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Original Article

Defatted coconut residue as alternative feedstuff for growing and finishing pigs

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Abstract

The potential of defatted coconut residue (DCR) as an alternative feedstuff for pig diets was assessed in three parts: physicochemical properties, nutrients availability and its effect on the performance of pigs. Bulk density and water holding capacity of DCR were 410 g/L and 2.83 g/g, and the contents of protein, fat and fiber were 14.92, 19.49, and 18.34%, respectively. Most of the fatty acid was saturated with a high portion of medium chains (41.63%), while the NDF made up the greatest part of the fiber (48.88%). The digestibility of protein, fat, and ME of the DCR in growing pigs were 24.61, 81.07%, and 3,021.6 kcal/kg, respectively, whereas the values in finishing pigs were 76.39, 83.26%, and 3,962.0 kcal/kg, respectively. Dietary inclusion of DCR up to 10% for growing-finishing pigs did not affect the growth performances. Therefore, DCR can be used as an alternative feedstuff with high ME value for pig diets.

Keywords: defatted coconut residue, physicochemical properties, digestibility, performance, pigs

1. Introduction

The growth in livestock production, particularly pigs and poultry, has led to increasing demand for feed and consequently for typical feedstuffs. Various alternative ingredients such as the by-products from the local food industry are increasingly of interest to reduce the feed cost. Coconut is a popular tropical fruit in Southeast Asian countries, which can be processed into coconut oil and coconut milk. Copra meal, a by-product from oil extraction contains about 20-26% crude protein (CP),1.9-7.46% ether extract (EE) and 9.22-9.48% crude fiber (CF) and is often used as alternative feedstuffs in swine feed (Jaworski, Shoulders, González-Vega & Stein, 2014; Kwon & Kim, 2015; Son, Ji & Kim, 2012; Son, Shin & Kim, 2013). Moreover, the residue from oil extraction using the expeller method results in a mixing of the coconut milk residue and low quality copra, producing defatted coconut residue (DCR) and this is another by-product that can also be used as feedstuff in animal feed due to the remaining nutrients it contains. Due to the different raw material used during the oil extraction process, the nutrients of the DCR can be varied and are different from those in copra meal. Therefore, to use DCR effectively, it is important to have information about its nutritional values and physical properties and its proper use in a swine diet. Hence, the objectives of this study were to examine the physical properties, nutrients composition and availability of DCR as well as its effect on the performance of growing and finishing pigs.

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2. Materials and Methods

The study on the potential of DCR as an alternative feedstuff for swine diet was divided into three parts. The physical properties and chemical compositions of DCR were determined in the first part, while nutrients digestibility and ME in growing and finishing pigs were evaluated in the second part. The effect of DCR on the growth performances of pigs was investigated in the third part by including it in the growing and finishing diets. The animal experimentation welfare of this study was approved by Institutional Animal care and Use Committee (ID#ACKU61-AGK-022).

2.1 Determination of physicochemical properties of DCR

The physical properties of DCR (bulk density and water holding capacity) were measured using the methods proposed by Syamsu, Yusuf & Abdullah (2015) and Robertson *et al.* (2000), respectively, whereas for the chemical composition analysis, the dry matter (DM), CP, CF, EE, crude ash, calcium, and total phosphorus were analyzed using the methods of AOAC (1990) and neutral detergent fiber (NDF) using the method of Van Soest, Robertson & Lewis (1991). The fatty acid profile, free fatty acid content (FFA) and peroxide value (PV) were evaluated according to Association of Official Analytical Chemists [AOAC], (2012), whereas amino acid profiles was determined using the methods of Official Journal of European Communities (1998). Additionally, the total, soluble and insoluble non-starch polysaccharides (NSP) and their constituent sugars were estimated by following the method described by Englyst, Quigley & Hudson (1994).

