

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*}, Mairizal¹, David Kusmawan², Akmal¹, Jul Andayani¹

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：本研究旨在评估在小农的油棕再植计划中使用老油棕树插条的生物量作为生产即食动物饲料的饲料原料来源的潜力并制定策略。本次观察研究在印度尼西亚占碑省满月甘拔士地区的人民油棕种植中心进行了三个月。使用系统抽样技术和使用简单数学方法分阶段进行的实地测量数据分析，选择五个已进入补种期的老油棕树样本。估算结果显示，在重新种植计划中，每公顷老油棕种植园的动物饲料成分的新鲜生物量潜力达到 56.76 吨生物量，其中包括 41.52 吨新鲜髓（73.15 百分）和 15.24 吨绿棕櫚葉（28.85 百分）。这种生物量的潜力是一公顷一年的生产性油棕种植园在植物之间提供新鲜草料的能力的 4.23 多倍，即 13.37 吨/公顷，这意味着由于重新种植计划，树木生物量可以替代椰子树之间的草料，生产棕櫚油超过四年。但是，由于采伐过程是同时进行的，因此必须在集体计划管理下进行，例如以村社的形式进行。

关键词：生物量、牛饲料、新鲜髓、新鲜棕櫚葉、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

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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@unjia.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 *cacabea*n [15], *Ottlochloa 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.

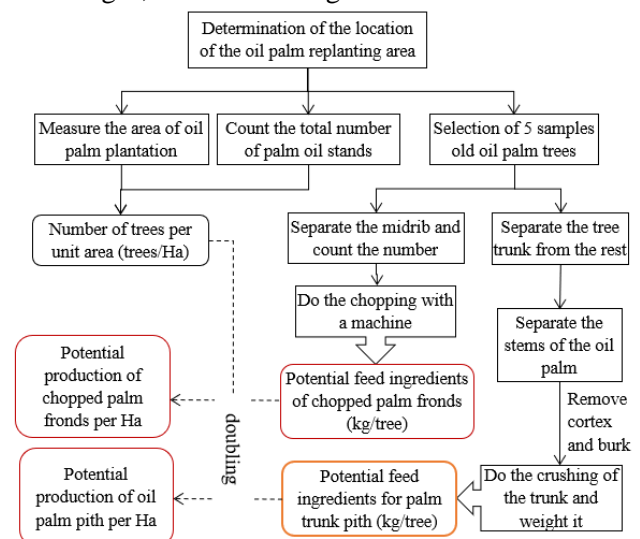


Fig. 1 Stages of field measurement of biomass potential

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).

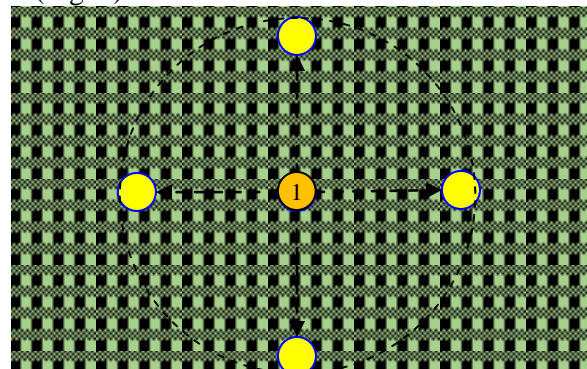


Fig. 2 Old oil palm tree sampling technique

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].

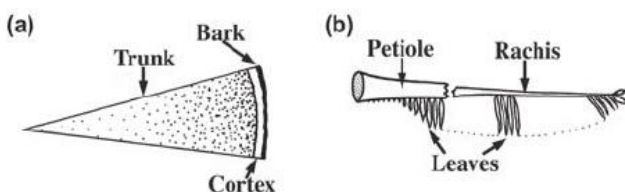


Fig. 3 Parts of the stem and midrib of the oil palm tree

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 CO₂/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 $0.46 - 0.62 \text{ g/cm}^3$, 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	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.

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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	$O = N \times M$
3	The pith portion proportion	P	%	$P = (D/O) \times 100$
4	Loss of weight during crushing	Q	%	$Q = (D - F)/F \times 100$
5	Proportion of fresh pith produced	R	%	$R = (E/O) \times 100$
B. Side product (fresh fronds chopping)				
1	Total weight of palm fronds per stem	S	kg	$S = G \times H$
2	The proportion of midrib without leaves	T	%	$T = (H/S) \times 100$
3	The proportion of fresh chopped midrib	U	%	$U = (J/T) \times 100$
4	Loss of weight during chopping	V	%	$V = ((T - U)/T) \times 100$
C. Estimation of potential as a raw material for feed ingredients				
1	Fresh egg shell production per Ha	W	kg	$W = F \times L$
2	Production of chopped fresh midrib per Ha	X	kg	$X = J \times L$
3	Production of animal feed raw materials per Ha	Z	kg	$Z = W + X$
4	Potential animal feed can be produced	FP	kg	$FP = Z / K$