journal of Extension*, 2016,12(1): 1-14.

[5] ARIF S., ISDIJOSO W., FATAH A.R., and TAMYIS A.R. *Strategic Review of Food Security and Nutrition in Indonesia: 2020. Update 2019–2020.* The SMERU Research Institute, 2020.

[6] CORLEY R.H.V., and TINKER P.B. The Classification and Morphology of the Oil Palm. Chapter 2. Wiley Online Library, 2015. Available from: https://doi.org/10.1002/9781118953297.ch2

[7] DWIYANTO K., SITOMPUL D., MANTI I., MATHIUS I.W., and SOENTORO. Assessment of Business Development of Oil Palm-Cow Integration System. In: *Proceedings of the National Workshop on Palm Oil-Cattle Integration Systems. Bengkulu, 9-10 September 2003*. Agency for Agricultural Research and Development, Jakarta, 2004: 11-22.

[8] EKAWATI. *Study of physical and mechanical properties of coconut wood (Cocos nucifera L.) based on stem depth and position.* Thesis. Forestry Faculty University of Tanjung Pura, Pontianak, Indonesia, 2001.

[9] ENDY, FARAH D., and MUFLIHATI. *Physical and mechanical properties of oil palm trunks (Elaeis guineensis Jacq) based on the position of the stem height*. Forestry Faculty University of Tanjung Pura. Pontianak, Indonesia, 2008.

[10] EFIZAL R. *Fundamentals of Plantation Production*. 1st ed. Graha Ilmu, Yogyakarta, Indonesia, 2014.

[11] ELIZABETH J., and GINTING S.P. Utilization of by-products of the coconut industry. In: *Proceedings of the National Workshop on the Oil Palm-Cattle Integration System. Bengkulu, Indonesia September 9-10th, 2003*. Center for Livestock Research and Development in collaboration with the Bengkulu Provincial Government and PT Agricinal, 2003: 110-119.

[12] ABDULLAH L. *Forage production modeling in smallholder oil palm plantations in East Aceh Regency*. Thesis of Master of Animal Science Program. Bogor Agricultural University, Bogor, Indonesia, 2021.

[13] GROMIKORA N., YAHYA S., and SUWARTO. Growth and production modeling of oil palm at different levels of frond pruning. *Journal of Agronomy*, 2014, 42(3): 228-235.