2.2 Evaluation of nutrient digestibility and ME of DCR in growing-finishing pigs

Ten crossbred barrows were allocated to two treatments with five replications in complete randomized design. Pigs were individually kept in metabolic cages, where the feces and urine could be collected. The apparent total tract digestibility of nutrients and the ME of the DCR were studied in two phases of growth. The first phase involved growing pigs with an average body weight (BW) of 28.67±1.91 kg, whereas the second phase was conducted using pigs with an averaged BW of 61.53±3.62 kg. Animals in both phases were randomly fed one of the experimental diets consisting of a corn-soybean based diet (T1) and a mixture of 90% basal diet and 10% DCR (T2). The nutrients component of basal diets for each period of growth were formulated based on the recommendation of National Research Council [NRC], (2012) and the feed ingredient compositions are shown in Table 1. A five-day-adaptation period was applied and followed with a five-day-collection period, which feces and urine samples were totally collected according to Adeola (2001) by using chromic oxide (Cr_2O_3) as indigestible marker. The chemical analysis for diets, feces and urine was done according to the methods of AOAC (1990). The apparent total tract digestibility of nutrients in DCR was calculated as described by Kong & Adeola (2014).

2.3 Effect of dietary DCR on the performances of growing and finishing pigs

In total, 162 crossbred barrows and gilts aged 11 weeks were allotted to three groups and six replicates (three replicates for barrows and three replicates for gilts) in completely randomized design. Each replicate consisted of nine pigs and kept in pens, where were equipped with a feeder and a nipple drinker to allow *ad libitum* access to feed and water. Animals in each pen were randomly fed one of three experimental diets consisting of: a control diet (T1) or diets containing 5% DCR (T2) or 10% DCR (T3), respectively. All experimental diets were least-cost formulated to meet the nutrients requirement of breed-line used in this study and the feed ingredient compositions for the growing and finishing diets are shown in Tables 2 and 3, respectively. Pigs were individually weighed and feed consumption was recorded at the end of each period (at 14 and 19 weeks of age) for productive performances calculation.

Table 1. Feed ingredients in basal diets for growing and finishing periods used for digestibility study.

Ingredients (%)	Period of growth	
	Growing period	Finishing period
Corn (7.5% CP)	38.00	73.50
Broken rice (7.5% CP)	23.50	-
Soybean meal (48% CP)	19.00	21.80
Extruded full fat soybean (34.9% CP)	8.50	-
Corn DDGS (26.8% CP)	7.00	-
Soybean oil	0.70	0.70
Limestone	1.14	1.45
Monocalcium phosphate	0.47	1.12
Salt	0.42	0.30
Vitamin and mineral premix	0.60	0.60
L-lysine	0.52	0.40
L-threonine	0.09	0.04
DL-methionine	0.06	0.09
Calculated nutrient composition (%, as fed basis)		
Dry matter	89.19	88.95
Crude protein	19.09	16.52
Ether extract	4.36	3.52
Crude fiber	2.77	2.62

2.4 Statistical analysis

Data from treatments in performance test were analyzed using analysis of variance (ANOVA) for completely randomized design and differences between means were determined using Duncan's new multiple range test. Treatment effects were considered to be significantly different at $P<0.05$.

3. Results

3.1 Physicochemical characteristics of DCR

DCR was produced using expeller extraction after mixing with coconut milk residue with low quality copra including coconut skin. Therefore, the physical property, which is related to the feed processing and feed utilization in animal was studied. The bulk density of the DCR after grinding and passing through a 2 mm-mesh was 410 g/L and the water holding capacity (WHC) was 2.83 g/g. The chemical composition as shown in Table 4 indicated that DCR contained high content of CF (18.34%) with NDF as the great part. The results from the enzymatic chemical analysis indicated that DCR contained 34.8% total NSP with the high content of insoluble fiber (32.0%) and mannose and glucose as the major mono-saccharides of NSP (Table 5). Moreover, DCR had high levels of remaining oil (19.49%), which consisted of saturated fatty acids as the main proportion of fatty acid profile (89.69%). Quality problems, especially rancidity of oil may be an issue in copra by products, which may result in a reduction in feed intake and feed efficiency by

Table 2. Feed ingredients and chemical composition of experimental diets in growing period used for performance study.

