The utilization of cassava by-products into complete ration on performances and feed digestibility of weaning male crossbred Landrace pigs

D P Zendrato, F Hasan, N D Hanafi*, Y L Henuk and A H Daulay
Animal Husbandry Department, Faculty of Agriculture, Universitas Sumatera Utara, Medan, Sumatera Utara, Indonesia.

E-mail: *nevidyana@yahoo.co.id

Abstract. A study was conducted to determine the utilization of cassava by-products, especially leaves, peel and pulp included into a complete ration on the performances and digestibility boar crossbred Landrace pigs. 16 crossbred white Landrace piglets with an initial live weight of 20.40 (± 1.27) kg used in this study. A completely randomized design was used in which the 16 piglets were randomly allocated to four diets and four replicates. The four dietary treatments were used: $T_0$ = positive control (commercial pig starter/grower added without dried cassava by-products); $T_{20}$ = commercial pig starter/grower added with 20% dried cassava by-products; $T_{40}$ = commercial pig starter/grower added with 40% dried cassava by-products; $T_{60}$ = commercial pig starter/grower added with 60% dried cassava by-products. The best result of adding cassava by-products in commercial starter/grower of pigs were at the level of 20% with FI of 1.547 kg/head/day, BWG of 0.296 kg/head/day, FCR of 5.22, DM digestibility of 77.72%, OM digestibility of 73.77%. It was concluded that cassava by-products derived from the making of cassava chips for human consumption can be included in pigs starter and grower diet up to 20%.

1. Introduction
Cassava (Manihot esculenta Crantz) is grown in tropical countries in Africa, Asia and Latin America, with 70% of the world’s cassava production coming from Nigeria, Brazil, Thailand, Indonesia and the Democratic Republic of the Congo. Thailand, Indonesia and Brazil are the most prominent exporters of cassava starch, with their production accounting for 95% of the world’s supply. Cassava root can be used to produce cassava chips, cassava pellets and cassava starch, which are in high demand throughout the world [1]. Cassava is one of Indonesia’s important commodities in the agricultural sector. It is one of rice food substitutes that is important in supporting the food security of the region, especially in Eastern Indonesia. Cassava is a third crop commodity in Indonesia, following rice and corn.

Globally, Indonesia is third largest country exporting dried cassava in the world, following Thailand and Vietnam [2]. Cassava root meal which has been used as good alternative energy source in poultry and pig diets is increasingly becoming an important energy source for feeding the world’s human population. There are however, several by-products of cassava harvest ranging from the leaves, peels and pulp which potential as feed ingredients in poultry rations. Cassava peels and pulps are moderate to high in energy and have been included in diets as replacements for conventional energy sources. Cassava leaves, moderate to good protein contents, have been used as protein supplements. Dietary recommendations of cassava by-products for poultry have varied considerably [3].
By-products from cassava tuber processing would be high in starch and low in protein and, could be used replace some levels of maize grains in diets for poultry and pigs at a cheaper rate [4]. Efficient use cassava by-products will reduce feed cost of monogastric production and provide additional source of income to cassava farmers and processors [3]. The residues of cassava root processing, is a valuable feedstuff in pig nutrition in the tropics that helps small and medium scale pig farmers to reduce their feeding costs. Its possible utilization of cassava for a replacement of maize up to a level of 57% and its better use by pigs when processed by fermentation or sun drying [5]. However, the major factors limiting the efficient utilization of these by-products in monogastric diets include the high fibre and low energy contents and likely presence of antinutritional factors, mainly hydrocyanic acid (HCN) in the bitter variety of cassava. Several technologies have been used to improve the utilization of cassava by-products by monogastric [3].