[14] GULTOM I.A., PUSPITA A.K., DARMAWAN Y.Y., and SUBING A. Analysis of corporate-based agricultural sector planning. *Management Journal*, 2020, 9(2): 16-20.
[15] HARYATUN. Techniques for identifying dominant weed species and nutrient availability status of nitrogen, phosphorus, and potassium of several types of weeds in lebak swamp land. *Agricultural Technology Bulletin*, 2008, 13: 19-22.
[16] HEVRIZEN R., and BASRI E. *Prospects for the use of by-products from plantations and palm oil processing as cattle feed in Lampung Province.* IPB Press Publisher, Bogor, Indonesia, 2017.
[17] HERYANTO R., MURDY S., and APROLITA. *Factors relating to farmers' decisions on palm oil replanting in Sungai Bahar District, Muaro Jambi Regency*. Agricultural Faculty, University of Jambi, Indonesia, 2018.
[18] IACCB. *Commercial cattle breeding with integrated system of oil palm and cattle.* Indonesia-Australia Commercial Cattle Breeding Program, 2020.
[19] KURNIAWAN R. *SDGs training, aligning NAP KSB into the framework of the Sustainable Development Goals.* Indonesian Sustainable Palm Oil Forum, 2019. Available from: http://foksbi.id/id/berita/baca/10-03-2019-training-sdgs-menyeleraskan-ran-ksb-ke-dalam-kerangka-tujuan-pembangunan-berkelanjutan
[20] LARASATI R.A. *The future of the Indonesian palm oil industry is in the hands of millennials.* Kompas, 2019. https://money.kompas.com/read/2019/11/28/164046026/masa- depan-industri-kelapa-sawit-ri-ada-di-tangan-milenial
[21] LEWIS K., RUMPANG E., KHO L.K., CALMONT J.M., TEH Y.A., GALLEGO-SALA A., and HILL T.C. An assessment of oil palm plantation aboveground biomass stocks on tropical peat using destructive and non-destructive methods. *Scientific Reports*, 2020, 10: 2230. https://doi.org/10.1038/s41598-020-58982-9
[22] LIMANSETO H. *The People's Oil Palm Rejuvenation Program Encourages Labor Absorption and Creates a Multiplier Effect.* Bureau of Communication, Information Services, and Sessions of the Coordinating Ministry for Economic Affairs**,** 2021. Available from: https://www.ekon.go.id/publikasi/detail/3312/program-peremajaan-sawit-rakyat-mendorong-penyerapan-tenaga-kerja-dan-menciptakan-multiplier-effect
[23] BIN AZMI M.A., ALIAS S., AZMI A.F.M., GHANI A.A.A., SHAHUDIN M.S., GOH Y.M., NOORDIN M.M., YUSOF M.T., ZUNITA Z., and HASSIM H.A. Determination of fibernolytic enzyme activities of white rot fungi isolated from oil palm fronds. *Indonesian Journal of Animal and Veterinary Sciences*, 2016, 21(2): 144-150.
[24] MATHIUS I.W. *Feed technology innovation based on by-products of the palm oil industry. National seminar on by-products of oil palm plantations and their processed industries as animal feed*. Center for Livestock Research and Development. Bogor, Indonesia, 2008: 9-24.
[25] MINISTRY OF AGRICULTURE. *Ministry of Agriculture Develops Farmer Corporations in Food Estate.* Press Release of the Ministry of Agriculture of the Republic of Indonesia, 2022. Available from: https://www.pertanian.go.id/home/?show=news&act=view&id=4654
[26] MPOC. *The Oil Palm Tree*. Malaysia Palm Oil Council, 2021. Available from: https://mpoc.org.my/the-oil-palm-tree/
[27] NIZAM Z. *Oil palm replanting: Appropriate technology and its challenges*. 2014. Available from: http://nazambun.blogspot.co.id/2014/02/html.
[28] NOVRA A. *Building the People's Beef Cattle Farming Industry*: *Sustainable Integrated Farming System Approach*. Publication Unit of the Faculty of Animal Husbandry, Jambi University, 2019.
[29] ORFFA. *FEFAC's feed sustainability charter: pioneering in sustainability: Our contribution to a sustainable livestock production*. European Feed Manufacturers' Federation, 2021. Available from: https://orffa.com/sustainability/fefacs-feed-sustainability-charter/
[30] PEN M., SAVAGE D., CIAT W.S., LORN L.S., and SENG M. Cattle Feeding and Management Practices of Small-holder Farmers in Kampong Cham Province, Cambodia. *International Journal of Environmental and Rural Development*, 2010, 1(1): 132-138.
[31] PRIANDA M.R. *Utilization of palm oil (Elais guineensis Jacq) waste and pure polypropylene (PP) plastic as a composite board with the addition of maleated polypropylene.* Thesis. Forestry Departement Faculty of Agriculture, West Sumatera University, Indonesia, 2009.
[32] PRIYANTI A. *Accelerated development of laboratory and field school-based crop-livestock integration system models: cattle-palm. Acceleration of beef cattle development through livestock crop integration system*. IPB Press Publisher, Bogor, Indonesia, 2017.
[33] PULUNGGONO H.B., SYAIFUL A., BUDI M. and SUPIANDI S. Decomposition of Oil Palm Frond and Leaflet Residues. *Journal of Agricultural Science*, 2019, 41(3): 524-536.
[34] SARAGIH B. *Agribusiness Systems and Enterprises*. Bogor Agriculture University, Indonesia, 2002.
[35] SIREGAR R. *The effect of increasing the level of addition of fermented oil palm stem pith in the ration on the digestibility of BK, BO and PK in-vitro.* Thesis. Faculty of Animal Science, Andalas University, Indonesia, 2017.
[36] SISWOKO E., MULYADI A., THAMRIN, and BAHRUDDIN. Estimation of Carbon Content of Waste Palm Tree Trunk Rejuvenation in Riau Province. *Journal of Environmental Science*, 2017, 11(2): 154-163.
[37] SYAFIRUDDIN H. Composition and structure of forage fodder under oil palm plantations. *Journal of Livestock Agribusiness*, 2011, 1: 25-30.
[38] UTAMI S., ASMALIYAH, F. and AZWAR. *Weed inventory under Pulai Darat (Alstonia angustiloba Miq.) stands and their relationship to weed control in Musi Rawas District, South Sumatra. Proceedings of the Exposure of Research Results 2006*. Center for Forest Research and Development and Nature Conservation, Padang, Indonesia, 2007: 135-144.
[39] UTOMO B.N, and WIDJAJA E. Development of beef cattle based on oil palm plantation industry. *Journal of Agricultural Research and Development*, 2012, 31: 153-161.
[40] ULUPUTTY M. The main weed on eggplant in Wanakarta Village, Waepo District, Buru Regency. *Journal of Agrology*, 2014, 3: 37-43.
[41] YUDISTINA V., MUDJI S., and NURUL A. The relationship between stem diameter and plant age on growth and yield of oil palm plants. *Journal of Science World*, 2013, 17(1): 43-48.

