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by Trisiwi Wahyu Widayati

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Feeding Effect of Different Levels of Agricultural and Food Waste on Growth Performance and Economics in Pig Production

Trisiwi Wahyu Widayati, Bernadeta Wahyuni Irianti Rahayu, Dwi Djoko Rahardjo and Marlyn Nelce Lekitoo
Department of Animal Science, University of Papua, Jl. Gn. Salju Amban Manokwari Papua Barat 98314, Indonesia

Abstract: This study was undertaken with the objectives to determine the feeding effect of different levels of agricultural and food waste on growth performance and cost effectiveness in pig production. This study was conducted at Manokwari regency, West Papua Province, Indonesia. The agricultural and food industry by-products used were collected from two traditional markets, five restaurants and 15 small-scale food industries. All materials used as ration were proximally analyzed to determine their nutritional values. Average daily gain (ADG), feed consumption and feed conversion ratio (FCR) were taken to determine the pigs' performance. Feed cost using local market prices was estimated in knowing the ability of agricultural waste product and food industry to substitute commercial feed. Tabulation was used to analyse the data. The result of this research indicates that the usage of agricultural and food industries' wastes as the alternative components of pigs' feed to substitute the commercial ones does not reduce the pigs' performance and production. Among three rations that use agricultural and food industry wastes, ration with the combination of 25% waste and 75% commercial feed had the best FCR. On the other hand, a mixture of 75% waste and 25% commercial feed is the most economic one, and able to reduce the cost of feeding up to 35.86%.

Key words: Agricultural by-product, pig, ration, ration cost.

1. Introduction

The paradigm of modern animal husbandry is based on zero waste concept. Use of agricultural and food industry by-products into useful materials is an important issue that needs to be done.

In the last 10 years many researchers have paid attention to the existence of waste both from agriculture and by-product from the food industry. Without proper management, wastes both from agricultural and food industry are considered to be a threat both ecologically and aesthetically to the environment and human health. Obi *et al.* [1] revealed that agricultural wastes are defined as the residues from the growing and processing of raw agricultural product as fruits, vegetable, meat, poultry dairy product and crop. Meanwhile, industry by-products are produced in the large amount in the food industry. Helkar *et al.* [2] state that about 38% of food wastes occur during food processing. Food wastes are produced by a variety of sources, animal-derived processing food wastes include by-products from breed animals such as carcasses, hides, hoofs, heads, feathers, manure, offal, viscera, bones, fat and meat trimmings, blood; wastes from seafood such as skins, bones, oils, blood; wastes from dairy processing industry such as whey, curd, and milk sludge from the separation process; vegetable-derived processing food wastes include peelings, stems, seeds, shells, bran, trimmings residues after extraction of oil, starch, juice and sugars. Improper management of foodstuffs also reduces the total economic value of food. Venkat [3] stated that the loss of economic value of food such as vegetables, fish, legumes caused by inefficiency in retail and consumer in America was as much as US$197.68 billion per year. Therefore, waste management is

Corresponding author: Trisiwi Wahyu Widayati, Ph.D., research field: social and economic of agriculture.

needed to increase the value of the waste. In some countries with a high demand for animal feeding such as Japan, South Korea and Taiwan, local law encourages using food waste to feed animal [4].