The fermentation of cassava root meal with *S. cerevisiae* enhanced the protein level from 4.4% to 10.9% in DM and decreased the cyanide content [6]. Therefore, the use of cassava and its by-products has enjoyed widespread patronage in the nutrition of many livestock species namely: swine, poultry and small ruminants. The purpose of this study was to determine the utilization of cassava by-products in monogastric diets.
(24 Hours). The way to collect feces is: Feces is taken every morning and in each pig that is treated, then weighed the total weight. Feces is stirred evenly, then 100 gram samples are taken to be put into the oven at 60°C for analysis of sample air dried material and then composite until the collection period is complete. The samples are then processed for analysis of dry matter (DM) and organic matter (OM). Data collection is done in 1 week before the end of the study. Percentage of dry matter digestibility is calculated by reducing consumption of dry matter with faecal dry matter and then divided by consumption dry matter, then multiplied by 100 percent, namely the following formula:

\[
\% \text{ DM Digestibility} = \frac{\text{Consumption DM (kg/head) } - \text{ feces DM (kg/head)}}{\text{Consumption DM (kg/head)}} \times 100\%
\]

Percentage of digestibility of organic matter is calculated by reducing consumption of organic matter with faecal organic matter then divided by consumption organic matter, then multiplied by 100 percent, namely the following formula:

\[
\% \text{ OM Digestibility} = \frac{\text{Consumption OM (kg/head) } - \text{ feces OM (kg/head)}}{\text{Consumption OM (kg/head)}} \times 100\%
\]

2.1.5. The Income Over Feed Cost (IOFC). Income Over Feed Cost (IOFC) is calculated by reducing income from the sale of pigs with costs incurred for feed. IOFC = Pig sales revenue-feed cost. Data obtained will be analysed using variance (Anova). If there are significant differences, it will be continued with the Duncan test [8].

2.2. Implementation of research

2.2.1. Making rations. Cassava by-products consisting of cassava leaves, cassava peel and cassava pulp are dried first and then ground using a grinder. After that it is mixed with other feed ingredients such as corn flour, rice bran, coconut meal, soybean meal, minerals and molasses. After all homogeneous ingredients are then given to pigs.

2.2.2. Preparation of cage and equipment. The cages used were individual units of 100x100x80 cm as many as 16 units. The cage floor is made of iron and between the cage units with one another separated by a partition. Cages are prepared a week before pigs enter the cage so that the cage is free of pests. The cage equipment is cleaned and disinfected using rodalon. The selected animals are healthy and normal (not disabled) pigs. The pig is put into a cage randomly. Feed adaptation was carried out before the implementation of the research for 2 weeks to familiarize the pigs with the new feed, which is a complete feed based on cassava. Weighing is carried out every week during the study period.

2.2.3. Research ration composition. The complete ration arrangement and nutrient content in the ration to be compiled for this study, it can be seen in Table 1 and 2.

| Material            | Treatment | T₀   | T20  | T₄₀  | T₆₀  |
|---------------------|-----------|------|------|------|------|
| Cassava by-products |           | 0    | 20   | 40   | 60   |
| Corn Flour          |           | 42   | 30   | 19   | 7    |
| Rice Bran           |           | 18.8 | 12   | 7.8  | 5    |
| Coconut Meal        |           | 12.2 | 13   | 9.2  | 5    |
| Soybean Meal        |           | 20   | 18   | 17   | 16   |
| Mineral             |           | 2    | 2    | 2    | 2    |
| Molasses            |           | 5    | 5    | 5    | 5    |
| Total               |           | 100  | 100  | 100  | 100  |
2.2.4. Analysis proximate and HCN on ration. Analysis proximate and HCN to determine the nutrient content and HCN content of the treatment ration that has been prepared.

2.2.5. Care and maintenance. Before pigs are given treatment, the initial weight of the pig is weighed and then weighing the pig is done once a week. Feed is given twice a day at 08.00 WIB and 16.00 WIB.

3. Results and discussion

3.1. Proximate analysis of the ration

Proximate analysis of the ration aims to determine the chemical composition of feed ingredient. The variables observed in the treatment diet included: Moisture Content, Ash, Crude Protein, Crude Fibre, Crude Fat, Nitrogen Free Extract (NFE) and EM from the ration arrangement using cassava by-products. The results of the analysis can be seen in Table 2 below. From Table 2, we can see that the proximate analysis of the ration with the use of cassava by-products is higher, it turns out to increase the crude fibre content in each treatment, which ranges from 6.48-10.58%. This result is not much different from the calculation of ration arrangement with crude fibre ranging from 6.33-9.35% which we can see in Table 1. According to [9] cassava by-products containing high fibre found on cassava leaves, cassava peel and cassava pulp is 11.4%.

