# The Use of Oil Palm Trunks as Ruminant Feed

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## Abstract

The oil palm plantations are regenerated every 25 years and a large amount of scrapped wood from field is totally discarded without any use. In these experiments the possibility of utilizing oil palm trunks (OPT) as ruminant feed was considered. The lignin content of OPT was found to be low while the content of soluble sugars was high. Furthermore, the digestibility was markedly improved with NaOH treatment or steaming. The portion of parenchyma tissues separated from OPT showed a high digestibility even under untreated conditions. The performance of the steers fed on NaOH-treated or ensiled OPT ration for 8 months suggested that OPT could become a promising roughage source for ruminants.

## Introduction

Oil palm trees are replanted after an economical age of about 25 years. In the 1990s in Malaysia, a large number of oil palm trees will be felled down for replanting. The maximum annual yield of palm trunk is estimated to reach 7.5 million tons on a DM basis by 1998 (Hussin *et al*., 1986). Currently, cut oil palm trunk (OPT) is usually discarded in the field without being used. The quality of OPT is not suitable for timber or pulp because of the high moisture, low cellulose content, or its softness. In addition, the trees left in the plantation may provide a breeding ground for pests and diseases or hinder replanting. Therefore, new avenues for usage of this material must be explored. It was reported by Mohd. Nor *et al.* (1984) that the hot water soluble fraction, mainly composed of soluble sugars, accounted for 14.1%. The high content of soluble sugars suggested that OPT could be used as animal feed. Thus, this study was undertaken to analyse the potential of OPT as ruminant feed after being subjected to steaming or alkali treatment.

## Materials and methods

Seven experiments were carried out to analyse the possibility of using OPT as ruminant feed in this study.

Experiment 1 was designed to investigate the chemical composition and *in vitro* digestibility of OPT and oil palm fronds and the effects of steaming on the quality of feed. OPT and oil palm fronds were harvested from oil palm trees more than 25 years of age. The oil palm fronds were separated into two parts, namely stem (petiole and rachis) and leaflets. After being ground through a 1 mm mesh screen, a portion of these samples was steamed at the pressure of 12.5 kg/ $cm^2$ for 5 minutes. Organic cell wall (OCW), organic cellular contents

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(OCC), and digestibility of OCW of these materials were determined using the enzymatic methods reported by Abe and Nakui (1979).

Experiment 2 was also conducted to determine the optimum steaming conditions of OPT for use as ruminant feed. Fifteen combinations of steaming conditions, namely 10, 30, and 60 minutes at 7.5 kg/cm$^2$, 1, 5, 10, 20, and 30 minutes at 10 kg/cm$^2$, 1, 5, 10, and 20 minutes at 12.5 kg/cm$^2$, and 1, 5, and 10 minutes at 15 kg/cm$^2$ were set up to determine the optimum steaming conditions for OPT. The steamed materials were analysed for *in vitro* digestibility by the method reported by Goto and Minson (1977) after the samples were dried and ground through a 1 mm mesh screen.

Experiment 3 was carried out to analyse the relationship between the NaOH content and *in vitro* digestibility of OPT and oil palm fronds. The samples prepared in Experiment 1 were used for the NaOH treatment. Seven levels of NaOH solutions (3, 6, 9, 12, 15, 18, and 21%) were prepared. Each solution was mixed with each sample of the three kinds of materials in equal amount and kept in sealed containers at room temperature for two weeks. The treated samples were sun-dried for 2 days and used for *in vitro* analysis as reported by Abe and Nakui (1979).

Experiment 4 was designed to analyse the relationship between *in vivo* digestibility and palatability of OPT and NaOH content. OPT was treated with five different levels (0, 3, 6, 9, and 12% of DM) of NaOH. After the samples of NaOH-treated OPT were adjusted to approximatley 50% of moisture content, they were kept in tightly sealed 200 1 drums for 1-3 weeks and blended with a basal ration at a percentage of 30% of total DM. Only in the 12% NaOH treatment, was the percentage of OPT limited to 20% on a DM basis because of the high NaOH content. Determination of *in vivo* digestibility of each treated OPT was carried out using four Kedah-Kelantan bulls. After a one week adaptation period, all the feces were collected for one week to measure the apparent digestibility of each component.