Papua is one of the provinces in the eastern part of Indonesia with the indigenous population called Papuan. Papuan has a unique culture and social life where they make pigs as the favorite animal. Pigs for the people of Papua are valuable in social, cultural and economic setting. Most of the communities use pigs in traditional ceremonies, and also as an exchange tool in several transactions. The market demand of this commodity is quite high and it has become a primary saving for many farmers. The selling price of this animal is sufficiently high, ones in weaning period can be sold from IDR 1,000,000 to IDR 1,500,000 ($70.88 to $106.32) and the price for ones aged 8-12 months varied from IDR 3,000,000 to IDR 5,000,000 ($212.64 to $354.40). Unfortunately so far, pigs in Papua have not been intensively raised yet. The animals usually are left to look for food by themselves, so the aspects of feeding, reproduction and health are not properly cared. In general, farmers feed their animal with only a single type of feed, such as tubers or roots which are low in quality. The minimum amount and the low quality of feed are factors that affect the slow growth of pig and make them more vulnerable to diseases [5, 6]. Another problem in raising pigs is that they are a monogastric animal and many of their feed competed with human's food. This condition causes a problem in feed availibility during intensive pig raising, thus it is imperative to find alternatives to high quality pigs' feed without competing with the people's [7, 8]. According to Ref. [9], West Papua has an ample amount of forages and agricultural by-products and has the potential to sustain the development of animal husbandry, which is 42,442,750 t produced from 4,244,274 ha. Furthermore, Pattiselanno and Iyai [10] reported that food wastes from restaurants, food industries and traditional fish markets were 2,056, 200 and 500 kg/d, respectively.

A good livestock development is dependent upon the availability of feed, socio-cultural conditions and local climate [11, 12]. In fact, the potential market of pig is high, but on the other hand there are still problems in the continuous feed: whether it is availability, quality or cost. Thus it is necessary to use the ingredients from agriculture and food industry by-products as an alternative of pig ration [13, 14]. Based on reasons above, a study was conducted to evaluate potential of agriculture and food industry by-products in Manokwari regency as nutrient source to pig and its ability to subtitute commercial ration in order to reduce ration cost.

2. Materials and Methods

2.1 Location of Study

The experiment was carried out from June to August 2017 at the Animal Research Laboratory of University Papua in Manokwari, Indonesia (134°04′ longitude and 00°48′ latitude) with a mean altitude of 110 m. Average temperature is 37 °C with daily variations from 37-39 °C.

2.2 Animal, Ration and Experimental Design

Twelve (12) male local pigs with an initial body weight (BW) of 12.54 ± 1.84 kg were arranged in a completely randomized design (CRD) with four treatments and three replications. The animals were housed in 12 individual cages.

Ration used in this experiment were formulated from agricultural and food industry by-products, i.e., fish waste, soybean curd waste, taro skin, soybean skin, vegetables waste and commercial pig ration. The agricultural and food industry by-products were collected from two traditional markets, five restaurants and 15 food industries in Manokwari regency. The four treatments were T1: combination of 75% agricultural and food industry by-products and 25% commercial ration; T2: combination of 50% agricultural and food industry by-products and 50% commercial ration; T3: combination of 25% agricultural and food industry

by-products and 75% commercial ration; T4: 100% commercial ration. Rations T1, T2 and T3 were formulated based on dry matter (DM) basis with iso-protein and iso-energy concept. The commercial pig ration (Charoen Pokphand 511) as control diet used in this experiment was produced by Charoen Pokphand, Indonesia. Formulation of pig ration in starter period is presented in Table 1.

2.3 Experimental Procedure

The experiment lasted 35 d and was comprised of 10 d for adaptation period, followed by four weeks for feed intake data collection. The rations supplied twice a day (at 08:00 and 16:00 h) *ad libitum*. Fresh water is available *ad libitum*. Individual ration refusals, if any, were collected, weighed daily and samples were collected for analysis. Before the start of the experiment, pigs were dewormed with 0.7 mL/kg BW of albendazole (PT. Kimia Farma, Indonesia). The animals were weighed each week throughout the experiment.

2.4 Statistical Analysis

Data were subjected to analysis of variance for a CRD using SPSS version 21. Comparison of means was carried out using the Duncan's multiple range tests, when the effect of treatment was significant ($p < 0.05$).

The linear model of experimental design was as follows:

$$Y_{ij}: \mu + T_i + \varepsilon_{ij}$$

where Y_{ij}: the score for observation of ith variable and jth replication; μ: the overall population mean; T_i: the effect of ith treatment level (type of ration); ε_{ij}: the error effect associated with ith treatment level and jth replication; i: 1, 2, 3, 4; j: 1, 2, 3.

