Research Article

Nutritive Value, Digestibility and Gas Production of Fermented Sugar Palm Peel with Pineapple Peel

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Received August 11, 2014; Accepted April 17, 2015

Abstract

An experiment was conducted to examine the nutritive value, digestibility and gas production of fermented sugar palm peel with pineapple peel. The treatment was conducted as a 3×2 factorial in a completely randomized design (CRD). The experiment consisted of six treatment combinations; sugar palm peel to pineapple peel ratios (2:1, 1:1 and 1:2 by weight) and fermentation times (day-14 and day-21). All treatment combinations were fermented under anaerobic condition in airtight plastic pouches. The result showed that ether extract content of fermented sugar palm peel with pineapple peel in 2:1 ratio at day-14 was significantly higher than other treatment combinations (P<0.05). Conversely, hemicellulose, acid detergent fiber (ADF) and acid detergent lignin (ADL) contents of fermented sugar palm peel with pineapple peel in 1:2 ratio at day-14 were significantly lower than other treatment combinations (P<0.05). The pH values were significantly different among treatment combinations (P<0.05). Overall, fermented sugar palm peel with pineapple peel at day-14 had lower pH value than those at day-21. *In vitro* dry matter digestibility of fermented sugar palm peel with pineapple peel in 1:2 ratio at day-14 were significantly higher than other treatment combinations (P<0.05). On the other hand, the volume of gas production was significantly different at 12 hr, and was not significantly different among treatment combinations (P>0.05) thereafter (24 hr, 48 hr and 72 hr). Fermented sugar palm peel with pineapple peel in 2:1 ratio at day-21 recorded the highest gas volume (45.16 ml). Results of this study suggested that the fermented sugar palm peel with pineapple peel in 1:2 ratio at day-14 produced a lower fiber content and higher digestibility silage, making it a suitable silage for ruminant animal since high fiber content had adverse effect on the nutrients digestibility.

Key Words: Sugar palm peel; Pineapple peel; Nutritive value; Digestibility.

Introduction

Pineapple (*Ananas comosus*) is a tropical plant, which is available in Prachuap Khiri Khan Province, Thailand. The post-processing of pineapples fruits yields pineapple peels, cores, bud ends and crowns as by-products. These by-products accounts for approximately 30-35% of fresh fruit weight (Bartholomew et al., 2003). Pineapple peel is rich in fiber (16-25%), with cellulose, hemicellulose and pectin being its major polysaccharides (Müller, 1978; Ketnawa et al., 2012). This high-fiber by-product makes it suitable to be used as ruminant feedstuff, whereby up to 17:3 ratio of pineapple peels can be included into cattle diet (Müller, 1978).

Conversely, sugar palm or Asian Palmyra palm (*Borassus flabillifer* Linn) is widely available in Phetchaburi Province, Thailand. The chief product of the palmyra palm is the palmyra sap, which has sucrose as the main sugar (Naknean et al., 2010). This coconut-like fruit and seed can be eaten raw, and the industrial scale processing of this fruit yields plentiful of fibrous sugar palm peels as one of the by-products (Rungrodnimitchai, 2011).

Both of these by-products are considered as agriculture wastes and currently, these wastes are accumulating and causing detrimental effects on the environment. Silage is fermented which fermentation is complete after about 14 days. The best fermentation process should comprise of substrate with high water soluble carbohydrate content (at least 2%) and of low moisture content (Bureenok, 2011). In addition, it is also recommended that the silage

ISSN 1905-9159
doi: 10.14456/sustj.2016.4

should have a pH less 4.5 (McDonald et al., 1991). Therefore, the objective of this study was to examine the effect of fermenting sugar palm peel with pineapple peel on the nutritive value and digestibility of these products in order to improve them as a value added agricultural by-products.

Materials and Methods

Sample collection

Sugar palm peel was obtained from a local dessert shop in Phetchaburi Province, whereas pineapple peel was obtained from pineapple processing factory in Prachuap Khiri Khan Province, Thailand. These peels were then chopped for subsequent experiment.

Fermentation of sugar palm peel with pineapple peel

A 3×2 randomized factorial design was used in this study. In this design, 3 different ratios of sugar palm peel to pineapple peel (2:1, 1:1 and 1:2 by weight) were fermented for day-14 and day-21, with 3 replicates per treatment and approximately 3 kg of each sample. All treatment combination was fermented at room temperature (30^{o}C) under anaerobic condition using airtight plastic pouches (approximately 6 liter) for day-14 and day-21, after which sample are collected at day-14 and day-21 for subsequent analysis.

Determination of silage pH

The pH of silage samples was measured at day-14 and 21 using a pH meter (Cyberscan, Eutech instrument, Singapore).