Experiment 5 was carried out to compare the *in vivo* digestibility of 4 different treatments of OPT by using cattle. OPT harvested from 35 years old trees was used for the *in vivo* digestibility trials. OPT was chipped to fragments less than 2 cm long and subjected to 4 kinds of treatments ; namely drying, steaming (12.5 kg/cm$^2$ for 5 minutes), NaOH treatment (6% of DM), and ensiling (in tightly sealed 200 1 drums). Five types of experimental feeds were prepared ; namely untreated dried OPT, steamed OPT, NaOH-treated OPT, ensiled OPT, and untreated dried rice straw. Each experimental feed was mixed with concentrate at a percentage of 30% of total ration. The *in vivo* digestibility of each experimental ration was determined in the same way as in Experiment 4.

Experiment 6 was carried out to investigate the possibility of using parenchyma and vascular bundles separated from OPT. Chipped OPT adjusted to 20% moisture content was sieved through a 2 mm mesh screen after the tissues of this material were loosened. The percentage of parenchyma recovered through the sieve was 38%. The portion retained on the sieve was defined as vascular bundles though a trace of parenchyma was still attached to the fiber. Four types of rations were prepared. Vascular bundles were mixed with the basal ration at a percentage of 10, 30, and 50% of total DM. Parenchyma was mixed with the basal ration at a percentage of 50% of total DM. Each ration was fed to four mature Malaysian indigenous sheep. After an adaptation period of two weeks, all the feces were collected for one week to measure the apparent digestibility of each ration.

Experiment 7 was designed to investigate the long-term effect of feeding OPT treated with and without NaOH on the growth rate or meat quality of growing steers. Twenty one Australian Commercial Crosses steers (Brahman × Shorthorn), one and half years old and with an average initial body weight of approximately 240 kg, were used. These animals were divided into three groups (seven animals in each group) and fed with OPT silage, 7% NaOH treated OPT, and rice straw rations. Each ration with 30% experimental feed on a DM basis was given *ad libitum* for eight months and mineral-salt lick and water were freely available for the animals throughout the experimental period. Finally, all the animals were slaughtered according to the procedure described by Dahlan *et al.* (1988). Voluntary intake of NaOH treated and ensiled OPT was also measured at different percentages (30, 50, and 70%) of OPT using Kedah-Kelantan bulls.

## Results and discussion

### 1 Chemical composition of OPT and oil palm fronds

The chemical composition of OPT and oil palm fronds is shown in Table 1. While the CP content in the oil palm leaflets was high, the CP and crude fat contents in the stem and trunk were negligible. The content of non-structural carbohydrates including sugars expressed as NCWFE in the trunk and stem was similar and was higher than that in the leaflets. The presence of a large fraction of NCWFE as carbohydrate source is important due to the extremely high digestibility of NCWFE. Cellulose contents of these oil palm by-products were lower than the hemicellulose content. The lignin content, known as Klason lignin, was the lowest in OPT, a value similar to that of rice straw (about 13%), a by-product widely used as ruminant feed. Enzymatic analysis data and estimated TDN of these oil palm by-products also indicated that OPT showed the highest values in terms of the increase of organic cellular contents (OCC) and estimated TDN by steaming. This finding suggested that OPT offered the highest potential for feed among these three fibrous by-products after steaming.

### 2 Optimum steaming conditions of OPT

While the DM loss by steaming at the low pressure of 7.5 kg/cm$^2$ was only 4% even for a period of 60 mimutes, the loss increased to 14% when a higher pressure of 15kg/cm$^2$ was applied for 10 minutes. The higher the pressure and the longer the steaming time, the lower was the recovery rate in DM. Therefore, in terms of recovery rate, a lower pressure and shorter steaming time were deemed preferable. However, *in vitro* digestibility showed a different tendency. While untreated OPT contained 33.9% of DMD and 35.4% of OMD, the maximum digestibility (more than 50% of DMD) at each steaming pressure was obtained at 60, 30, 10, and 5 minutes for pressures of 7.5, 10, 12.5, and 15 kg/cm$^2$, respectively. Although a longer steaming duration induced a higher digestibility at low pressures of 7.5 and 10 kg/cm$^2$, a steaming duration above 10 minutes at 12.5 kg/cm$^2$ and above 5 minutes at 15 kg/cm$^2$