参考文:

[1] ABE H.、MURATA Y.、KUBO S.、WATANABE K. 和 TANAKA R. 使用近紅外光譜法估計油棕樹幹中維管束與薄壁組織的比率。生物資源, 1998, 8: 1573-1581.

[2] AFRIZAL、R. SUTRISNA、和 MUHTARUDIN。東楠榜攝政布米阿貢區可能用作反芻動物飼料的草料。綜合畜牧科學雜誌, 2014, 2(2): 93-100.

[3] ALFAIDA, S.M. SULEMAN S.M. 和 NURDIN H.M. 巴黎木桐麗晶酒店巴黎市中心區佩拉瓦巴魯村的沿海植物類型及其作為錢包的用途。e-Jipbiol, 2013, 1: 19-32.

[4] ANGGREANY S. 和 DWI S. 農民參與占碑省的油棕改種。推廣學報, 2016,12(1): 1-14.

[5] ARIF S.、ISDIJOSO W.、FATAH A.R. 和 TAMYIS A.R. 印度尼西亞糧食安全和營養戰略審查：2020 年。2019-2020 年更新。社會監測和早期反應股研究所，2020 年。

[6] CORLEY R.H.V. 和 TINKER P.B. 油棕的分類和形態。第 2 章。威利在線圖書館，2015 年。可從以下網址獲得：https://doi.org/10.1002/9781118953297.ch2

[7] DWIYANTO K.、SITOMPUL D.、MANTI I.、MATHIUS I.W. 和 SOENTORO。 油棕-奶牛一體化系統業務發展評估。在：國家棕櫚油-牛集成系統研討會論文集。 明古魯，2003 年 9 月 9-10 日。農業研究與發展局，雅加達，2004 年：11-22。

[8] EKAWATI。基於莖深和位置的椰子木 (可可果仁) 物理力學特性研究。論文。丹戎普拉大學林業學院，印度尼西亞坤甸，2001 年。

[9] ENDY、FARAH D. 和 MUFLIHATI。基於莖高位置的油棕樹幹 (油棕) 的物理和機械特性。丹絨普拉大學林業學院。坤甸，印度尼西亞，2008 年。

[10] EFIZAL R. 種植園生產基礎。第一版。科學館，印度尼西亞日惹，2014 年。

[11] ELIZABETH J. 和 GINTING S.P. 椰子工業副產品的利用。在：國家油棕牛一體化系統研討會論文集。 印度尼西亞明古魯，2003 年 9 月 9 日至 10 日。畜牧研究與發展中心與明古魯省政府和有限公司農用的合作，2003：110-119。

[12] ABDULLAH L. 東亞齊縣小農油棕種植園的草料生產模型。動物科學碩士課程論文。茂物農業大學，印度尼西亞茂物，2021 年。

[13] GROMIKORA N.、YAHYA S. 和 SUWARTO。油棕在不同修剪水平下的生長和生產模型。農學雜誌, 2014, 42(3): 228-235.