Nutritive value determination

The silage samples were dried at 60^{o}C for 48 hrs. The dried samples were analyzed for dry matter (DM), crude protein (CP), ash, ether extract (EE) (AOAC, 1990), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) (Van Soest et al., 1991). Hemicellulose was calculated as NDF-ADF and cellulose as ADF-ADL. Gross energy was determined by bomb calorimeter.

Gas production and *in vitro* dry matter digestibility

Two cattle fed on a roughage diet were used as the donors of rumen fluid. Rumen digesta was collected from each animal via the ruminal fistula before morning feed. The rumen digesta were then homogenized, and strained through filter cloth (Sommart et al., 2000) after which 660 ml of the resulting rumen fluid was added to a the reduced medium (39^{o}C).

The reduced medium was prepared as described by Makkar et al. (1995). The reduced medium consists of 1,095 ml H_2O, 730 ml buffer solution (35 g $NaHCO_3$ and 4 g NH_4HCO_3 made up to 1 liter with distilled water), 365 ml macromineral solution (6.2 g KH_2PO_4, 5.7 g Na_2HPO_4, 2.2 g NaCl and 0.6 g $MgSO_4$. $7H_2O$ made up to 1 liter with distilled water), 0.23 ml micromineral solution (10.0 g $MnCl_2.4H_2O$, 13.2 g $CaCl_2.2H_2O$, 1 g $CoCl_2.6H_2O$, 8.0 g $FeCl_3.6H_2O$ and made up to 100 ml with distilled water), 1.4647 g $^{15}N_2$-urea and 60 ml freshly prepared reduction solution containing 580 mg $Na_2S.9H_2O$ and 3.7 ml 1M NaOH. The mixture was stirred under CO_2 at 39oC using a magnetic stirrer fitted with a hot plate.

Approximately 0.5 g of dried sample was transferred into 50 ml serum bottle (Makkar et al., 1995). The bottles were pre-warmed in a water bath at 39^{o}C for about 1 hr. prior to injection 40 ml of rumen medium (using a 50 ml syringe). The bottles were stoppered with rubber stoppers, crimp sealed and incubated in a water bath at 39^{o}C. The bottles were gently shaken for 30 min after the start of incubation and then at three hour intervals for 12 hr.

Gas production was measured by reading and recording the amount of gas volume after incubation using a 100 ml glass syringe connected to incubation bottle with a 23 gauge, 1.5 inch needle. Readings of gas production was recorded at 12, 24, 48 and 72 hr after incubation periods. *In vitro* dry matter digestibility (IVDMD) was estimated after the last gas measurement by drying the bottle content at 100-105^{o}C.

Statistical analysis

Data were subjected to analysis of variance using Proc. ANOVA (SAS, 1998). Treatment combinations means were statistically compared using Duncan's New Multiple Range Test (Steel and Torrie, 1980).

Results and discussion

Nutritive value of fermented products

Sugar palm peel contained 82% moisture, 1.4% crude protein, 46% hemicellulose and 31% cellulose. Whereas, pineapple peel contained 85% moisture, 2.3% crude protein, 52% hemicellulose and 16% cellulose. The nutritive values of each treatment combinations are shown in Table 1. Result showed that nutritive values were significantly different among treatment combinations ($P<0.05$). Fermented sugar palm with pineapple peel (S:P) in the ratio of 1:2 at day-14 had lower hemicellulose, ADF and ADL content and higher ether extract content as compared to other treatment combinations ($P<0.05$). The pH values were significantly different among treatment combinations ($P<0.05$). Fermented sugar palm peel with pineapple peel at day-14 had lower pH value than at day-21. The lower fiber content of treatment with S:P in ratio of 1:2 may be attributed to the higher acidity of pineapple. In addition, the silage of this study has light brown (yellow) color, slightly acidic and fruity smell (Figure 1).

doi: 10.14456/sustj.2016.4

Up to date, only a few researchers had reported on fermenting sugar palm peel alongside with pineapple peel, thus there is limited information available regarding this process. Nevertheless, there are reports on the effectiveness of ensiling agro by-products. For example, Sruamsiri et al. (2007) has reported that pineapple waste silage had crude protein, NDF and ADF approximately 7.42, 70.43 and 34.58% respectively, which is slightly better than pineapple waste. In addition, Rowghani et al. (2008) reported that olive cake silage had low NDF content and the addition of molasses, urea and formic acid can improve nutritive value of corn silage. However, it is noted that the best fermentation process should comprise of substrate with high water soluble carbohydrate content (at least 2%) and of low moisture content (Bureenok, 2011). In addition, it is also recommended that the silage should have a pH less 4.5 (McDonald et al., 1991). In this study, the pH value of sugar palm peel fermented with pineapple peel was in the range of 3.24-3.68 which slightly acid. Besides, it is observed that the silage used in this study has light brown (yellow) color with slightly acidic and fruity smell (due to the lactic acid). Previous study by Suksathit et al. (2011) showed that pineapple silage had low pH value (3.06). This acidic property of the silage may induce partial acid hydrolysis of hemicelluloses, contributing to the lower fiber content observed. Correspondingly, Yahaya et al. (2004) found that fermented juice with epiphytic lactic acid bacteria silage had low ADF and ADL content due to the decrease in pH value induced by the fermentation of silage by these lactic acid bacteria.