In T60 there was a decreasing in crude protein, namely by using cassava by-products on a ration at the level of 60%. This is because the higher use of cassava by-products on the ration does not increase the protein but increases the fibre. The highest fat was at T0, which was 7.72% and the lowest was 4.12%. This is because in treatment T0, the preparation of rations without the use of cassava by-products while in T20, T40 and T60 uses cassava by-products which reduce the fat of the treatment. This result is still in the normal range. According to [10] the maximum need for crude fat in pig saplings is 7%.

### Table 2. Nutritional content of the treatment ration (DM)

| Nutrition Content          | Treatment | T0     | T20    | T40     | T60     |
|----------------------------|-----------|--------|--------|---------|---------|
| Crude Protein (%)          |           | 17.167 | 17.179 | 17.169  | 17.1635 |
| Energy Metabolism (Kcal/kg)|           | 2627.36| 2676.42| 2722.72 | 2749.58 |
| Crude Fibre (%)            |           | 7.489  | 6.333  | 8.373   | 9.359   |
| Crude Fat (%)              |           | 3.57   | 4.2976 | 3.1196  | 2.791   |
| Ca (%)                     |           | 0.4784 | 0.40272| 0.55222 | 0.6269  |
| P (%)                      |           | 0.4192 | 0.4128 | 0.4092  | 0.3989  |

### Table 3. Proximate analysis of treatment ration

| Treatment | Moisture Content (%) | Ash (%) | Crude Protein (%) | Crude Fibre (%) | Crude Fat (%) | NFE (%) | EM (Kcal/kg) |
|-----------|----------------------|---------|-------------------|-----------------|---------------|---------|--------------|
| T0        | 36.02                | 7.25    | 17.44             | 6.48            | 7.72          | 25.09   | 3315.38      |
| T20       | 36.32                | 12.41   | 18.12             | 8.49            | 5.97          | 18.69   | 2089.37      |
| T40       | 41.37                | 7.45    | 16.06             | 9.60            | 5.21          | 20.31   | 1755.45      |
| T60       | 43.69                | 7.94    | 14.00             | 10.58           | 4.12          | 19.67   | 1173.49      |

NFE levels at T0 is higher than T20, T40 and T60. This happens because NFE is influenced by the content of other nutrients, namely crude protein, as fed, ash, crude fat and crude fibre [11]. [12] added
that the NFE content of feed material is highly dependent on other components, such as water, ash, crude protein, crude fibre and crude fat. If the amount of as fed, ash, crude protein, crude fat and crude fibre is reduced from 100, the difference is called nitrogen free extract (NFE). Decreasing NFE levels is viewed from the aspect of nutrition is less profitable, because the less NFE, means the fewer components of organic matter that can be digested so that less energy can be produced. Based on the energy calculation according to [9], the energy produced is getting smaller while weaning piglets require a fairly large amount of energy which is around 3300 Kcal/kg [13]. [10] also added that the maximum energy requirement for weaning piglets is 2900 Kcal/kg. Lack of energy in food can inhibit weight gain in pigs which has a major effect on feed efficiency [14].

3.2. Analysis of cyanide acid (HCN) ration

Analysis of cyanide acid (HCN) ration content can be seen in Table 3. Based on the analysis of the content of cyanide acid/HCN in rations containing cassava by-products ranging from 2.11-13.40 mg/kg (ppm). In treatment T_0 without the using of cassava by-products, the HCN content produced was lower than treatment T_20 (20%), T_40 (40%) and T_60 (60%).

| Treatment | Cyanide acid /HCN (mg/kg) | Feed intake (kg/head/day) | Body weight (kg) | The amount of HCN consumed by pigs (mg/kg body weight) |
|-----------|---------------------------|---------------------------|------------------|--------------------------------------------------------|
| T_0       | 2.11                      | 1.778                     | 20.350           | 0.18                                                   |
| T_20      | 5.28                      | 1.546                     | 19.725           | 0.41                                                   |
| T_40      | 8.24                      | 1.724                     | 21.125           | 0.67                                                   |
| T_60      | 13.40                     | 1.542                     | 20.400           | 1.01                                                   |