**Table 1 Chemical composition and estimation of total digestible nutrients (TDN) from enzymatic analysis and *in vitro* digestion method of oil palm trunks and fronds**

| | Crude protein | Crude fat | NCWFE | Cellulose | Hemicellulose | Lignin | Silica | OCW | OCC | TDN |
|---|---|---|---|---|---|---|---|---|---|---|
| | % based on dry matter | | | | | | | | | |
| Oil palm trunk | | | | | | | | | | |
| Not steamed | 3.2 | 0.6 | 11.9 | 34.0 | 35.8 | 12.6 | 1.4 | 82.4 | 14.4 | 23.6 |
| Steamed | — | — | — | — | — | — | — | 65.2 | 31.1 | 36.4 |
| Oil palm leaflets | | | | | | | | | | |
| Not steamed | 14.8 | 3.2 | 6.5 | 16.6 | 27.6 | 27.6 | 3.8 | 71.8 | 20.0 | 27.5 |
| Steamed | — | — | — | — | — | — | — | 67.8 | 23.2 | 31.6 |
| Oil palm stem | | | | | | | | | | |
| Not steamed | 1.9 | 0.5 | 12.6 | 31.7 | 33.9 | 17.4 | 0.6 | 83.0 | 14.1 | 16.3 |
| Steamed | — | — | — | — | — | — | — | 75.6 | 21.5 | 21.5 |

Note : NCWFE : Nitrogen cell wall free extracts, mainly consisting of sugars and organic acids.
OCW : Organic cell wall. OCC : Organic cellular contents.

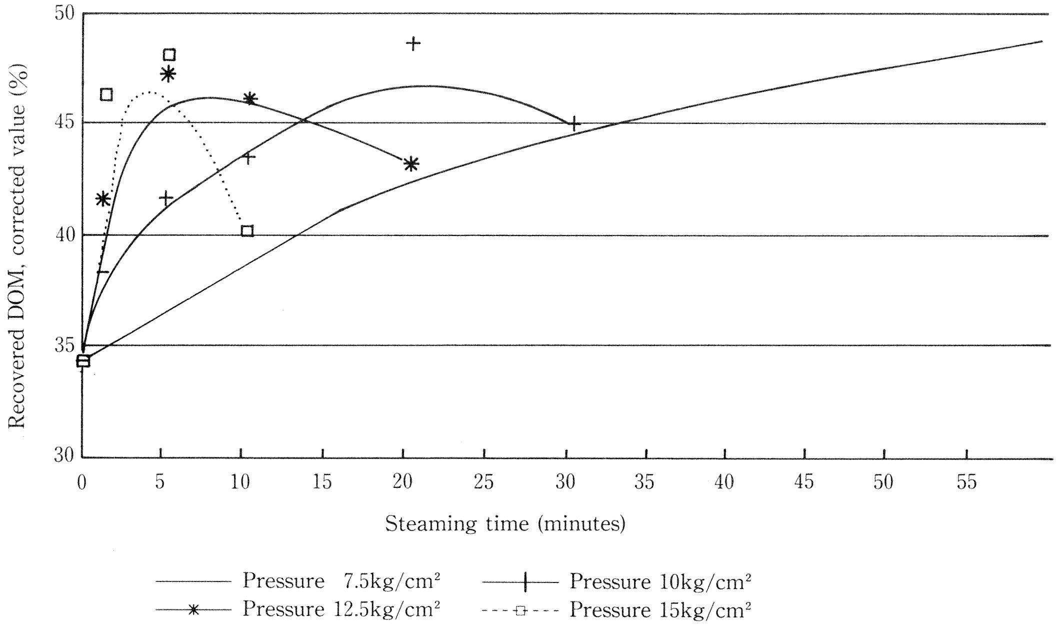

**Fig. 1 Digestible organic matter content recovered in oil palm trunk steamed under various conditions.**

reduced the digestibility. This reduction was probably due to the higher loss of digestible organic matter during steaming because of the low recovery rate. Therefore, the optimum steaming point should be determined based on the balance of loss and gain of digestible matter by steaming. The percentage of digestible organic matter recovered after steaming was considered to be a good indicator for the evaluation. The percentage of DOM recovered at each steaming pressure is shown in Fig 1. From this figure, the optimum steaming time at each pressure was found to be approximately 60, 20, 7, and 4 minutes at 7.5, 10, 12.5, and 15 kg/cm$^2$, respectively. For practical purposes, the optimum steaming point was considered to be about 7 minutes at 12.5 kg/cm$^2$ because a shorter steaming time and the consistency in the quality of the steamed materials were required.

