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Growth performance of pigs fed diets containing distillers dried tapioca pulp (DDCP), a by-product from ethanol manufacturing

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Abstract The distillers dried tapioca pulp (DDCP) is a by-product, resulting from manufacture of ethanol that is an effective alternative feed source for pig diets. This study was investigated the effects of DDCP in dietary production performance during two growth phases of pigs; growing pigs (initial body weight being 27.59±2.36 kilogram) and fattening pigs (65.72±2.31 kilogram body weight). Results found that DDCP showed positive effects on production performance in both growing and fattening pigs. Inclusion of DDCP in diets at 5-15% for growing pigs had greater ($p<0.05$) body weight gain (BWG) and average daily gain (ADG) than those in control, with no significant differences among DDCP treated diet populations observed. However, only DDCP in diets at 10 to 15% had higher feed intake (FI) and average daily feed intake (ADFI). Results also found that inclusion of DDCP in diets at 20% for fattening pigs had highest final weight (FW), BWG and ADG ($p<0.05$); but lowest feed conversion ratio (FCR) and feed cost gain (FCG). In conclusion, these results indicated that DDCP can be incorporated in growing pig and fattening pig diets, up to 15% and 20%, respectively. However, DDCP at 5% and 20%, suggested to incorporate in growing pig and fattening pig diets due to, the best growth performances were observed with these diets.

Keywords: Tapioca Pulp, Production performance, Growing and fattening pigs

Introduction

There are many countries including Thailand are being faced with increasing energy and fuel concerns. It is expected there will be shortage of fossil fuels in the near future (Ritchie, 2017) Therefore, most countries are attempting to find alternative energy sources to produce fuel for power. One source of energy is called biofuel, which originates from processing of agricultural crops such as tapioca, sugarcane, molasses, corn, wheat, and yam. Biofuel is an alternative energy currently receiving worldwide attention.

Thailand has high potential for agricultural production and able to adopt biofuel processing as one of the country's ways of energy production. Thai Government has been supported for the use of ethanol, a type of biofuel substitute instead of fossil fuels. Many production plants are located around the

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country, and currently producing ethanol fuel. The most popular crop used in ethanol production is tapioca. In Thailand, there is excessive production of tapioca; note to be around 4 million excess tons per year. With that amount, the excess can be used to produce over 2 million liters of ethanol fuel per day for the year round without effect on other industrial structures around the country (Pannee, 2008). By producing ethanol from tapioca helps reduce overproduction problems in the market.

In the process of ethanol production using tapioca is the primary producing material which resulted in a large amount of waste materials after production. During the biofuel process, flour in the tapioca is converted into sugar before entering into yeast fermentation. The separation between alcohol and waste occurs after complete fermentation has occurred. In this process, 6-10% alcohol is obtained which can be distilled into ethanol (Sriroth *et al.*, 2008). After drying out, the wastes (tapioca pulp, from the ethanol production) are still enough nutrition for animal feed, especially parts that contain yeast residue. According to chemical analysis of tapioca pulp after ethanol production, it has been found that moisture content is low (8.44%) and some nutrients are still available, particularly digested carbohydrates (40.64%) and protein (9.61). With these results, tapioca pulp can be used as feedstuff in animal feed. (Khampa *et al*., 2011; Thongkratok *et al*., 2010).

Raising pigs often involves in high food costs (about 60-70 percent of total cost of production) (Kanto, 2011). The tapioca pulp uses as an ethanol by-product and ingredient for pig feed should be attracted the option, and as an alternate lower priced feed source. The quantity used in animal feed formulas needs to be monitored, as it may affect yield and quality in pork production. Application of the proper amounts of tapioca by-product can increases the efficiency of animal feed management, and concurrently decreasesby-product waste originating from ethanol production plants (available around the country), for maximum benefit (Sunato *et al*., 2013; Wachirapakorn *et al*., 2016). For Thailand pork producers, tapioca pulp, a by-productmade from ethanol manufacture should be useful for increasing pig farm performance measures, and reducing production costs. The study aimed to investigate the study investigated the effects of DDCP in dietary production performance, during 2 growth phases of pigs; growing pigs and fattening pigs.

Materials and methods

Pigs, housing and experimental design

The experiment consisted of two trials which, based on two growth phases of pigs, growing pigs and fattening pigs. A total of 32 crossbred pigs

(Large White x Landrace x Duroc) were obtained from a local commercial pork producer. Pigs were housed in stainless steel pens (2×3 m^2) with steel batten flooring. Pens were located in an evaporative cooling housing system, with average temperature in the housing rooms ranging from 25 to 28 ℃, continuing from the start to the end of the trial. Each pen was equipped with a bite drinker and a collective stainless steel feeder, allowing pigs access to the feed throughout the whole day. After an acclimation period of 7 days, pigs were randomly allocated to 4 dietary treatments of 16 pigs each, composed of 4 subgroups (blocks) containing 2 males and 2 females per subgroup. The experiment was arranged as a randomized complete block design (RCBD), with 4 replications. Initiat body weight (BW) of the growing and fattening trial pigs were 27.59±2.36 kg. and 65.72±2.31 kg, respectively.