From Table 4 it is also known that the amount of HCN consumed by pigs ranges from 0.18-1.01 mg HCN/kg body weight, where the range of HCN in the ration is still within tolerance. This is closely related to the HCN in feed, feed consumption and body weight of the pigs. This is consistent with the statement [15] which stated that depending on the amount consumed HCN can cause death if at a dose of 0.5-3.5 mg HCN/kg body weight. According to [15] the cyanide acid of 50 mg/kg (ppm) is still safe for consumption, but exceeding that level can cause poisoning. High cyanide will cause a bitter taste. The danger of HCN to health is especially in the respiratory system, where oxygen in the blood is bound by HCN compounds and the disruption of the respiratory system (difficulty breathing). In this study the method of drying in the sun is used to reduce the cyanide in the ration. Drying sunlight is also the method of choice in tropical countries because it reduces HCN, below toxic levels without any apparent effect on nutritional quality. Solar drying also has the advantage of saving energy and equipment costs that are limited in small scale farming systems. [16] and [17] reported that 90% decrease in HCN in dried cassava leaves. [18] also observed that sun drying reduces the HCN of cassava pulp and increases its nutritional value.

3.3. Performance

3.3.1. Feed Intake. From the diversity analysis (Table 5) by giving cassava by-products to 60% shows a significant influence (P<0.01) on feed intake. The highest treatment was found in treatments T_0 (1.788) and T_40 (1.724). These results are still in the normal range with the feed intake according to [13] which stated that consumption of pork rations weighing 20-35 kg is around 2.5 kg/head/day. This is closely related to the level of palatability of pigs to rations. This is in accordance with the statement [19] which stated that feed quality is not only determined by the nutrient content and feed digestibility or feed ingredients, but also determined by the level of palatability of the feed given. Palatability is a very important factor for determining the level of feed consumption, where the palatability of feed is determined by taste, smell and colour which influence physical and chemical factors of feed. Means of
feed intake in dry matter, weight gain and feed conversion ratio in pig can be seen in Table 5.

**Table 5. Means of feed intake, weight gain and feed conversion ratio in pig**

| Treatment | Feed intake (kg/head/day) | Weight gain (kg/head/day) | Feed conversion ratio |
|-----------|---------------------------|---------------------------|-----------------------|
| T₀        | 1.788ᵃ                   | 0.328ᵃ                   | 5.46ᶜ                 |
| T₂₀       | 1.547ᵇ                   | 0.296ᵇ                   | 5.22ᶜ                 |
| T₄₀       | 1.724ᵃ                   | 0.268ᶜ                   | 6.45ᵇ                 |
| T₆₀       | 1.543ᵇ                   | 0.194ᵈ                   | 7.96ᵃ                 |

Note: Different superscripts on the same column had significant difference (P<0.01)

The higher of giving cassava by-products will result in reduced consumption. This result is shown by research [20] which states that the consumption of rations in weaning New Zealand White rabbits have decreased with the addition of fermented cassava by-products up to 30% in rations. This result is related to research [21] which states that consumption of quail rations given fermented of cassava by-products in ration mixes up to 30% also decreased consumption. From Figure 1 on the ration consumption obtained R Square value of 33.44% which means that there is an influence of the level of cassava by-products consumption of pig ration by 33.44% and the rest 66.56% is influenced by other factors. According to [22], the factors that influence the consumption of rations are feeding method, smell of feed, environmental conditions or temperature of the cage, availability of drinking water, number of animals and animal health.