Ingredients (%)	Control diet	DCR included diets	
		5%	10%
Brocken rice (7.5% CP)	20.00	20.00	20.00
Corn (7.5% CP)	34.55	29.50	25.97
Wheat (10.34% CP)	8.00	8.00	8.00
Soybean meal (48% CP)	18.40	17.40	16.34
Corn DDGS (26.8% CP)	6.00	6.00	6.00
Extruded full fat soybean (34.9% CP)	6.00	6.00	6.00
Meat and bone meal (51% CP)	3.00	3.00	2.84
DCR	0.00	5.00	10.00
Rice bran oil	1.15	1.72	1.79
Limestone	0.88	1.27	0.93
Monocalcium phosphate	0.43	0.45	0.40
Vitamin and mineral premix	0.68	0.68	0.68
Salt	0.37	0.37	0.37
L-lysine HCl	0.33	0.36	0.38
L-threonine	0.09	0.10	0.12
DL-methionine	0.12	0.15	0.18
Analytical composition (%DM)			
Crude protein	21.71	22.09	21.79
Ether extract	5.54	6.35	8.34
Crude fiber	2.95	3.59	4.38
Calcium	1.12	1.09	1.19
Total phosphorus	0.69	0.71	0.69

Table 3. Feed ingredients and chemical composition of experimental diets in finishing period used for performance study.

Ingredients (%)	Control diet	DCR included diets	
		5%	10%
Broken rice (7.5% CP)	20.00	19.93	10.00
Corn (7.5% CP)	17.08	11.10	16.94
Wheat (10.34% CP)	15.00	15.00	15.00
Soybean meal (48% CP)	13.40	11.75	10.72
Corn DDGS (26.8% CP)	12.00	12.00	12.00
Tapioca pulp (2.2% CP)	6.00	6.00	6.00
Rice bran (12.6% CP)	6.00	6.00	6.00
Extracted Rice bran (16.0% CP)	3.32	6.00	6.00
Extruded full fat soybean (34.9% CP)	3.00	3.00	3.00
DCR	0.00	5.00	10.00
Limestone	1.86	1.88	1.83
Monocalcium phosphate	0.81	0.73	0.82
Vitamin and mineral premix	0.64	0.64	0.64
Salt	0.30	0.30	0.30
L-lysine HCl	0.45	0.48	0.5
L-threonine	0.07	0.10	0.10
DL-methionine	0.07	0.09	0.15
Analytical composition (% DM)			
Crude protein	18.78	18.61	19.04
Ether extract	4.46	4.27	5.69
Crude fiber	4.13	6.67	7.05
Calcium	0.94	1.07	1.26
Total phosphorus	0.66	0.84	0.84

the animals. Therefore, the FFA concentration and PV are normally used as parameters indicating the oxidative process of fat and oils. The DCR had a high FFA content (33.25%), but low PV (4.5 mEq/kg) as shown in Table 6.

The crude protein content of DCR was averaging 14.92% and the amino acid profile in Table 7 showed the low lysine ratio (3.60% of CP) with the high proportion of arginine (10.59% of CP). However, the ratio of essential amino acids of DCR was quite high with 40.99% of CP.

Table 5. Mono-saccharide composition of NSP in DCR

	Monosaccharides (g/100 g sample)									Total NSP	Lignin
	Rha	Fuc	Ara	Xyl	Man	Gal	Glu	GlcA	GalA		
Soluble	0.1	0.0	0.3	0.0	1.0	0.7	0.3	0.0	0.5	2.8	-
Insoluble	0.0	0.0	1.0	1.1	21.6	1.3	6.5	0.0	0.5	32.0	-
Total	0.1	0.0	1.3	1.1	22.6	2.0	6.8	0.0	1.0	34.8	11.0

Note: Rha - Rhamnose;Fuc - Fucose;Ara - Arabinose; Xyl - Xylose; Man - Mannose; Gal - Galactose; Glu - Glucose; GlcA - Glucuronic acid; GalA- Galacturonic acid

Table 4. Physical properties and nutrients composition of DCR

Items	Amount
Physical property	
- Bulk density (g/L)	410
- Water holding capacity (g/g)	2.83
Nutrients composition (as %DM)	
- Crude protein	14.92
- Ether extract	19.49
- Neutral detergent fiber	48.88
- Crude fiber	18.34
- Crude ash	4.46
- Calcium	0.20
- Total phosphorus	0.36
- Gross energy (kcal/kg)	5,373

