Songklanakarin J. Sci. Technol.
40 (6), 1300-1305, Nov. – Dec. 2018

http://www.sjst.psu.ac.th

Original Article

Feeding value of dried cashew nut testa in finishing pigs: Effects on nutrient digestibility and gut morphology

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Received: 8 March 2017; Revised: 1 July 2017; Accepted: 6 August 2017

Abstract

This study aimed to investigate the effect of soaking dried cashew nut testa (DCNT) in distilled water on tannin removal. Distilled water was used at a 1:10 (w/v) ratio for 0, 24, and 48 h. Soaking DCNT in distilled water for 24 h reduced tannin concentration in DCNT by 26.4% (quadratic, P<0.01). The soaked and unsoaked DCNT were then used for the next experiment. A total of 24 LYD barrows (initial average BW of 82.1 kgs) were used to determine the effect of DCNT on nutrient digestibility and gut morphology in finishing pigs. The pigs were randomly allotted to 4 treatments using a randomized complete block design with 6 pigs per treatment. The treatments were: 1) corn-soybean meal (SBM) diet with no DCNT, 2) corn-SBM diet with 5% unsoaked DCNT, 3) 5% unsoaked DCNT with added fat, and 4) 5% soaked DCNT. All diets included 0.30% Cr_2O_3 to serve as an inert marker. The results revealed that the unsoaked DCNT diet had reduced apparent total tract digestibility (ATTD) of crude protein (CP), ether extract (EE), and neutral detergent fiber (NDF) than the corn-SBM diet (P<0.05). However, pigs fed the soaked DCNT diet had greater ATTD of CP and EE compared with those on the unsoaked DCNT diet (P<0.05). There were no significant differences in gut characteristics of finishing pigs fed corn-SBM or DCNT diets. In conclusion, feeding 5% DCNT to finishing pigs reduces nutrient digestibility without affecting gut morphology. Soaking DCNT in distilled water for 24 h can reduce tannin concentration and mitigate its effects on nutrient digestibility.

Keywords: dried cashew nut testa, tannin, nutrient digestibility, gut morphology, finishing pigs

1. Introduction

It has been reported that more than 50% of the total cost of feeding in pig production (Perry, 2000) is the energy component which constitutes the greatest portion. The competition between man and animals for feed ingredients tends to be critical, particularly in energy sources. For example, when the price of maize is high in some years, alternative feed ingredients with lower costs have been explored to decrease the cost of feeding and maintain the quality of feed ingredients.

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In recent years, agro-industrial co-products such as rice bran and palm kernel meal have become important feed ingredients in animal diets. However, it is important to consider the following factors when identifying new co-product ingredients: 1) it must have a steady supply or availability of the raw material; 2) cost-effectiveness as a feed ingredient in terms of handling, processing, transportation, and nutritive value; 3) consistency of raw materials from batch to batch; 4) quality as a feed material, protein and fat values; and 5) effect on meat quality.

Cashew nut is one of the most promoted plants of the Thai government since 1984 (Papademetriou & Herath, 1998). Thailand exported about 117 million baht worth of cashew nut products in 2004. The cultivated area for cashew nuts was 26,445 hectares and the production of cashew nut

was 42,126 tons (DAE, 2012) . Most of the cashew nut plantations and processing factories are located in the southern, eastern, and northeastern parts of Thailand. Cashew nut processing begins with cleaning and then separation of the edible part from the inedible part. One of the co-products of this process is dried cashew nut testa (DCNT) , which is the skin of the nut kernel that is normally used either as fertilizer, feed for dairy cattle or disposed as agricultural waste. However, an alternative use for DCNT may be as feedstuff for pigs. On a dry matter (DM) basis, the nutrient composition was shown to be crude protein (CP), 14. 12% , gross energy (GE), 5,111 kcal/ kg, and ether extract (EE) 11. 11% . The metabolizable energy (ME) was 733. 3 kcal/ kg DM (Poommarin, 2014) . The effect of condensed tannin (CT) concentration can reduce nutrient utilization and affect the intestinal function of animals (DAE, 2012). However, there is no research to show the nutrient digestibility and gut morphology of DCNT as a diet on the pig model. Therefore, the objectives of this study were to reduce the condensed tannin concentration of DCNT by a soaking method and to determine the nutrient digestibility and gut morphology of finishing pigs fed DCNT diets.