***In vitro* dry matter digestibility**

In vitro dry matter digestibility (IVDMD) of treatment combinations is shown in Figure 3. The results showed that the IVDMD of the S:P in 1:2 ratio at day-14 days was significantly higher than other treatment combinations ($P<0.05$) due to pineapple peel is high acid which acidic property of the silage may induce partial acid hydrolysis of fiber. Shultz et al. (1974) reported that silage treated with various additives (alkaline, acid, enzyme, molasses, urea and limestone) had higher IVDMD than untreated silage. In this study, we found that sugar palm peel and pineapple peel silages alone had the value of IVDMD of 19.84 and 25.91% respectively. When sugar palm peel fermented together with pineapple peel at 1:2 ratio for 14 days, IVDMD of 36.88% is highest. This illustrated that agricultural by-products available locally can be fermented with pineapple peel as an alternative silage.

Table 1 The nutritive values of fermented sugar palm peel with pineapple peel

Nutritive value (% of dry matter)	Sugar palm peel to Pineapple peel ratio (S:P)					
	Day-14			Day-21		
	2:1	1:1	1:2	2:1	1:1	1:2
Ash	$6.77^{bc}\pm0.42$	$7.41^{ab}\pm0.73$	$7.98^{a}\pm0.16$	$6.60^{c}\pm0.38$	$6.82^{bc}\pm0.43$	$7.38^{abc}\pm0.29$
CP	$5.56^{a}\pm0.24$	$5.26^{b}\pm0.35$	$4.63^{c}\pm0.46$	$3.07^{d}\pm0.09$	$1.55^{e}\pm0.20$	$2.80^{d}\pm0.29$
EE	$0.40^{bc}\pm0.12$	$0.34^{c}\pm0.08$	$0.58^{a}\pm0.03$	$0.34^{c}\pm0.09$	$0.21^{d}\pm0.55$	$0.47^{b}\pm0.18$
NDF	$56.41^{b}\pm0.82$	$53.84^{d}\pm1.02$	$54.97^{cd}\pm1.00$	$56.15^{bc}\pm1.09$	$55.86^{bc}\pm1.41$	$58.44^{a}\pm1.94$
ADF	$38.18^{a}\pm0.98$	$35.15^{b}\pm0.58$	$31.91^{c}\pm1.77$	$38.64^{a}\pm0.75$	$34.53^{b}\pm0.65$	$32.41^{c}\pm1.45$
ADL	$12.13^{a}\pm0.34$	$7.55^{d}\pm0.40$	$6.66^{e}\pm0.36$	$8.50^{c}\pm0.78$	$9.94^{b}\pm0.42$	$9.54^{b}\pm1.54$
Hemicellulose	$48.33^{b}\pm1.07$	$54.36^{a}\pm1.19$	$46.14^{d}\pm1.37$	$46.80^{cd}\pm0.52$	$47.65^{bc}\pm1.00$	$48.90^{b}\pm2.71$
Cellulose	$25.26^{c}\pm1.45$	$20.80^{e}\pm1.37$	$24.59^{c}\pm0.83$	$33.08^{a}\pm0.41$	$30.14^{b}\pm1.32$	$22.89^{d}\pm1.60$
GE (kcal/kg)	$3,761.3^{b}\pm82.2$	$3,668.4^{b}\pm222.7$	$3,779.0^{b}\pm143.7$	$3,677.4^{b}\pm187.7$	$3,849.5^{ab}\pm102.3$	$4,009.6^{a}\pm259.4$
pH	$3.24^{d}\pm0.02$	$3.30^{d}\pm0.02$	$3.40^{c}\pm0.01$	$3.50^{b}\pm0.08$	$3.47^{bc}\pm0.01$	$3.68^{a}\pm0.04$

^{a,b,c,d,e} Values on the same row with different superscripts differ significantly ($P<0.05$).
CP: Crude protein, EE: Ether extract, NDF: Neutral detergent fiber, ADF: Acid detergent fiber, ADL: Acid detergent lignin, GE: Gross energy.