[14] GULTOM I.A.、PUSPITA A.K.、DARMAWAN Y.Y. 和 SUBING A. 基於企業的農業部門規劃分析。管理雜誌, 2020, 9(2): 16-20.

[15] HARYATUN。谷沼澤地幾種雜草的優勢雜草種類和氮、磷、鉀養分有效性鑑定技術。農業技術通報, 2008, 13: 19-22.

[16] HEVRIZEN R. 和 BASRI E. 楠榜省種植園和棕櫚油加工副產品用作牛飼料的前景。茂物農業研究所出版社，茂物，印度尼西亞，2017 年。

[17] HERYANTO R.、MURDY S. 和 APROLITA。穆阿羅詹比攝政區雙溪巴哈區農民決定重新種植棕櫚油的相關因素。印度尼西亞佔碑大學農業學院，2018 年。

[18] 印尼-澳大利亞商業肉牛育種。油棕和牛綜合系統的商業養牛。印度尼西亞-澳大利亞商業牛育種計劃，2020 年。

[19] KURNIAWAN R. 可持續發展目標培訓，將小睡凱士比納入可持續發展目標的框架。印度尼西亞可持續棕櫚油論壇，2019 年。來源：http://foksbi.id/id/berita/baca/10-03-2019-training-sdgs-menyeleraskan-ran-ksb-ke-dalam-kerangka-tujuan-pembangunan -伯克蘭巨坦

[20] LARASATI R.A. 印度尼西亞棕櫚油行業的未來掌握在千禧一代手中。羅盤，2019 年。https://money.kompas.com/read/2019/11/28/164046026/masa-depan-industri-kelapa-sawit-ri-ada-di-tangan-milenial

[21] LEWIS K.、RUMPANG E.、KHO L.K.、CALMONT J.M.、TEH Y.A.、GALLEGO-SALA A. 和 HILL T.C. 使用破壞性和非破壞性方法評估熱帶泥炭上油棕種植園地上生物量儲量。科學報告，2020 年，10：2230。https://doi.org/10.1038/s41598-020-58982-9

[22] LIMANSETO H. 人民油棕振興計劃鼓勵勞動力吸收並產生乘數效應。通信、信息服務局和經濟事務協調部會議，2021 年。可從以下網址獲取：https://www.ekon.go.id/publikasi/detail/3312/program-peremajaan-sawit-rakyat-mendorong- penyerapan-tenaga-kerja-dan-menciptakan-乘數效應

[23] BIN AZMI M.A.、ALIAS S.、AZMI A.F.M.、GHANI A.A.A.、SHAHUDIN M.S.、GOH Y.M.、NOORDIN M.M.、YUSOF M.T.、ZUNITA Z. 和 HASSIM H.A. 從油棕葉中分離的白腐真菌的纖維分解酶活性的測定。印度尼西亞動物與獸醫學雜誌，2016 年，21(2)：144-150。

[24] MATHIUS I.W. 基於棕櫚油工業副產品的飼料技術創新。油棕種植園及其加工工業副產品作為動物飼料的全國研討會。家畜研究與發展中心。印度尼西亞茂物，2008 年：9-24。

[25] 農業部。農業部在食品區發展農民公司。印度尼西亞共和國農業部新聞稿，2022 年。來源：https://www.pertanian.go.id/home/?show=news&act=view&id=4654

[26] 馬來西亞棕油理事會。油棕樹。馬來西亞棕櫚油委員會，2021 年。可從：https://mpoc.org.my/the-oil-palm-tree/

[27] NIZAM Z. 油棕再種植：適用技術及其挑戰。2014 年。可從以下網址獲取：http://nazambun.blogspot.co.id/2014/02/html。

[28] NOVRA A. 建設人民肉牛養殖業：可持續綜合農業系統方法。佔碑大學畜牧學部出版單位, 2019.