3. Results

The agricultural and food industry by-product availability in Manokwari regency is shown in Table 2. The utilization of agricultural and food industry wastes is expected to improve their economic value as pigs' feed.

The most important factor in livestock's ration formulation is the balance between energy and protein composition. That is why proximate analysis was conducted, with the result displayed in Table 3.

In the farm business, the feeding part is the most expensive of all the operational cost. A study conducted by Sala and Delia [15] indicated that the feeding part covered 80% of the livestock upkeep cost. As shown in Table 4, waste utilization was able to reduce the feeding cost, the most cost reduction was achieved with 75% of waste mixture.

Three kinds of treatments were made from wastes, while the last one was commercial feed as the control. Tabulation and statistic tests results of agricultural waste usage as starter pigs' feed are presented in Table 5.

The result indicated that the utilization of all four kinds of ration was able to increase the pigs' daily weight gain, with the highest average from T3 ration (0.465 ± 0.05 kg daily) followed by T4, T2 then T1.

The analysis of variance showed that there were no

Table 1 The composition of pig rations (%) in starter period.

Feedstuffs	T1	T2	T3	T4
Fish waste	18.57	12.37	6.17	
Soybean curd waste	15.70	10.47	5.23	
Taro skin	8.82	5.9	2.94	
Vegetables waste	16.04	10.69	5.37	
Restaurant waste	15.87	10.57	5.29	
Commercial ration*	25	50	75	100
Total	100	100	100	100

* Contained corn, rice bran, soybean meal, coconut meal, meat and bone meal, wheat meal, canola, calcium, phosphorus, vitamin, trace mineral and anti-oxidant.

Table 2 Types and potentials of local feed in Manokwari regency.

No.	Feed commodity	Potential (kg/year)[a]	By-products	Potential (kg/d)[b]
1	Soybean	15,191.00	Soybean curd waste	2,400.00
			Soybean skin	55.50
2	Fish	27,911.00	Fish waste	1,000.00
3	Mung bean	1,891.00	Mung bean skin	83.40
4	Rice	115,865.80	Rice bran	11,586.60
5	Bananas	9,441.10	Bananas skin	127.50
6	Taro		Taro skin	11.40
7	Vegetables	4,345.20	Vegetables waste	546.00
8	Restaurant	1,521	Restaurant waste	2,056.06

[a] BPS-Statistic of Papua Barat Province (2014) [16]; [b] Primary data of survey.

Table 3 The potential and nutrients content of ingredients in pig ration.

No.	Ingredients	Nutrients content			
		Dry matter (DM) (%)	Crude protein (CP) (%)[a]	Gross energy (GE) (kcal/kg)[a]	Metabolizable energy (ME) (kcal/kg)[b]
1	Fish waste	29.41	31.21	3,432.94	2,709
2	Soybean curd	14.31	23.85	4,950.57	3,906
3	Soybean skin	15.96	15.1	4,022.23	3,174
4	Taro skin	26.45	4.26	3,648.96	2,879
5	Vegetables waste	9.84	15.8	3,683.99	2,907
6	Restaurant waste	35.84	13.72	4,202	3,315
7	Commercial pig ration (Charoen Pokphand 511)	87	19.5	-	3,315.12

[a] DM basis; [b] Based on calculation.

Table 4 Feeding cost reduction of each treatment compared to commercial ration.

No.	Feedstuffs	Prices (IDR/kg)	T1		T2		T3		T4	
			As fed (kg/head/day)	Cost (IDR)	As fed (kg/head/day)	Cost (IDR)	As fed (kg/head/day)	Cost (IDR)	As fed (kg/head/day)	Cost (IDR)
1	Fish waste	1,250	0.196	245	0.124	155	0.064	80		
2	Soybean curd	800	1.074	859	0.683	546	0.354	283		
3	Taro skin	1,400	0.309	433	0.197	276	0.102	143		
4	Vegetable waste	1,500	1.613	2,420	1.025	1,538	0.534	801		
5	Restaurant waste	500	0.426	213	0.27	135	0.14	70		
	Commercial ration Charoen Pokphand 551	11,000	0.263	2,897	0.502	5,524	0.782	8,599	1	11,000
	Total feed		3.882	7,067	2.802	8,175	1.977	9,977	1	11,000
	Cost reduction (%)			35.76		25.69		9.3		0