2. Materials and Methods

2.1 Reduction of condensed tannins of dried cashew nut testa by soaking in water

Dried cashew nut testa samples were collected from a cashew nut factory located in Chonburi Province, Thailand. The same batch of DCNT was stored at a feed mill at room temperature for 3 months during the experiment. On a DM basis, DCNT contained 5,111 kcal/kg GE, 733 kcal/kg ME, 14.1% CP, 30.2% acid detergent fiber (ADF), 35.5% neutral detergent fiber (NDF), 9.1% acid detergent lignin, 11.1% acid-hydrolyzed EE, 2.94% ash, and 64.88 g/kg CT. The DCNT was randomly divided into three treatments using a completely randomized design with six replicates per treatment. The treatments were DCNT soaked in distilled water for 0 h (DCNT-0), 24 h (DCNT-24), and 48 h (DCNT-48). After the soaking period, the levels of CT in the DCNT were determined using the butanol-HCl method (Terrill, Rowan, Douglas, & Barry, 1992).

2.2 Apparent total tract digestibility

A total of 24 (LargeWhite×Yorkshire×DurocJersey; LYD) barrows with an average BW of 85 kg were used for this experiment. The pigs were blocked by initial weight and randomly allotted to 4 treatment diets: corn-soybean mean (SBM), unsoaked DCNT, unsoaked DCNT+ fat, and soaked DCNT-24 using a randomized complete block design (RCBD) (Table 1). All experimental diets were formulated as recommended by the National Research Council (2012) and included 0.30% of chromic oxide (Cr_2O_3) to serve as the inert marker. There were 6 replicate pigs per treatment. All pigs were housed in semi-slatted floor pens. They were confined in individual pens (0.6×2.2×1.2 m) equipped with a feeder and water supply. Drinking water was provided at all times and feed was supplied two times daily at 7:00 AM and 4:00 PM. All pigs were fed *ad libitum* for 3 weeks and the feces were collected at the last 5 days (Adeola, 2001) . Grab samples of fresh feces were collected twice daily from each pig by rectal stimulation and the collected samples were stored at -20 °C for subsequent analyses. Fecal samples were dried in a forced-air oven at 65 °C for 48 h and then ground through a 40 mesh sieve prior to chemical analysis for Cr_2O_3 (Bolin, King, & Kloserman, 1952) DM, CP, EE (AOAC, 1990) , NDF, ADF (Van Soest & Robertson, 1980) , and GE. The apparent total tract digestibility (ATTD, %) of DM, CP, EE, NDF, ADF, and GE in the diet were calculated.

2.3 Gut morphology

Three pigs from each treatment were used. On the last day of the experiment, after 24 h of fasting, the pigs were stunned by a stunning gun and killed. The tissue samples from the duodenum and jejunum were immediately collected. The middle sections of the duodenum and jejunum were aseptically isolated, flushed with a 0. 90% normal saline solution, and fixed with 10% formaldehyde-phosphate buffer (Liu *et al.*, 2010). Histological measurements were conducted according to the procedures described by Shen *et al.* (2009).

2.4 Condensed tannin analysis

The condensed tannins of DCNT were determined using the butanol-HCl method (Terrill *et al.*, 1992). The method is based on the oxidative cleavage of the interflavan bonds in the presence of mineral acids in alcoholic solutions at about 95 °C for 70 min to yield pink-colored anthocyanidins, which are measured at 550 nm. For the calculation, tannic acid was extracted and purified from *Stylosanthes guianensis* CIAT 184, as a standard equivalent (Pootaeng-On, Napawan, Sarawoot, Sayopoo, & Pantipa, 2014).

2.5 Statistical analysis

The CT concentrations of the DCNTs were analyzed as a completely randomized design using the MIXED procedure of the Statistical Analysis System (SAS) (SAS Institute Inc., Cary, NC, USA) and the orthogonal polynomial contrasts were used to test for linear and quadratic effects of increasing duration of soaking on the CT concentrations. The ATTD of the nutrients were analyzed as a randomized complete block design using the MIXED procedure of the SAS with pig as the experimental unit. The model included diet as the fixed effect and pig as the random effect. Gut morphology parameters were analyzed as a completely randomized design using the MIXED procedure of the SAS The model included the diets as the fixed effect and pig as the random effect. All data were calculated using the least square means for each independent variable and the means were separated using the PDIFF option of SAS. A level of significance was set at $P<0.05$ for all statistical tests and considered a trend at $P<0.10$.