Table 6. Fatty acid profile of oil in DCR

Fatty acid	g/100g extracted oil	% of total fatty acid
Caprylic acid	3.46	4.77
Capric acid	3.75	5.16
Lauric acid	34.42	47.37
Myristic acid	14.36	19.76
Palmitic acid	7.63	10.50
Stearic acid	1.54	2.13
Oleic acid	5.45	7.50
Linoleic acid	2.05	2.82
SFA	65.16	89.69
USFA	7.50	10.31
MCFA	41.63	57.29
LCFA	31.03	42.71
FFA (%)	33.25	
PV (mEq/kg)	4.5	

Note: SFA – saturated fatty acid; USFA – unsaturated fatty acid; MCFA – medium chain fatty acid; LCFA – long chain fatty acid; FFA – free fatty acid; PV – peroxide value.

3.2 Nutrients digestibility and ME of DCR

The total tract digestibility of DM, CP and EE as well as the digestible energy (DE) and ME of the DCR in growing and finishing pigs were shown in Table 8. The digestibility of DM and CP in growing pigs was quite low with 54.71 and 24.61%, respectively, whereas the DCR could be better utilized by finishing pigs. Remarkably, the digestibility of EE in the DCR was high compared to other nutrients and there was little difference between the EE digestibility in the growing (81.07%) and finishing pigs (83.26%). Furthermore, the DE and ME of DCR in growing pigs (3,277 and 3,021 kcal/kg) were lower than the finishing period (4,081 and 3,962 kcal/kg, respectively).

Table 7. Amino acid composition in DCR

Amino acids	DCR	
	g/100 g sample	% of crude protein
Essential amino acids		
Lysine	0.44	3.60
Methionine	0.23	1.91
Threonine	0.37	3.04
Tryptophan	0.13	1.09
Valine	0.61	4.96
Isoleucine	0.39	3.18
Leucine	0.77	6.29
Phenylalanine	0.52	4.23
Arginine	1.30	10.59
Histidine	0.26	2.10
Total	5.02	40.99
Non-essential amino acids		
Alanine	0.56	4.53
Aspartic acid	0.98	7.99
Cysteine	0.17	1.35
Glutamic acid	2.17	17.69
Glycine	0.53	4.32
Proline	0.45	3.68
Serine	0.56	4.57
Tyrosine	0.27	2.22
Total	5.69	46.35

3.3 Effect of dietary DCR on growth performances of growing and finishing pigs

The performance results of pigs aged 11-19 weeks (Table 9) indicated that diets containing 5-10% DCR had no significant effects on any of the performance indices in the growing and finishing periods ($P>0.05$). The increasing fiber level from up to 10% DCR in the diet did not have a detrimental effect on the feed intake of pigs in both stages of growth.

4. Discussion

The physical properties of feed ingredient, either bulk density or WHC, normally related adversely to the feed intake of animals. The bulk density of DCR (410 g/L) was similar to copra meal (422 g/L) as published by Syamsu *et al.* (2015). However, the bulk densities of the DCR and copra meal were lower than for the typical feed ingredients such as

Table 8. Nutrients digestibility (%) and ME (kcal/kgDM) of DCR in growing and finishing pigs

	Digestibility (%)			DE	ME
	DM	CP	EE		
Growing pigs					
DCR	58.71±7.69	24.61±2.56	81.07±17.0	3,277±343.0	3,021±271.5
Finishing pigs					
DCR	79.81±7.02	76.39±0.62	83.26±3.97	4,081±179.1	3,962±159.0

Note: Data are shown in mean ± standard deviation. DCR - defatted coconut residue; DM - dry matter; CP - crude protein; EE - ether extract; DE - digestible energy; ME - metabolizable energy.

Table 9. Effects of dietary inclusion of DCR on productive performances of growing and finishing pigs