Experimental diets and feeding

Distillers dried tapioca pulp (DDCP) used in the experiment, was obtained from a ethanol processing factory in Chachoengsao, Thailand. DDCP was sprayed directly on a clean concrete floor and turned occasionally to reduce moisture content before it was assembled into diets. Diets were based on broken rice, rice bran, corn, fish meal, soybean meal, palm oil and DDCP (Table 1). Four diets were formulated as follows: control and DDCP at levels of 5%, 10%, 15% in growing pig trials; while at levels of 10%, 20%, 30% in fattening pig trials. All diets were formulated to similar calculated protein level at 18% and 16% for growing and fattening pigs, respectively, and calculated for metabolizable energy level at 3,150 kcal for both phases. All other nutrients were calculated to meet or exceed minimum nutrient requirements of swine by the 1998 National Research Council (NRC) recommendations. Diets were mixed every 7 days and placed into plastic bags in order to maintain feed quality and avoid mould issues. Chemical compositions of the experimental diets are shown in Table 1. Pigs in all treatments were fed ad libitum, throughout the experimental period.

Individual BW of eachl pig was measured before starting of feeding trial and every two weeks throughout the experimental period using an electronic scale to evaluate average daily weigh gain (ADG). Supplied and residual feed weightwas recorded for each pen every day in the morning to calculate feed consumption, feed conversion ratio (FCR) and average daily feed intake (ADFI). Feed consumption was determined by subtracting the difference between supplied and residual feed in each replicate pen. FCR was calculated by dividing total feed consumption by body weight gain (BWG) of pigs for every pen during experimental period.

Table 1. Ingredient and chemical composition of the experimental diets (% of DM)

Item	Distillers Dried Tapioca Pulp from ethanol production							
	Growing pigs				Fattening pigs			
	0%	5%	10%	15%	0%	10%	20%	30%
Ingredients (%)								
Tapioca pulp	0	5.00	10.00	15.00	0	10.00	20.00	30.00
Rice bran	19.50	11.50	10.00	7.00	19.50	10.00	9.50	0
Broken rice	23.50	18.50	21.50	20.50	23.50	20.50	16.50	22.00
Corn	31.25	39.50	33.50	30.50	31.25	37.00	31.90	25.50
Palm oil	1.00	1.50	2.50	3.00	1.00	2.50	3.50	4.00
Fish meal	6.50	9.20	12.00	10.00	6.50	9.00	6.10	8.40
Soybean meal (44%)	14.50	10.50	7.25	10.50	14.50	6.00	9.00	6.50
L-lysine	0.25	1.00	0.25	0.50	0.25	1.00	1.00	1.00
DL-Methionine	1.50	1.50	1.50	1.20	1.50	1.00	1.00	2.00
Dust stone	0.50	0.50	0.50	0.50	0.50	1.00	0.50	0.15
DCP(P/18)	1.00	0.80	0.50	0.80	1.00	1.50	1.50	0.15
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.15
Premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.15
Calculated composition								
Metabolizable energy (kcal/ kg)	3196.66	3169.75	3185.50	3150.26	3159.93	3154.14	3151.03	3153.29
Crude protein (%)	18.12	18.46	18.04	18.12	16.54	16.31	16.04	16.62
Crude fiber (%)	4.18	4.57	5.46	6.67	4.21	5.45	8.24	9.71
Calcium (%)	0.80	0.88	0.93	0.91	1.19	1.20	0.88	0.53
Phosphorus (%)	0.51	0.51	0.52	0.51	0.56	0.61	0.53	0.30
Lysine (%)	1.14	1.71	1.14	1.31	1.59	1.57	1.49	1.47
Methionine (%)	8.13	6.79	7.61	7.02	7.74	6.78	5.68	8.14
Methionine+ Cystine (%)	2.07	2.70	2.06	1.74	1.26	1.50	1.44	2.41

At the end of fattening trial, one pig from each replication was randomly sampled to measure back fat thickness. Three positions of back fat thickness were measured by digital vernier caliper (Fowler®, USA). Thicknesses of back fat at the 1st rib and last rib on the lumber vertebra were measured.

Statistical analysis

All data was analysed using one-way analysis of variance (ANOVA). Treatments showing significant differences at the probability level of p<0.05 were compared using Duncan's new multiple range test.