3. Results and Discussion

3.1 Reduction of condensed tannins of dried cashew nut testa by soaking in water

The unsoaked DCNT contained 64. 88 g/ kg DM of CTs (Figure 1) . However, the concentration of CTs was re-

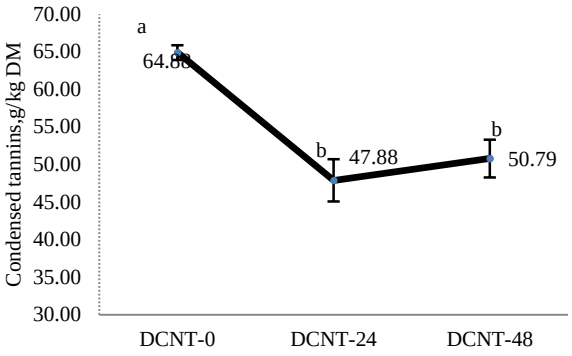

Figure 1. Effect of soaking dried cashew nut testa in distilled water for 24 and 48 h on condensed tannins concentration.
[1/] Data are least square means of 6 observations of all treatments, DCNT-0 = unsoaked dried cashew nut testa DCNT-24 = soaked dried cashew nut testa with distilled water at 24 h, DCNT-48 = soaked dried cashew nut testa with distilled water at 48 h, [a,b]P<0.01

duced in the DCNT soaked for 24 h (47.88 g/kg DM) and 48 h (50.79 g/kg DM) in distilled water (quadratic, P<0.01). The significant reduction in the CT content measured in the DCNT after soaking in water conformed to previous research (Afify, El-Beltagi, Abd El-Salam, & Omran, 2012; Kalpanadevi & Mohan, 2013; Kayembe & Rensburg, 2013; Mubarak, 2005; Vijayamari, Siddhuraju, Pugalenthi, & Janardhanan, 1998; Wina, Tangendjaja, & Susana, 2005). Mubarak (2005) evaluated the effect of soaking mungbean seeds (*Phaseolus aureus*) in distilled water for 12 h at a 1:10 ratio on tannin content. Losses of tannins may be due simply from leaching into the water. Losses may also be attributed to decreases in extractability because lower molecular weight phenolic compounds become insoluble in water. Alternatively, during the period of soaking, the enzyme poly-phenoloxidase may be activated, resulting in degradation and consequent losses of polyphenols (Kalpanadevi & Mohan, 2013). From the above results, it can be concluded that soaking DCNT for 24 h in distilled water can effectively reduce the CT content. This significant reduction may potentially improve the acceptability and value of DCNT as a feedstuff in swine diets.

Table 1 shows the CT compositions in corn-SBM, unsoaked DCNT, unsoaked DCNT+FAT, and soaked DCNT diets which were 2.28, 5.04, 4.82, and 3.87 g/kg DM, respectively. Although corn-SBM diet did not include DCNT, the CT concentration was 2.28 g/kg DM. It can be explained that the corn-SBM diet contained a high amount of corn (67.51%). Juliano (1993) reported that the tannin content in corn was 0.4%.

Table 1. Diet composition (as-fed basis).

Ingredient (%)	corn-SBM	Unsoaked DCNT	Unsoaked DCNT+Fat	Soaked DCNT
Corn	67.51	62.51	62.51	62.51
Soybean meal, CP 44%	19.65	19.69	15.73	19.69
Cassava meal	10.00	10.00	10.00	10.00
Unsoaked DCNT	-	5.00	5.00	-
Soaked DCNT	-	-	-	5.00
Palm oil	-	-	3.70	-
Monocalcium phosphate, P21%	1.05	1.05	1.06	1.05
Limestone	0.80	0.78	0.80	0.78
Salt	0.40	0.40	0.40	0.40
L-Lys·HCl	0.20	0.19	0.31	0.19
L-Threonine	0.07	0.06	0.12	0.06
DL-Methionine	0.02	0.02	0.05	0.02
L-Tryptophan	0.00	-	0.02	-
Choline choride	0.02	0.02	0.02	0.02
Vitamin-mineral premix[1/]	0.25	0.25	0.25	0.25
Cr_2O_3	0.03	0.03	0.03	0.03
Total	100.00	100.00	100.00	100.00
Analyzed composition				
DM, %	90.8	91.5	92.4	91.6
GE, kcal/kg	3,486	3,562	3,856	3,582
CP (N×6.25), %	13.2	13.2	13.1	13.7
EE, %	2.58	3.09	8.88	4.00
NDF, %	15.5	20.7	20.3	20.5
ADF, %	3.23	4.69	4.55	4.47
CF, %	2.32	2.84	2.64	2.81
Ca, %	0.80	0.84	0.84	0.85
total P, %	0.36	0.32	0.33	0.35
Condensed Tannins (g/kg DM)	2.28	5.04	4.82	3.87