## 3 NaOH treatment of OPT and oil palm fronds

The relationship between the NaOH content and OM digestibility of the OPT and oil palm fronds is indicated in Fig. 2. The untreated samples showed an almost similar OM digestibility (20-23%). However, after treatment with NaOH, the digestibility was highest for OPT. The digestibility of OPT increased linearly by treatment with up to 7.5% NaOH, with smaller increases in digestibility for treatment with more than 7.5% NaOH. The maximum OM digestibility was 62.5% for 10.5% NaOH treatment, which was the highest value among the three materials examined. Although the OM digestibility of the stem and leaflets also increased with the increase in the level of NaOH, the rates were lower than those of OPT. Digestible OM contents of stem and leaflets on a DM basis showed little improvement with NaOH treatment at levels exceeding 6% due to the decrease in the OM content in the treated materials. Thus, OPT was considered to offer the best potential for ruminant feeds by the application of NaOH treatment as well as by steaming.

Chemical composition and *in vivo* digestibility of OPT treated with different NaOH

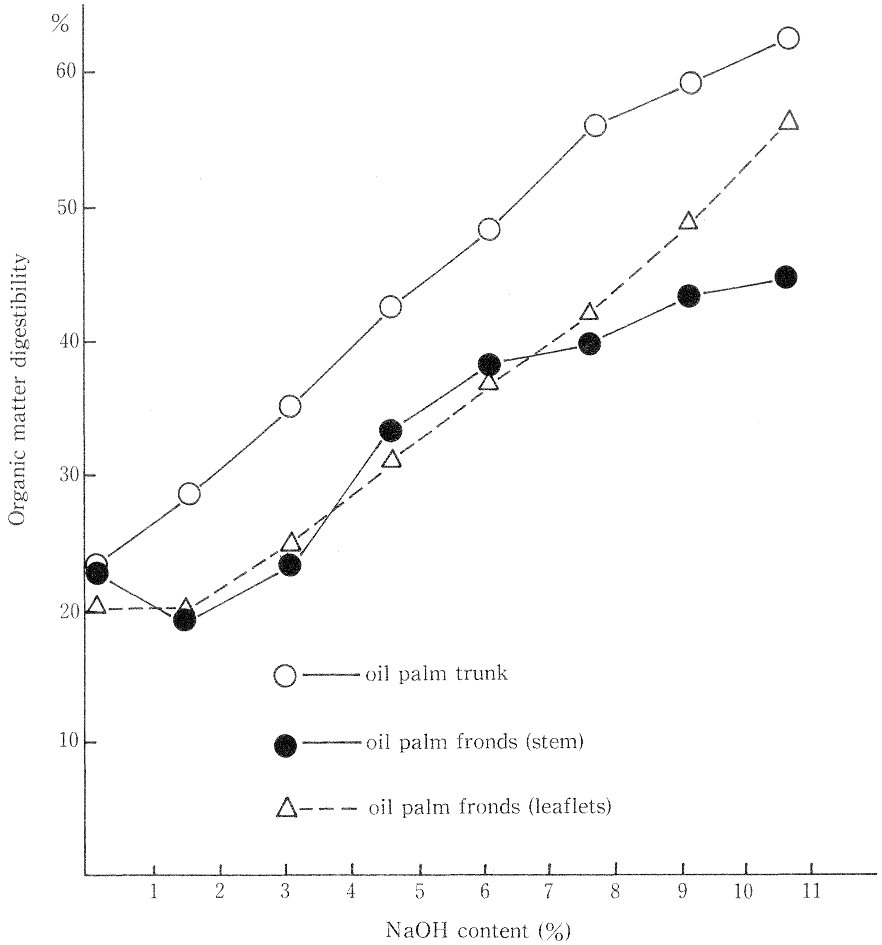

**Fig. 2 Relationship between NaOH content and *in vitro* OM digestibility of oil palm trunk and fronds.**

levels are shown in Table 2. The NDF content decreased when the NaOH content increased. The ADF content also showed a similar tendency, although the value in untreated OPT was slightly lower than expected. Judging from the decrease of the NDF and ADF content, the cellular component of OPT was estimated to be degraded to smaller molecules with NaOH. The apparent DM digestibility linearly increased by 2.8% unit for 1% NaOH content increase when the NaOH content ranged from 3% to 12%. In the other types of materials such as maize cobs (Kategile and Frederikson, 1979) or straw (Rexon and Thomsen, 1976), DM digestibility was reported to increase linearly by 2.3% unit per 1% NaOH content up to 5% NaOH content on a DM basis, suggesting that OPT required a higher NaOH level to improve the quality than other agricultural by-products. The palatability of OPT treated with 9 and 12% NaOH level was lower than that of OPT treated with a NaOH level below 6%. In terms of digestibility and palatability, the most suitable content of NaOH was found to range between 6 and 9% of DM.