[29] ORFFA。歐洲飼料製造商聯合會的飼料可持續性憲章：可持續性先鋒：我們對可持續畜牧業生產的貢獻。歐洲飼料製造商聯合會，2021 年。可從以下網址獲取：https://orffa.com/sustainability/fefacs-feed-sustainability-charter/

[30] PEN M.、SAVAGE D.、CIAT W.S.、LORN L.S. 和 SENG M. 柬埔寨磅湛省小農戶的牛飼養和管理實踐。國際環境與農村發展雜誌，2010 年，1(1)：132-138。

[31] PRIANDA M.R. 利用棕櫚油 (油棕) 廢料和純聚丙烯塑料作為複合板，添加馬來化聚丙烯。論文。印度尼西亞西蘇門答臘大學林業系農業學院，2009 年。

[32] PRIYANTI A. 加速開發基於實驗室和田間學校的作物-牲畜一體化系統模型：牛-棕櫚。通過牲畜作物一體化系統加速肉牛發展。茂物農業研究所出版社，茂物，印度尼西亞，2017 年。

[33] PULUNGGONO H.B.、SYAIFUL A.、BUDI M. 和

SUPIANDI S. 油棕葉和小葉殘渣的分解。農業科學學報, 2019, 41(3): 524-536.
[34] SARAGIH B. 農業企業系統和企業。茂物農業大學，印度尼西亞，2002 年。
[35] SIREGAR R. 在日糧中增加發酵油棕莖髓的添加水平對 BK、BO 和 PK 體外消化率的影響。論文。印度尼西亞安達拉斯大學動物科學學院，2017 年。
[36] SISWOKO E.、MULYADI A.、THAMRIN 和 BAHRUDDIN。廖內省廢棄棕櫚樹樹幹再生碳含量的估算。環境科學雜誌, 2017, 11(2): 154-163.
[37] SYAFIRUDDIN H. 油棕種植園飼料的組成和結構。畜牧業農業綜合企業雜誌，2011，1：25-30。
[38] UTAMI S.、ASMALIYAH、F. 和 AZWAR。南蘇門答臘慕西拉瓦斯區陸島（洋芋）林下的雜草庫存及其與雜草控制的關係。2006 年研究成果公開會議記錄。森林研究與發展和自然保護中心，印度尼西亞巴東，2007 年：135-144。
[39] UTOMO B.N 和 WIDJAJA E. 基於油棕種植業的肉牛發展。農業研究與發展雜誌, 2012, 31: 153-161.
[40] ULUPUTTY M. 布魯攝政哇 區瓦納卡塔村茄子上的主要雜草。農業學報, 2014, 3: 37-43.
[41] YUDISTINA V.、MUDJI S. 和 NURUL A. 莖粗和株齡對油棕植物生長和產量的關係。世界科學雜誌, 2013, 17(1): 43-48.

Appendix 1 The step-by-step formula for the analysis of biomass potential

No.	Indicator	Symbol	Unit of measurement	Formula
A.	**Primary product (fresh pit crusher)**			
1	Volume of logged oil palm trees	N	m-3	$N = 3{,}14 \times B \times (0{,}5\ C)^2$
2	Convert volume to weight	O	kg	O = N x M
3	The pith portion proportion	P	%	P = (D/O) x 100
4	Loss of weight during crushering	Q	%	Q = (D- F)/F) x 100
5	Proportion of fresh pith produced	R	%	R = (E/O) x 100
B.	**Side product (fresh fronds choppering)**			
1	Total weight of palm fronds per stem	S	kg	S = G x H
2	The proportion of midrib without leaves	T	%	T = (H/S) x 100
3	The proportion of fresh chopped midrib	U	%	U = (J/T) x 100
4	Loss of weight during choppering	V	%	V = ((T - U)/T) x 100
C.	**Estimation of potential as a raw material for feed ingredients**			
1	Fresh egg shell production per Ha	W	kg	W = F x L
2	Production of chopped fresh midrib per Ha	X	kg	X = J x L
3	Production of animal feed raw materials per Ha	Z	kg	Z = W + Z
4	Potential animal feed can be produced	FP	kg	FP = Z / K