Results

When DDCP was contained in diets for growing pig, it affected growth performance and feed intake (FI), but did not affect FW, FCR and FCG. Results showed that growing pigs (N=4) fed diets containing DDCP at level of 5, 10 and 15 percent had higher BWG (32.25, 36.88 and 35.63 kg, respectively) and ADG (0.84, 0.88 and 0.85 kg per day, respectively) (p<0.05) than those of control (32.50 kg and 0.78 kg per day). However, no significant differences among DDCP treated diet populations were observed. FI and ADFI tended to increase in-line with higher DDCP levels. Growing pigs fed with diets contained DDCP at 10 and 15 percent resulted to higher FI (79.53 kg and 77.64 kg/day, respectively) and ADFI (1.89 and 1.85 kg/day/pig, respectively) than those fed diets containing DDCP at 0 (70.79 kg and 1.69 kg/day/pig) and 5 percent (73.73 kg and 1.76 kg/day/pig) (P<0.05). The performance of experimental growing pigs fed diets containing DDCP is shown in Table 2.

The DDCP contained in dietary for fattening pigs also affected growth performance FCR and feed cost/kg gain (FCG), but did not affect FI, ADFI, FCG and back fat thickness. It was found that fattening pigs (N=4) fed diets containing 20 percent DDCP resulted in highest FW (109.88 kg), BWG (42.75kg) and ADG (1.02 kg per day) (P<0.05), but did not differ from those fed diets containing 10 percent DDCP (105.38 kg of FW; 40.25 kg of BWG and 0.96 kg per day of ADG) (P>0.05). No significant differences in FW, BWG and ADG were shown with feed diets containing 30 percent (102.63 kg of FW; 37.38 of BWG and 0.89 kg per day of ADG) and control (101.63 kg of FW; 36.25 kg of BWG and 0.87 kg per day ADG). Fattening pigs fed diets containing 10 and 20 percent DDCP resulted in lower FCR (2.84 and 2.75, respectively) than control (3.05) and 30 percent DDCP (3.07) (P<0.05). Results also showed that feed cost per kg gain was highest in fattening pigs fed diets containing 30 percent DDCP, and lowest in fattening pigs fed diets containing 20 percent DDCP. Performance of experimental growing pigs fed diets containing DDCP is shown in Table 3.

Table 2. Effects of dietary contained DDCP on growth performance of growing pigs

Parameters	Distillers Dried Tapioca Pulp from ethanol production (%)			
	0	5	10	15
Initial weight (kg)	27.75±3.18	27.63±1.89	26.88±3.22	28.13±1.65
Final weight (kg)	60.25±1.71	62.88±1.25	63.75±2.96	63.75±2.40
Weight gain (kg)	32.50±2.35^{b}	35.25±1.04^{a}	36.88±0.76^{a}	35.63±1.89^{a}
Average daily weight gain (kg/day/pig)	0.78±0.06^{b}	0.84±0.03^{a}	0.88±0.02^{a}	0.85±0.04^{a}
Feed intake (kg)	70.89±5.19^{b}	73.73±3.43^{b}	79.53±2.95^{a}	77.64±4.67^{a}
Average daily feed intake (kg/day/pig)	1.69±0.12^{b}	1.76±0.08^{b}	1.89±0.07^{a}	1.85±0.11^{a}
Feed conversion ratio	2.19±0.18	2.09±0.10	2.16±0.12	2.18±0.11
Feed cost/kg gain	29.96±2.46	30.20±1.45	31.98±1.83	30.67±1.49

*Mean values (mean ± SD) in raw with different superscript are significantly different (P<0.05).

Table 3. Effects of dietary contained DDCP on growth performance of fattening pigs

Parameters	Distillers Dried Tapioca Pulp from ethanol production (%)			
	0	10	20	30
Initial Weight (kg)	65.38±1.93	65.13±2.63	67.13±2.32	65.25±2.66
Final weight (kg)	101.63±3.40^{b}	105.38±5.84^{ab}	109.88±4.27^{a}	102.63±2.50^{b}
Weight gain (kg)	36.25±2.47^{b}	40.25±3.50^{ab}	42.75±2.53^{a}	37.38±1.11^{b}
Average daily weight gain (kg/day/pig)	0.87±0.06^{b}	0.96±0.08^{ab}	1.02±0.06^{a}	0.89±0.03^{b}
Feed intake (kg)	110.25±4.43	114.05±9.06	117.45±4.36	114.8±2.73
Average daily feed intake (g/day/pig)	2.63±0.10	2.72±0.22	2.80±0.10	2.73±0.06
Feed conversion ratio	3.05±0.10^{a}	2.84±0.08^{b}	2.75±0.08^{b}	3.07±0.13^{a}
Feed cost/kg gain	37.42±1.19^{b}	38.48±1.09^{b}	34.68±0.96^{c}	42.59±1.77^{a}
Back fat thickness	12.00±0.58	12.38±0.95	12.50±0.71	11.75±0.65

*Mean values (mean ± SD) in raw with different superscript are significantly different (P<0.05).