**Table 2 Chemical composition and digestibility of oil palm trunk *per se* treated with NaOH**

| | DM | OM | CP | EE | Ash | NDF | ADF | Hemicellulose | GE |
|---|---|---|---|---|---|---|---|---|---|
| | (%) | % based on DM | | | | | | | (Cal/g) |
| Chemical composition | | | | | | | | | |
| Untreated OPT | 49.9 | 97.0 | 1.9 | 0.4 | 3.0 | 90.4 | 59.0 | 31.4 | 3,932 |
| 3% NaOH OPT | 51.9 | 93.2 | 1.8 | 0.2 | 6.8 | 81.0 | 64.6 | 16.4 | 4,038 |
| 6% NaOH OPT | 52.1 | 89.8 | 1.7 | 0.2 | 10.2 | 76.3 | 56.0 | 20.3 | 3,945 |
| 9% NaOH OPT | 53.7 | 87.0 | 1.5 | 0.2 | 13.0 | 66.0 | 50.3 | 15.7 | 3,859 |
| 12% NaOH OPT | 55.0 | 84.1 | 1.5 | 0.3 | 15.9 | 61.9 | 45.9 | 16.0 | 3,697 |
| Digestibility (%) | | | | | | | | | |
| Untreated OPT | 35.2 | 37.5 | 16.5 | 84.4 | 12.6 | 14.0 | 7.0 | 15.4 | 1,578 |
| 3% NaOH OPT | 34.6 | 33.5 | 36.4 | 87.7 | 38.6 | 23.4 | 5.7 | 38.7 | 1,057 |
| 6% NaOH OPT | 44.2 | 40.4 | 38.9 | 87.9 | 63.6 | 40.5 | 49.6 | 71.6 | 1,649 |
| 9% NaOH OPT | 49.8 | 47.2 | 25.9 | 89.9 | 63.2 | 46.6 | 20.0 | 62.2 | 1,813 |
| 12% NaOH OPT | 60.1 | 58.9 | 12.9 | 81.2 | 66.4 | 62.2 | 35.4 | 38.4 | 2,092 |

**Table 3 Chemical composition and apparent digestibility of rice straw and oil palm trunks subjected to various treatments**

| | DM | OM | CP | CF | EE | NFE | NDF | ADF | GE |
|---|---|---|---|---|---|---|---|---|---|
| | (%) | % based on DM | | | | | | | (Cal/g) |
| Chemical composition | | | | | | | | | |
| Rice straw | 91.0 | 77.8 | 9.4 | 29.1 | 0.9 | 38.4 | 69.0 | 54.8 | 4,512 |
| Oil palm trunk | | | | | | | | | |
| Dried | 92.6 | 96.6 | 2.4 | 39.4 | 0.6 | 54.2 | 74.4 | 52.2 | 4,375 |
| Steamed | 33.6 | 97.0 | 1.7 | 36.0 | 0.7 | 58.6 | 56.0 | 48.3 | 4,584 |
| NaOH-treated | 32.6 | 89.1 | 1.6 | 35.8 | 0.4 | 51.3 | 68.7 | 45.9 | 4,274 |
| Ensiled | 27.8 | 96.2 | 2.3 | 38.5 | 0.2 | 55.2 | 81.1 | 53.8 | 4,357 |
| Digestibility (%) | | | | | | | | | |
| Rice straw | 35.1 | 28.2 | −1.9 | 43.5 | 63.3 | 19.2 | 36.7 | 12.2 | 38.3 |
| Oil palm trunk | | | | | | | | | |
| Dried | 42.7 | 38.1 | −79.1 | 48.2 | 88.7 | 38.2 | 25.9 | 49.7 | 39.8 |
| Steamed | 54.6 | 50.0 | 0 | 34.6 | 118.3 | 68.1 | 32.0 | 70.1 | 56.2 |
| NaOH-treated | 54.2 | 47.1 | 153.2 | 25.7 | 190.7 | 65.7 | 38.0 | 70.2 | 54.3 |
| Ensiled | 50.5 | 48.2 | 67.6 | 24.3 | nd | 65.5 | 60.3 | 96.9 | 48.3 |