3.3.2. Daily weight gain. Based on the results of the analysis of diversity (Table 5) from the yield of cassava by-products mixed in rations showed a very significant effect (P<0.01) on weight gain in pigs. The highest weight gain was found at T₀ (0.328) and the lowest at T₆₀ (0.194). This is closely related to the crude fibre which is too high in T₆₀ ration (10.58%) which cannot be digested well by pigs. According to [10] the maximum requirement for crude fibre in saplings is 5%. [23] also stated that crude fibre has the greatest influence on digestibility, the higher crude fibre of feed ingredients will cause a decreasing in digestibility which affects the body weight gain of pigs. In T₆₀ the pig's body weight gain is the lowest. This is because in T₆₀ the use of cassava by-products up to the level of 60% can reduce the growth of pigs weight because it contains high HCN which disrupts the palatability of the ration because of its bitter taste. This result is in accordance with the HCN analysis that has been tested stating that the highest HCN is found in T₆₀. This is also closely related to the lowest protein content of rations on T₆₀ (13.40 mg/kg).

The results of the study of cassava by-products in this ration did not differ from studies [20] which stated that weight gain in weaning New Zealand White rabbits decreased with the addition of fermented cassava by-products by up to 30% in the ration. [24] also reported that the use of cassava by-products could replace up to 66% of coconut flour (26% of the ration) in improving the diet of pigs without any side effects on weight gain.

From Figure 1 on the gain of pig's weight obtained R Square value of 94.15% which means that there is an influence of the level of cassava by-products on the gain of pig's weight of 94.15% and the rest 5.85% is influenced by other factors. From the results of the study showed that consumption of cassava by-products which was higher in the ration showed the lower palatability and smell of feed which livestock disliked. This affects weight gain even though its digestibility is very good which we can see in Table 6 with T₆₀ (72.05%). This is in accordance with the statement [22] stated that the digestibility of a food ingredient can be influenced by factors including the composition of food ingredients, type of food, feed consumption, food preparation, animal factors and the amount of food.

3.3.3. Feed Conversion Ratio (FCR). Based on the results of the analysis of the diversity (Table 5) of the yield of cassava by-products mixed in the ration showed very different influences significant (P<0.01) for feed conversion in pigs. The highest ration conversion was found in T₆₀ (7.96), then followed by T₄₀ (6.45), treatment T₀ (5.46) and followed by treatment T₂₀ (5.22). In treatments T₀ and
There were no significant differences. We know this from ration consumption and weight gain in pigs. The lowest conversion rate was found in T20. This is because the ration consumption at T20 is the lowest and weight gain on T20 is also not much different from the weight gain at T0. So that the conversion of ration produced by T20 is the lowest and followed by T0. The highest ration conversion is at T60. This is followed by ration consumption and low body weight gain on T60. This is closely related to its low protein but high crude fibre and is followed by the highest HCN on T60. The high and low conversion of feed is determined by the balance between energy metabolism and nutrients, especially proteins and amino acids [25].

The results of the study of cassava by-products in this ration did not differ from studies [21] that the conversion of quail cattle rations fed by fermented cassava by-products in the ration mixture was up to 30% higher. This is because the higher use of fermented cassava by-products made a decreasing in body weight of quails, as a result of the higher content of crude fibre in the ration. Research [24] that substituted cassava by-products to the level of 30% with corn flour and soybean reduced the profit and feed efficiency of pigs growing linearly with increasing use of cassava by-products.

From Figure 1 in the ration conversion obtained R Square value of 82.00%, which means that there is an influence level of cassava by-products use on pig ration conversion of 82.00% and the remaining 28.00% is influenced by other factors. The smaller ration conversion shows that the less feed needed to produce per kg of body weight. The lower the number of feed conversion means the better the efficiency of feed use [26]. Feed conversion is a very important factor to determine the profit and loss of a livestock business [27].

### 3.4. Feed digestibility

Means of dry matter digestibility and organic matter digestibility of feed in pigs can be seen in Table 6.

| Treatment | Dry matter digestibility (%) | Organic matter digestibility (%) |
|-----------|------------------------------|----------------------------------|
| T0        | 77.09a                       | 75.46a                           |
| T20       | 77.72a                       | 73.77a                           |
| T40       | 73.49b                       | 71.15b                           |
| T60       | 72.05b                       | 68.93b                           |

Note: Different superscripts on the same column had significant difference (P<0.01)

The relationship between the use of cassava by-products with the digestibility of dry matter and digestibility of organic matter in pigs can be seen in Figure 2 below.