doi: 10.14456/sustj.2016.4

Figure 1 Picture of silage

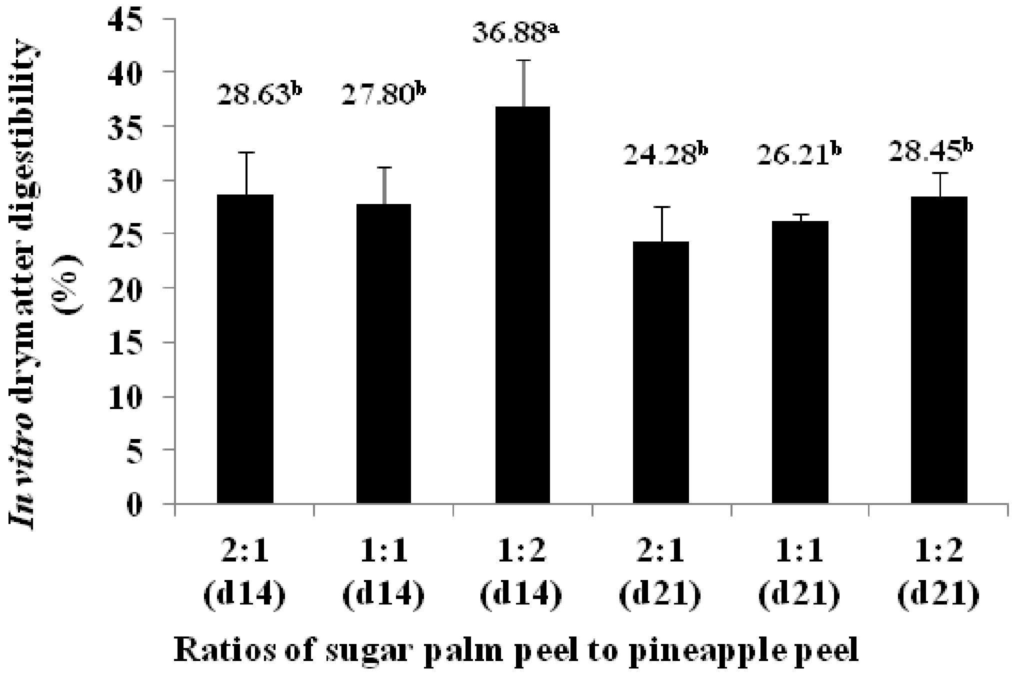

Figure 2 *In vitro* dry matter digestibility (% of dry matter) of fermented sugar palm peel with pineapple peel

doi: 10.14456/sustj.2016.4

Table 2 The gas production (ml/0.5 g substrate) of fermented sugar palm peel with pineapple peel

fermentation time (hr)	Sugar palm peel to Pineapple peel ratio (S:P)					
	Day-14			Day-21		
	2:1	1:1	1:2	2:1	1:1	1:2
12	33.84^{c}±1.93	34.79^{bc}±2.90	39.22^{abc}±1.38	45.16^{a}±5.46	41.00^{ab}±6.97	39.75abc±3.18
24	66.67±1.90	70.06±4.05	72.92±2.19	77.99±8.57	74.86±8.89	75.21±9.31
48	93.51±1.17	95.93±3.17	98.73±1.55	102.75±6.62	100.53±5.44	103.40±7.11
72	105.20±0.90	105.90±3.40	107.30±2.03	112.16±6.98	111.10±4.94	112.10±7.43

^{a,b,c} Values on the same row with different superscripts differ significantly (P<0.05).

Gas production

Gas production of treatment combinations during the fermentation is shown in Table 2. The volume of gas production was not significantly different among treatment combinations (P>0.05) except for production at 12 hr. Gas volume of the S:P in 2:1 ratio at day-21 was significantly higher than 1:1 and 1:2 ratio at day-14 (P<0.05). According to Pereira et al. (2013), pineapple silage presented high gas volume (28.16 ml), as they are one of the highest contributors to fibrous carbohydrate, which represent sources of fast available energy for initial microbial growth of ruminal organism. Thus, supporting the observed higher initial gas volume in treatment of S:P in 1:2 ratios at day-14 days. In contrast, fermenting sugar palm peel with pineapple peel in a 2:1 ratio at day-21 resulted in higher gas volume (45.16 ml) due to the volume of gas depends on sugar content and fermentation time.

Conclusion

Results of this study suggested that the fermenting sugar palm peel with pineapple peel in 1:2 ratio at day-14 is suitable silage for ruminant animal due to the lower fiber content and higher digestibility since that high fiber content would cause adverse effect on the nutrients digestibility.

Acknowledgement

The authors would like to thanks the Faculty of Animal Sciences and Agricultural Technology, Silpakorn University for providing necessary facilities to carry out this research and ICT campus's fund for funding agency.

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doi: 10.14456/sustj.2016.4