### 4 Effect of various treatments on the *in vivo* digestibility of OPT

Chemical composition and estimated apparent digestibility of OPT and rice straw are shown in Table 3. OPT *per se* showed a higher digestible energy without any treatment than rice straw. Steamed OPT showed the highest digestibility in DM, OM, and DE. NaOH-treated OPT and silage also exhibited a higher digestibility than untreated OPT or rice straw. Thus, it was considered that OPT could become a promising roughage source for ruminant if a suitable processing method for OPT were to be developed.

**Table 4 Chemical composition and digestibility of vascular bundles and parenchyma separated from oil palm trunk**

| | DM | OM | CP | EE | Ash | NDF | ADF | Hemicellulose | Lignin | GE |
|---|---|---|---|---|---|---|---|---|---|---|
| | | % based on DM | | | | | | | | (Cal/g) |
| Chemical composition | | | | | | | | | | |
| Vascular bundles | — | 98.3 | 1.1 | 0.3 | 1.7 | 92.0 | 70.1 | 21.9 | 10.2 | 4,438 |
| Parenchyma | — | 96.5 | 3.2 | 0.7 | 3.5 | 67.4 | 40.3 | 27.1 | 38.5 | 4,356 |
| Digestibility (%) | | | | | | | | | | |
| Vascular bundles | 19.1 | 14.1 | 58.1 | 92.0 | 28.6 | 3.9 | 10.0 | 10.5 | — | 10.4 |
| Parenchyma | 49.7 | 49.9 | 48.9 | 84.0 | 44.0 | 25.5 | 10.5 | 50.1 | — | 48.7 |

### 5 Digestibility of vascular bundles and parenchyma tissues of OPT

The chemical composition and *in vivo* digestibility of the parenchyma and vascular bundles are shown in Table 4. Vascular bundles consisted mainly of cell wall components such as NDF or ADF. However, ADF lignin only accounted for 10% of the total DM. On the other hand, the parenchyma consisted of 67% of NDF, 40% of ADF, and 38% of lignin. Though the vascular bundles showed higher NDF and ADF contents than the parenchyma, the lignin content was higher in the parenchyma. This finding suggested that the parenchyma could be separated into two different components ; namely highly digestible and low digestible parts. The cellular contents which were estimated by subtracting the NDF content from the total DM and considered to correspond to the highly digestible part, and lignin, to the low digestible part, accounted for one-third of the total DM, respectively.

While the DM and OM digestibility of the vascular bundles was only 19 and 14%, in the parenchyma the values of both the DM and OM digestibility were nearly 50%. In addition, since the palatability of the parenchyma was adequate for sheep, it was suggested that the parenchyma could become a good source of feed for ruminants. However, since the DM and OM digestibility of the vascular bundles was low, they can not be expected to become an energy source.

### 6 Long-term feeding of OPT to growing steers.

The chemical composition and digestibility of the experimental rations are shown in

**Table 5 Chemical composition and digestibility of experimental rations used for long-term feeding**

| | DM | OM | CP | EE | NDF | ADF | P | Ca | Mg | GE |
|---|---|---|---|---|---|---|---|---|---|---|
| | | % based on DM | | | | | | | | (Cal/g) |
| Ration (70% Basal ration + 30% Experimental feed) | | | | | | | | | | |
| Chemical composition | | | | | | | | | | |
| OPT silage ration | — | 93.7 | 11.8 | 2.0 | 56.6 | 38.0 | 0.35 | 0.67 | 0.19 | 4,047 |
| NaOH-OPT ration | — | 91.3 | 11.8 | 2.0 | 55.5 | 37.2 | 0.35 | 0.69 | 0.18 | 4,004 |
| Rice straw ration | — | 91.2 | 13.1 | 2.3 | 58.0 | 37.1 | 0.37 | 0.82 | 0.21 | 4,018 |
| Digestibility (%) | | | | | | | | | | |
| OPT silage ration | 63.0 | 64.8 | 60.4 | 87.6 | 50.5 | 40.2 | 58.4 | 38.2 | 42.0 | 2,439 |
| NaOH-OPT ration | 68.9 | 69.8 | 64.7 | 87.7 | 59.8 | 50.3 | 62.5 | 44.9 | 38.4 | 2,802 |
| Rice straw ration | 65.9 | 69.2 | 64.6 | 77.4 | 63.5 | 61.3 | 54.2 | 52.2 | 47.3 | 2,649 |