SBM = soybean meal, DCNT = dried cashew nut testa, CP = crude protein, Cr_2O_3 = chromic oxide, DM = dry matter, GE = gross energy, EE = ether extract, NDF = neutral detergent fiber, ADF = acid detergent fiber, CF = crude fiber, Ca = calcium, P = phosphorus. [1/]The vitamin-mineral premix provided the following quantities of vitamins and micro minerals per kilogram of complete diet: Vitamin A, 3,200,000 IU; vitamin D3, 600,000 IU; vitamin E, 3.000 g vitamin K3, 0.5000 g; thiamin, 0.304 g; riboflavin, 0.960 g; pyridoxine, 0.656 g; cyanocobalamin, 6.00 mg; niacin, 6.000 g;D-pantothenic acid, 4.8000 g; folic acid, 0.2000 g; biotin, 6.000 mg; ascorbic acid 4.000 g; choline choride 20.00 g; Cu, 40.000 g; Fe, 50.000 g; Mn 16.000 g; Zn 40.000 g; Co 0.240 g; Se 0.040 g.

3.2 Apparent total tract digestibility

There were no significant differences in the ATTD of DM among the different dietary treatments; however, the unsoaked DCNT diet had lower ATTD of CP, GE, EE, and NDF than the corn-SBM diet ($P<0.05$) (Table 2). Lizado, Peiniau, and Aumaitre (1995) used different tannin sorghums in weanling pig diets. Medium (7.7 g/kg) and high (32.5 g/kg) tannin diets had lower ATTD of CP and GE, whereas the low tannin (2.5 k/ kg) diet was similar to the corn-based diets. Tannins may reduce nutrient digestibility either through the formation of complexes or inhibiting activities of enzymes in digestive secretions. Once the tannin-protein complex is formed, the bound protein is rendered indigestible in the animal (Schiavone *et al.*, 2008). Mohamed, Molham, Abdul wali, and Abdulkarim (2001) compared digestive enzyme activities between pigs fed zero, low, and high tannin diets, and showed that the low and high tannin diet inhibited α-amylase activity by 37 and 77% , trypsin activity by 22 and 56%, and lipase activity by 6 and 43%, respectively, compared to the activities in pigs fed the zero tannin diet. Likewise, Longstaff and McNab (1991) also observed that feeding low and high tannin diets reduced lipase activity by approximately 6 and 43% , respectively. It has also been proposed that tannins interfere with intestinal protective mucus glycoprotein, thus increasing the excretion of endogenous nitrogen from the mucus. Lastly, it has been previously demonstrated that dietary tannins are able to bind intestinal brush border proteins as well as luminal digestive enzymes such as trypsin and α-amylase (Ahmed, Smithard, & Elli, 1991). Adding fat to the unsoaked DCNT improved ATTD of EE ($P < 0.01$). However, no significant differences in ATTD of GE, CP, NDF, and ADF were observed between the unsoaked DCNT diet with and without added fat. These results conform with the findings of Brooks (1971) that reported 10% of soybean oil was added to the diets of growing pig diets. They observed an increase in fat digestibility but there were no improvements in the digestibilities of DM, CP, and crude fiber. In contrast, other studies showed that adding fat to swine diets increased the digestibility of nutrients (Jones, Hancock, Harmon, & Walker, 1992). Azain (2001) reported significant improvements in ileal digestibilities of DM, CP, and energy when growing pigs were fed 10% fat compared with those fed diets without added fat.