T1: combination of 75% agricultural and food industry by-products and 25% commercial ration; T2: combination of 50% agricultural and food industry by-products and 50% commercial ration; T3: combination of 25% agricultural and food industry by-products and 75% commercial ration; T4: 100% commercial ration.

Table 5 Effect of agricultural and food industry by-products in ration on average daily gain (ADG), feed intake, feed conversion and feed cost.

Variables	Treatments				*p*-value	Sig.
	T1	T2	T3	T4		
ADG (kg/head/day)	0.444 ± 0.01	0.445 ± 0.03	0.465 ± 0.05	0.457 ± 0.02	0.791	ns
Feed intake (kg/head/day)	1.054 ± 0.01	1.004 ± 0.05	1.042 ± 0.04	1.002 ± 0.05	0.353	ns
Feed conversion ratio (FCR)	2.375 ± 0.06	2.259 ± 0.09	2.25 ± 0.13	2.193 ± 0.02	0.159	ns
Feed cost (IDR/kg)	7.066^{a}	8.174^{b}	9.976^{c}	11.017^{d}	0.000	**

T1: combination of 75% agricultural and food industry by-products and 25% commercial ration; T2: combination of 50% agricultural and food industry by-products and 50% commercial ration; T3: combination of 25% agricultural and food industry by-products and 75% commercial ration; T4: 100% commercial ration.
Means with different superscripts in the same row differ significantly ($p < 0.01$); ** $p < 0.01$; ns: non-significant.

significant differences among treatments, whether it was T1, T2, or T3 against T4 (the control) for the pigs' performance, which were denoted by daily weight gain, feed intake, and feed conversion.

4. Discussion

The re-utilization of agricultural and food industry is expected to not only improve the environment but also to increase the wastes' economic value.

Wastes utilizations as shown in Table 1, were adjusted to crude protein (CP) and metabolizable energy (ME) requirements for starter-pigs' metabolism which were 19.5% and 3,150 kcal/kg. The feed used was vegetable waste, fish waste, tofu waste, taro waste and wastes from restaurants. The reason for the utilization of those wastes was that they were easily obtained in Manokwari. Two kinds of ingredients which were fish waste and soybean curd used in this study were included as protein sources, while others such as vegetable waste, restaurants' waste and taro skin were used as the energy sources. Taro skin had the lowest CP content (4.26%), otherwise the highest CP content obtained was from fish waste (31.21%). Tofu waste was the leftovers from the tofu-making process and weighed around 25%-35% of the final tofu product. The tofu waste used in this research had 23.85% CP content, this was consistent with the statement of Mathius and Sinurat [16] that tofu waste could be utilized as protein source feed since they had high gross protein value, around 23%-29%. The commercial feed (Charoen Pokphand 511) was used in this research as the control.

Growth is defined as the interaction between genetic, food and the environment [18]. Livestocks' growth as the result of efficient maintenance could be measured by feed intake, body-weight gain and the FCR [19, 20]. The body-weight gain of starter-phase pigs fed with four different feed is shown in Fig. 1.

As seen in Fig. 1, the pigs fed with T1 and T2 had more fluctuate graph compared to the ones fed with T3 and T4. The body-weight gains of T1 and T2 treatments were declining in the first two weeks, it was because the pigs were adapting to the new feed. Furthermore, during the period between the second and third weeks, the weight gain increased, but it went down again during the period between the third and fourth weeks. On the other hand, the weight gains for the T3 and T4 (control) treatments had a linear continuous growth from the first to the fourth weeks.