**Table 6 Voluntary intake, body weight gain and carcass composition of steers fed oil palm trunk and rice straw rations**

| | OPT silage ration group | NaOH-OPT ration group | Rice straw ration group |
|---|---|---|---|
| Voluntary intake (kg/head/day) (g/kg$^{0.75}$) | 5.82(77.0) | 7.32(95.1) | 7.69(101.0) |
| Daily body weight gain (kg/day) | 0.658±0.171 | 0.716±0.142 | 0.717±0.158 |
| Feed efficiency (kg, DM intake/body weight gain) | 8.84 | 10.23 | 10.73 |
| Half carcass (kg) | | | |
| Meat | 56.5±8.6 | 56.3±6.5 | 56.1±4.8 |
| Bone | 28.9±6.0 | 27.7±3.0 | 30.3±2.3 |
| Fat | 16.4±2.4 | 25.8±5.5 | 23.4±4.5 |

Table 5. The content of CP or macro-minerals such as Ca, P, or Mg was considered to be adequate in all the rations. The NaOH-treated OPT ration showed the highest DM and OM digestibility while OPT silage ration the lowest. Rice straw ration showed a higher DM digestibility than the OPT silage ration. The estimated DM digestibility of OPT silage *per se* was 41%, while the NaOH-treated OPT showed the highest value of DM and OM digestibility (59.2% and 54.1%). Rice straw also showed a higher DM digestibility of 48% than the rice straw used in Experiment 5. All the animals remained in good condition throughout the experimental period.

Voluntary intake, body weight gain, and half carcass composition of the steers fed on each ration are shown in Table 6. DM intake was the highest for the group fed on rice straw ration. However, there were no significant differences in the body weight gain among the rations. Thus, the feed conversion rate was the highest for the group fed on an OPT silage ration. Regarding the half-carcass composition, there were no significant differences in the meat and bone weight among the groups while fat weight was the lowest for the group fed an OPT silage ration. However, there were no significant differences among the groups in the meat quality such as rib eye area, marbling score, meat color score, fat color score, texture and water-holding capacity, or carcass pH. In this experiment, the use of ensiled and alkali-treated OPT did not adversely affect the growth performance and digestive physiological functions of the cattle when OPT was fed at a percentage of 30% of the total ration. Moreover, alkali-treated or even untreated OPT exhibited a better feed efficiency than good quality rice straw. Although steam-treated OPT was not used in long-term feeding, it was anticipated that it may show a better feed efficiency than alkali-treated or untreated OPT due to the higher *in vivo* digestibility value compared with other treatments as indicated in Experiment 5. Therefore, it was confirmed that OPT can be used as ruminant feed in any form when it accounts for 30% of the total intake. Judging from the voluntary intake of OPT in our other experiment, the maximum percentages of ensiled and NaOH-treated OPT in the total ration were considered to increase up to 50 and 70%, respectively.

It was confirmed in this study that OPT may become a promising roughage source for cattle. However, the constraints on the use of OPT as economical ruminant feed include the cost of processing such as felling, chipping, treatment, transportation, and storage. The cost of processing OPT could be reduced by several factors such as location where OPT is harvested, processed and fed to animals, facilities and machines used, or the processing methods. Therefore, further investigations on economical methods of processing of OPT will be required through model plant or farm.

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## Discussion

**Argañosa, A. S. (Philippines)** : Did you estimate the cost of processing OPT into animal feed?

**Answer** : During the feeding experiments concomitant studies were carried out to determine the processing cost of OPT chips. When the Pallman flaker was used (instrument used by forest product workers), the cost including harvesting, transport to processing plant, processing, energy and labour amounted to 25 cents (M$-Ringgit)/kg/dry matter basis. When the Junkkari chipper (from Finland) was used the cost amounted to 20 cents.

**Haryanto, B. (Indonesia)** : What happens if steamed OPT is used as medium for fungi before being used as ruminant feed?

**Answer** : The steamed material is not suitable as medium for fungi because the hemicellulose fraction is destroyed by steaming. If you want to use OPT as medium for fungi, you should use untreated OPT. Biological treatment of OPT is not practical because very large amounts would be required, hence the need for a large machine.