3.3 Gut morphology

There were no significant differences in villus height, crypt depth, and villus: crypt ratio in either the duodenum or jejunum of the finishing pigs fed corn-SBM or DCNT diets (Table 2). Shorter villi and deeper crypts have fewer absorptive cells which ultimately affects nutrient absorption. However, the results of studies evaluating the effects of feedstuffs high in tannins on gut morphology are inconsistent. Makinde, Mapathyb, Kingbemi, and Mandisodza (1996) studied the effects of using increasing levels of cowpea in weanling pig diets on gut morphology. Cowpea is high in tannin, and pigs fed 100% cowpea had shorter villi but greater crypt depth than pigs fed soybeans. Thus, the villus:crypt ratio was unaffected by cowpea inclusion in the diet. Nyamambi, Ndlovu, Naik, and Kock (2007) observed in broiler chicks that increasing the levels of tannin in the diet reduced duodenal villus height and crypt depth. In contrast, finishing pigs fed diets supplemented with 0.2% tannins extracted from chestnut wood had greater villus height and villus:crypt ratio than pigs fed the control diet (Bavdek, Brus, Skok, & Škorjanc, 2013).

Table 2. Effects of dried cashew nut testa (DCNT) on the apparent total tract digestibility of nutrients and gut morphology in finishing pigs.

Item	Diet[1/]				SEM	*P-value*
	corn-SBM	Unsoaked DCNT	Unsoaked DCNT+Fat	Soaked DCNT		
ATTD[2/], %						
DM	86.2	84.1	84.5	85.6	0.75	0.19
CP	78.0[a]	71.3[c]	72.7[bc]	76.3[ab]	1.5	< 0.05
GE	86.1[a]	82.6[b]	83.1[b]	84.2[ab]	0.86	< 0.05
EE	67.4[c]	62.50[d]	81.9[a]	75.2[b]	1.5	< 0.01
NDF	73.4[a]	66.5[b]	66.6[b]	67.0[b]	1.5	< 0.05
ADF	50.8	42.5	43.6	44.7	2.6	0.15
Duodenum[3/]						
Villus height (µm)	471	453	454	468	22.3	0.91
Crypt depth (µm)	372	382	384	388	15.3	0.89
Villus:crypt	1.26	1.19	1.18	1.21	0.06	0.78
Jejunum[3/]						
Villus height (µm)	444	425	456	458	26.11	0.81
Crypt depth (µm)	346	339	354	372	11.1	0.25
Villus:crypt ratio	1.28	1.26	1.29	1.24	0.08	0.95

SBM = soybean meal, DCNT = dried casher nut testa, SEM = standard error of the mean, ATTD = apparent total tract digestibility, DM = dry matter, CP = crude protein, GE = gross energy, EE = ether extract, NDF = neutral detergent fiber, ADF = acid detergent fiber.
[1/]corn-SBM = corn-soybean meal based diet; Unsoaked DCNT = corn-soybean meal based diet with 5% untreated DCNT; Unsoaked DCNT+Fat = corn-soybean meal based diet with 5% untreated DCNT and 3.7% added palm oil; Soaked DCNT = corn-soybean meal based diet with 5% DCNT pre-treated by soaking in distilled water for 24 h
[2/]Data are least square means of 6 observations for all treatments
[3/]Data are least square means of 3 observations for all treatments
[a,b,c,d]Values within a row lacking a common superscript are different ($P< 0.05$)

4. Conclusions

The results of this experiment conclude that soaking DCNT for 24 h reduced the concentration of condensed tannins compared with unsoaked DCNT (quadratic, $P<0.01$). The inclusion rate of dried cashew nut testa in the diets for nutrient digestibility and gut morphology observation was 5%. There were 4 dietary treatments: corn-SBM, unsoaked DCNT, unsoaked DCNT+ fat, and soaked DCNT. The CT concentrations of the diets were 2.28, 5.04, 4.82, and 3.87 g/kg, respectively. The corn-SBM diet had greater ATTD of CP and GE than the unsoaked DCNT diets ($P<0.05$), whereas the ATTD of EE was the greatest in pigs fed unsoaked DCNT+fat ($P<0.01$). Soaking of DCNT improved the ATTD of CP and EE ($P<0.05$). The NDF was not significantly different between the soaked and unsoaked DCNT (Table 2). Gut morphology was not significantly affected by the inclusion of 5% DCNT in the diet.

Acknowledgements

The authors are grateful to Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) for the research grant and the Faculty of Animal Sciences and Agricultural Technology, Silpakorn University for allowing us to use their facilities**.**

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