The weight fluctuation of the pigs with T1 and T2 treatments were thought to be caused by their monogastric nature, which lacked the ability to utilize feed with high amount of crude fiber content [20]. Because of that, even when the feed was made with the concept of iso-protein and iso-energy in mind, the lack of cellulose enzyme was the reason why not all of the feed was fully digested. However several studies have demonstrated that when pigs are feed with raw fiber high content of cellulose and lignin, there was a positive influence on their health status [14].

In feed intake aspect, the highest intake was seen in pigs fed with T1, followed by T2, T3 and lastly T4. Allegedly, it was because of the relatively higher palatability of agricultural and food industry wastes.

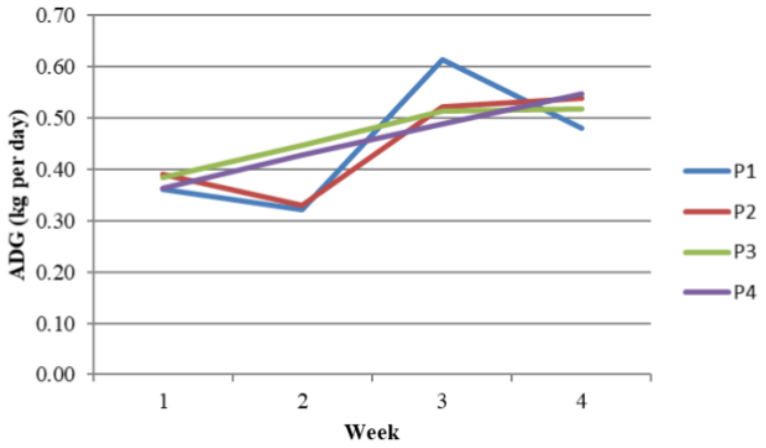

Fig. 1 The average body weight of pig during experiment.

Feed with many wastes was more liked by the pigs. This matched with a study conducted by Wea [22] about the usage of market wastes such as water spinach, fish waste and chaff as a mixture for pigs' ration, in which the more they are mixed, the higher the consumption rate.

Feed conversion is the amount of feed which needed to be consumed to gain 1 kg of BW. The lower the value, the higher the efficiency of the feed to increase the livestocks' BW [23]. The lowest to the highest conversion rates were T4 (100% commercial feed), followed by T3, T2 and T1. This fits with studied Ref. [24] which stated that livestock feed in form of pellets was superior in terms of digestibility, because they need less energy to be digested. Therefore, to improve pigs' ability to digest feed made from agricultural and food industry wastes in the future, it is necessary to consider the production process, to determine which kind of size or form that is easier to digest.

The result of a research done by Warouw *et al.* [25] and Kueain *et al.* [26] showed that feeding cost took around 44.66% to 55% of all production cost. Such high percentage could be reduced by finding alternative source of feed, which will not reduce the output quality. The result of the research regarding feeding cost is shown in Table 4, using three kinds of waste-based rations, proved that T1 ration could reduce the feeding cost up to 35.86%, T2 25.80% and T3 could reduce the cost compared to commercial feed by 9.45%.

In Manokwari, the commercial ration's cost is IDR 11,000 ($0.77)/kg. However, the availability is not continuous yet. Considering the potential of market and food industry wastes are adequate, it is reasonable to strive to process those wastes to provide for the continuous availability of livestock feed. Cooperation with the local government is needed to build a collection center for the wastes from the markets' hub. The collection process will simplify further processing to create livestock feed which has economic value while bolstering the environment's hygiene.

5. Conclusions

The results of this study showed that there are no significant differences between the pigs' performance, whether they are fed with agricultural and food industry wastes or with commercial feed. Feeding treatment with the combination of 25% waste and 75% commercial feed gave the highest FCR average. On the other hand, the mixture of 75% waste and 25% commercial feed had the most economic price, and

could reduce the feeding cost up to 35.86%. Due to no signifant difference between thoese treatments, the farmers should not hesitate to use the mixture of 75% waste and 25% commercial feed.

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