#### 3.4.1. Dry matter digestibility

Based on the results of the analysis of the diversity (Table 6) of the yield of cassava by-products mixed in the ration, the effect was very significantly different (P <0.01) on digestibility of ration dry matter in pigs. The highest dry matter digestibility was found in treatment T20 (77.72%), then followed by treatment T0 (77.09%), treatment T40 (73.49%) and treatment T60 (72.05%). The higher level of utilization of cassava by-products in the ration decreased the digestibility value of rations in pigs.

The difference in digestibility of dry matter from these treatments is due to differences in consumption of dry matter and nutrient in feed. The T60 treatment has a lower crude protein and a higher crude fibre compared to other treatments that we can see in Table 3. This is consistent with statement [28] which stated that pigs are animals that have simple digestive devices, which do not able to digest rations that have high crude fibre content. The results of the study [29] reported that the addition of molasses to the cassava by-products as much by 3% resulted in the digestibility of dry matter by 70.08%. This is because the addition of molasses can reduce the crude fibre of cassava by-products. [30] also reported that the by-product of fermented cassava could reduce the crude fibre and produce digestibility of dry matter by 61.87%.
From Figure 2 on the digestibility of dry matter ration in pigs, the R Square value of 82.36%, which means that there was an influence of the level of cassava by-products on the digestibility of ration dry matter in pigs by 82.36% and the rest 17.64% are influenced by other factors. The high digestibility values reflect the contribution of certain nutrients to livestock, while feed that has low digestibility indicates that the feed is less able to supply nutrients to be absorbed in meeting basic living needs and production goals [31].

3.4.2. Organic matter digestibility. Based on the results of the analysis of the diversity (Table 6) of the yield of cassava by-products mixed with rations, the effect was very significantly different (P <0.01) on digestibility of organic matter rations in pigs. The lowest digestibility of organic matter was found in T_60 treatment of 68.93% and the highest was found in treatment T_0 of 75.46%. Digestion of organic matter shows the amount of nutrients such as fats, carbohydrates and proteins that can be digested by livestock [32].

The treatments of T_0 and T_20 had the same effect on the digestibility of organic matter but had significantly different from the treatments of T_40 and T_60. The differences in the digestibility of organic matter in the treatments T_0 and T_20 against T_40 and T_60 are caused by the treatment of T_40 and T_60, the higher yield of cassava by-products in the ration causes the nutritional content to be lower and the mineral to be higher. Because the higher the mineral value, the lower the digestibility of organic matter and on the contrary. This is in accordance with statement [33] which stated that low minerals will increase the digestibility value of dry matter and organic matter.

The results of the study [29] reported that the addition of molasses to the cassava by-products as much as 3% resulted in the digestibility of organic matter by 64.30% due to the optimal development of lactic acid bacteria. [30] also reported that fermented cassava by-products produced 60.09% dry matter digestibility. From Figure 2 on the digestibility of pig pad ration organic matter, the R Square value of 99.36%, which means that there is an influence of the level of cassava by-products use on the digestibility of dry ingredients in pigs by 99.36% and the rest 0.64% are influenced by other factors. Increased digestibility of organic matter is always accompanied by increasing digestibility of dry matter rations. This is in accordance with the statement [32] which stated that the increase in organic matter digestibility is in line with the increase in dry matter digestibility, because most dry matter components consist of organic matter so that the factors affecting the digestibility of dry matter will also influence digestion organic material.

4. Conclusions
The best proximate analysis with the use of cassava by-products in the ration reaches the level of 20%. Analysis of cyanide/HCN in rations increased with the use of cassava by-products increasing at around 2.11-3.40mg/kg. The best results from giving cassava by-products are at the level 20% with FI of 1.547 kg/head/day, BWG of 0.296 kg/head/day, FCR of 5.22, DM digestibility of 77.72%, OM digestibility of 73.77%. Cassava by-products derived from the making of cassava chips for human consumption can be included in pigs starter and grower diet up to 20%.

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