Discussion

After growing pigs were fed diets containing different 3 levels of DDCP (5%, 10% and 15%) for 6 weeks, their growth showed increases higher than pigs on the control diet (Table 2). This is due to the fact that pigs fed treatment diets had higher feed intake than those in control. Accordingly, limiting feed intake directly affects growth potential; this study, therefor, allows pigs to feed ad libitum. This study found edible ability of growing pigs increased with diets containing DDCP, probably due to higher fiber. When more fiber was mixed into the diet, it caused the feed to become spongier and resulted in pigs consuming more feed. Although growing pigs were able to consume more feed, their FCR and FCG values were not different from the control. This is due to the fact that most fiber in tapioca pulp is regarded as insoluble fiber (Djuma'ali *et al.*, 2011).

Fiber properties act as a water absorber in the digestive tract, causing feed to have a high specific gravity and thus move rapidlythrough the small intestine. The resultis that enzymes in the digestive system of the growing pig do not become fully functional associated with decreased nutrient utilization and low net energy values (Rangilal *et al*., 1995; Noblet and Le, 2001; Jimenez – Moreno *et al*., 2010). In addition, fiber content in the diet of monogastrics should not exceed 5%. (Pond *et al.*, 2005), consistent with Bowland (1972), who reported that raising pigs with feed contained more than 5 percent fiber, resulted in reduced digestibility of nutrients. Fiber content in diets containing 5%, 10% and 15% DDCP was higher than in the control, at 1.10, 1.31 and 1.60 times, respectively (Table 1). Inclusion of DDCP in diets at 5% to 15%, even though not improving feed efficiency and also could not reduce feed cost in diet for growing pigs, it showed positive growth effect and reduces agro-based industrial waste. A similar finding was reported by Kosoom *et al.* (2009), as they mentioned that cassava pulp can be used in diets of nursery pigs up to 15%, without negative effects on growth performance of piglets. However, our results differ from previous studies (Kosoom *et al*., 2009), who reported that there was no significant difference in FI, ADG and FCR of piglet fed cassava pulp, with levels of 0%, 5%, 10% and 15%.

Charoenwattanakun *et al.* (2009) noted that when the proportion of fiber was increased 1-1.5 % from the control feed, feed intake of pigs tended to decrease. However, in this study, when the proportion of fiber in treatment diets for fattening pigs was increased 29 -130% from control (Table 1), the feed intake was not significantly different from control. Even though DDCP levels were different, FI and ADFI in each treatment was not statistically different. This probably due to there was similar energy and protein contained in each diet. This indicates that DDCP can be incorporated in diets of fattening pigs, up to 30%, without affecting feed intake.

However, this study found inclusion of 30% DDCP in diet for fattening pig, resulted in lower BWG and ADG, than when including DDCP at 20% ($p<0.05$). DDCP at 20% also resulted in highest FCR and FCG. While the fattening pigs fed diet containing 10-20% DDCP showed better growth rate and FCR than other treaments. Enhancing DDCP content in diet, resulted to higher fiber content. Fiber composition in diet containing 20% and 30% DDCP (by calculation) was 8.24% and 9.71%, respectively (Table 1), which is higher than NRC (1998) standard. NRC suggested that fiber in the diet for fattening pig should not be exceeding than 7.5%. This is due to spongy feed causes the stomach to tighten quickly and move feed faster through intestine. The result was a negative impact on nutrient digestibility, decreased growth rate, and increased FCR, resulting in higher production costs. Therefore, inclusion of 30% DDCP to fattening pig diets is not considered useful.

The experiment concluded that inclusion of 20% DDCP in fattening pig diets was the most optimal level, and the pigs showed highest feed utilization. Our results differed from previous studies of Charoenwattanakun *et al.* (2009) that stated tapioca pulp can be incorporated in diets for growing and fattening pigs up to 30% without affecting growth rate. The difference was due to the difference in the quality of tapioca pulp. Previous studies used tapioca pulp, and by-product from starch production whereas this study used tapioca pulp by-product from ethanol production. Nutritional composition of tapioca pulp from starch production showed 53.55% carbohydrate, 2.83% ash, 13.59% fiber, 0.13% fat and 1.98% protein (Khempaka *et al*., 2009), while tapioca pulp from ethanal production showed 40-45% carbohydrate, 11.89% ash, 35.72% fiber, 1.07% fat and 7.27% protein (Chintanawit *et al*., 2008). This trial also showed that increasing level of DDCP in the diets had no affect on back fat thickness. A similar finding was reported by Charoenwattanakun *et al.* (2009), who reported no significant differences in back fat thickness of pigs when using 10 to 30% tapioca pulp in their diets.

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