Performances	Control diet	DCR-inclusion		SEM	P-value
		5%	10%		
Growing period (11-14 weeks old)					
Initial weight (kg)	31.97	31.97	31.97	0.689	1.000
Final weight (kg)	61.45	61.42	61.29	0.955	0.998
Weight gain (kg)	29.48	29.45	29.32	0.369	0.979
ADG (kg)	1.05	1.05	1.05	0.013	0.953
ADFI (kg)	2.07	2.09	2.06	0.039	0.939
FCR	1.96	1.98	1.96	0.023	0.980
Finishing period (15-19 weeks old)					
Final weight (kg)	100.25	99.11	98.63	1.265	0.853
Weight gain (kg)	38.80	37.69	37.34	0.551	0.321
ADG (kg)	1.11	1.08	1.07	0.016	0.320
ADFI (kg)	3.01	3.06	2.97	0.069	0.648
FCR	2.71	2.84	2.78	0.034	0.056
Whole period (11-19 weeks old)					
Weight gain (kg)	68.28	67.14	66.66	0.783	0.494
ADG (kg)	1.08	1.07	1.06	0.012	0.496
ADFI (kg)	2.59	2.63	2.57	0.053	0.779
FCR	2.39	2.46	2.42	0.026	0.294

corn (651 g/L), wheat (665 g/L.), soybean meal (701 g/L) and palm kernel meal (519 g/L) (Giger-Reverdin, 2000), as a result of the large particle size and high NDF content of the DCR. In addition, the WHC of the DCR was lower than for oil extracted copra meal (4 g/g) as reported by Giger-Reverdin (2000) and Ngoc, Len and Lindberg (2012). Increasing fat content will decrease the WHC (Raghavendra *et al.*, 2006), while the soluble fiber content has a positive correlation with WHC (Giger-Reverdin, 2000). The DCR used in the current study had a high fat content (19.49 % DM) and low soluble fiber (2.80%) resulting in a lower WHC compared to other studies.

The nutrients composition of the DCR was quite different from copra meal or copra expeller values in other published data as, 20.1-22.0% CP, 1.90-7.46% EE and 9.22-9.48% CF (Jaworski *et al.*, 2014; Kwon & Kim, 2015; Son *et al.*, 2012, 2013). The lower protein content with the higher EE and CF in the DCR resulted from the different raw materials and oil extraction process. Although, the DCR had high GE, which can be used as a good, cheap energy source for the diet, the high CF, especially the high NDF content could interfere with nutrients digestion by the animals. This should be taken into account, when DCR is used as a feedstuff in non-ruminant diets.

The fatty acid profile of the DCR was agree well with the coconut oil, which usually contains a high portion of medium chain fatty acids (MCFAs), particularly lauric acid, compared to other edible oils (Dayrit, 2015). Furthermore, the saturated fatty acid in coconut oil can be up to 90% of the total fatty acid (Chowdhury, Banu, Khan & Latif, 2007), whereas oleic acid and linoleic acid are the main unsaturated fatty acid in DCR. Although, the DCR contained a high content of SFA, which has high oxidative stability, it had a high FFA content (33.25%), which is more than the CODEX standard for FFA of 0% reported by Dayrit *et al.* (2007), probably due to the amount of low quality copra in the DCR. However, the PV of the DCR was less than the CODEX standard for the PV of coconut oil (<15 mEq/kg oil).

The DCR had a lower amino acid profile compared to the copra meal or copra expeller in other previous studies, resulting from its lower protein concentration. However, the ratio of essential amino acid in the DCR was higher than reported by Stein, Casas, Abelilla, Liu & Sulabo (2015), but the protein quality of the DCR was still less than that of soybean meal with less lysine (3.60% of total protein) compared to soybean meal as 6.20% (NRC, 2012). Moreover, Sulabo, Ju, and Stein (2013) remarked that the standardized ileal digestibility of lysine from copra meal (72.8%) was clearly lower than for soybean meal (87.6%). Nevertheless, the high ratio of arginine in DCR leads to the less lysine utilization in animals. Normally, lysine is the first limiting amino acid in a pig diet; thus, both the composition and digestibility of amino acids should be considered for diets containing DCR to ensure that it meets the requirement of pigs.

The CF content derived from acid-base hydrolysis is not a reliable analytical procedure for the fiber content in the feed ingredients, especially where a sample has high soluble fiber. Therefore, dietary fiber (DF) is preferably represented for un-degraded carbohydrate by endogenous enzymes (Choct, 2015). The solubility of the DF sources, soluble and insoluble fiber, may lead to changes in the gut environment by altering the growth of the gut microflora (Jha & Berrocoso, 2015). Although the total DF content (45.8%), obtained from total NSP and lignin content, agreed well with that of copra meal reported by Jaworski *et al.* (2014), but the amount of soluble NSP of the DCR was lower (2.8 vs 5.5%, respectively), probably due to the mixing of coconut skin in the DCR resulting in a high level of insoluble NSP compared to the copra meal.

The nutrients digestibility and ME value of the DCR in finishing pigs were higher than in the growing period due to the more developed and larger gastrointestinal tract and better hindgut fermentation in finishing pigs (Lindberg, 2014). Jang and Kim (2013) reported the digestibility of DM, CP, EE and energy of copra meal in pigs were 71.3, 60.6, 55.9, and 69.8%, respectively, whereas the organic matter, CP and energy digestibility of copra meal from O'Doherty and McKeon (2000) were 87.9, 84.6 and 85.5%, respectively. The nutrients digestibility of the DCR in the present study were quite different from the amounts of copra meal or copra expeller in previous studies, which may have resulted from several factors such as differences in the chemical composition, the dietary inclusion level and the body weight of pigs. The high digestibility of EE in the DCR was seemingly resulting from the high residual oil, which is a rich source of MCFAs. Medium chain triglycerides are easily degraded by pancreatic lipase and directly absorbed by portal circulation (Ooyama, Kojima, Aoyama, & Takeuchi, 2009) and the MCFAs are more water soluble, which facilitates absorption through the unstirred water layer compared to long chain fatty acids. Moreover, the EE digestibility in the growing and finishing pigs was not different, because there was sufficient secretion of lipase and bile salts in the growing pigs (Kitts, Bailey & Wood, 1956). Although, the DCR had a high digestibility of fat, the ME value in growing pigs (3,022 kcal/kg) was lower than from copra meal (3,496 kcal/kg) as reported by Sulabo et.al. (2013), whereas the ME in finishing pigs (3,962 kcal/kg) was quite high but in agreement with data published by NRC (2012) and Stein *et al.* (2015) (4,019 and 4,010 kcal/kg DM, respectively). Based on the present study, the ME: DE ratio of the DCR in growing and finishing pigs was 92% and 97%, respectively.The lower protein digestibility of the DCR may have been responsible for the lower ME: DE ratio in the growing pigs, because dietary digestible protein affects nitrogen excretion and energy loss in urine, which are the main factors affecting the ME content (Noblet & van Milgen, 2004).

Although DCR has a low digestibility of CP, there was no negative impact on the growth performance in this trial. These present results were in agreement with Kim *et al.* (2001), who reported that partial replacement of soybean meal with 2-4% copra meal did not affect growth performance during the whole finishing period, although a diet with copra meal in it had a lower CP level. In contrast, some studies reported that using copra meal or copra expeller meal in pig diets reduced the growth rate and feed intake (Kim *et al.*, 2017; O'Doherty & McKeon, 2000). The lower inclusion level of the DCR in the present study resulted in reduced negative effects from both the fiber and arginine content. A high dietary arginine level has been associated with reduced feed intake and low lysine availability, which lead to growth performance depression in young pigs (Hagemeier, Libal, & Wahlstrom, 1983). Thorne, Wiseman, Cole and Machin (1992) reported that using 30% copra meal in the diet increased the arginine and ADF content from 9.9 and 54 g/kg to 18.6 and 121 g/kg, respectively, and had negative effects on pig performances. Moreover, increasing the dietary soluble fiber by using copra meal increased the digesta viscosity and slowed the rate of passage thereby reducing pig feed intake (Jaworski *et al.*, 2014). Although, the inclusion of 10% DCR could cause high bulk in the gut, it had no effect on the feed intake of pigs, probably due to the lower soluble fiber concentration (2.8%) of DCR used in the present study.

5. Conclusions

DCR, a by-product from expeller oil extraction with a mixing of coconut milk residue and low quality copra, had contents of high CF (18.34%) and NDF (48.88%), which may limit utilization in growing pigs due to the negative effect on protein digestibility. However, DCR contained high energy both DE (3,277 and 4,081 kcal/kg) and ME (3,021 and 3962 kcal/kg) for growing and finishing pigs, respectively. Based on this study, up to 10% DCR can be used as an alternative feedstuff in the diets of growing and finishing pigs without any detrimental effect on productive performances.

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