Influence of Dietary Fiber and Sodium Bicarbonate on Digestibility, Rumen Fermentation, Blood Metabolites and Performance of Dairy Cows Fed Pineapple Peel-Concentrate Mixed Diets

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Abstract

Three mid-lactation primiparous crossbred Holstein dairy cows averaging 440.0±7.3 kgBW were assigned in a 3x3 Latin square design. Each cow was fed one of three experimental diets including: T1) control, pineapple peel (PL)-concentrate pellet (CT) mixed diet at ratio of 70:30, T2) PL-CT mixed diet at ratio of 50:30 plus 20 % rice straw (RS) as dietary fiber (DF) supplementation and T3) PL-CT mixed diet at ratio of 70:30 with 1.2 % sodium bicarbonate ($NaHCO_3$). The results revealed that feed intake and nutrient digestibility were unaffected by DF or $NaHCO_3$ supplement ($P>0.05$). Body weight was slightly increased by DF and $NaHCO_3$ inclusion ($P>0.05$). Differences in rumen pH and concentration of volatile fatty acids were small ($P>0.05$). Supplemental DF and $NaHCO_3$ did not influence on blood metabolites, blood electrolytes, milk yield and milk composition ($P>0.05$). Results suggest the PL-CT mixed diet with or without both DF and $NaHCO_3$ can be effectively used by dairy cows without adversely affecting digestive efficiency, metabolites and performance. Further research should be conducted to examine these effects with larger number of animals over a longer period of time.

Keywords: Pineapple peel; rice straw; sodium bicarbonate; dairy cow.

1. Introduction

There is a period during which high quality roughage is insufficient in the dry season in Thailand. Both agricultural and horticultural crop residues have a good potential that could lessen the gap between demand and supply of feeds for ruminant animals. Pineapple peel (PL) is a cannery by-product of Pineapple (*Ananas comosus*), a tropical fruit which largely grows in Brazil, Thailand, Philippines, China and several other countries [1]. The nutrients in PL consist of dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and ash which are 12.6%, 88.6%, 8.7%, 67.7%, 50.3%, and 11.4%, respectively [2]. PL is a potential roughage source for ruminants due to the large amount of fiber and some sugars [3-4] which may be used by rumen microbes to digest and synthesize for animal energy supply. Farmers in northern Thailand

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currently use PL as dairy feed because it is a seasonally available feed source. PL is high in moisture content, so it decays very quickly if appropriate preservative methods are not taken [5]. PL mixed with rice straw or ensiling PL is commonly used as a method for dairy feeding in this region [6, 7]. The chemical property of PL is rather low in pH (3.06-3.84) [8, 3] which may affect rumen ecology and productive performance if a large amount of pineapple peel is being fed to dairy cows.

Feeding diets high in nonstructural carbohydrates or acids usually decrease ruminal pH and cause ruminal acidosis [9, 10]. In clinical acidosis, cows will suffer from rumenitis, metabolic acidosis, lameness, hepatic abscessation, pneumonia and death while those in subclinical acidosis will lower feed intake, lower feed digestibility and, subsequently, lower milk fat content [11].

Rice straw (RS) is a local agricultural by product which is abundant in effective fiber that can be used as dietary fiber (DF) to promote chewing activity and saliva secretion. Saliva contains $NaHCO_3$ which acts as a buffer to control and maintain ruminal pH in ruminants [12]. Sodium bicarbonate ($NaHCO_3$) is one dietary buffer which is commonly used to prevent ruminal pH reduction and enhance ruminal fermentation in a low roughage diet [12,13]. NRC (1989) [14] suggested that $NaHCO_3$ should be added 1.2-1.6% in concentrate mixture to control ruminal pH when diets were high in nonstructural carbohydrates or acids.

This study was designed to determine whether feeding PL with or without DF and $NaHCO_3$ supplement would allow for acceptable digestion efficiency, rumen fermentation, blood metabolites, blood electrolytes and productive performance by lactating dairy cows.

2. Materials and Methods

Three primiparous, midlactation crossbred Holstein cows initially averaging 440.0$\pm$ 7.3 kg body weight (BW) were assigned in a 3x3 Latin square. There were four 21-d experimental periods including 14-d for adjustment to feed and 7-d for data collection each. Treatments consisted of : T1) control, pineapple peel (PL)-concentrate pellet (CT) mixed diet at ratio of 70:30, T2) PL-CT mixed diet at ratio of 50:30 plus 20 % rice straw (RS) as supplementation of dietary fiber (DF) and T3) PL-CT mixed diet at ratio of 70:30 with 1.2 % sodium bicarbonate ($NaHCO_3$) (Table 1). Each cow was fed depending on its body weight, milk yield and milk fat following the recommended nutrient requirement as recommended by NRC (2001) [15]. All diets were formulated to contain approximately 15 Mcal/d of NEL and 1,200 g/d of dietary CP concentration (Table 1). Before feeding, each feed ingredient was weighed individually before distribution as a mixed feed. The PL used in this experiment was collected from a cannery factory in Kanchanaburi province in the western part of Thailand. After collection, it was stored approximately 30 kg each in a sealed double layer polyethylene plastic bag without any preservative agents. The CT in this experiment was manufactured by the CPF (Thailand) Public Company Limited while the $NaHCO_3$ was manufactured by Siribuncha Company, Thailand. Each lactating dairy cow was housed individually in a 3.0x6.0 m^2 pen in which drinking water and mineral blocks were available throughout. Cows were fed twice daily at 0700 h and 1700 h at 110 % of expected intake throughout the experiment. Cows were milked twice daily at 0600 and 1500 h. Animal management and experimental protocol were performed with respect to animal care and welfare.

2.1 Sampling and Analyses

Feed offered and refused were recorded daily in the last 7-d of each data collection period. In the first 7-d of each adaptation period, PL and CT were collected and dried in a 60°C hot air oven for 72 h for DM concentration determination in order to correct daily feed intake. All cows were weighed three times (d1, d14 and d21) of each period to calculate and predict feed intake. Regular feed samples from individual cows were collected during the last 7-d of each period. Then, feed samples were dried at 60°C for 72 h and ground, composited and analyzed for chemical composition including DM, CP, EE, ash, Ca, and P by the method of AOAC (1984) [16]. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were measured by the method of Goering and Van Soest (1970) [17]. Acid insoluble ash (AIA) as a natural marker in feed was measured by the method of Van Keulen and Young (1977) [18].

During the last 5-d of each data collection period, fecal grab samples were collected twice daily at 12 h intervals, pooled on an equal wet-weight basis for each cows, dried at 60°C for 72 h, ground and analyzed for DM and CP by the method of AOAC (1984) [16], for NDF and ADF by the method of Goering and Van Soest (1970) [17] and for AIA by the method of Van Keulen and Young (1977) [18]. Digestibility coefficients of nutrients were calculated using equations given by Schneider and Flatt (1975) [19] as follows: DM digestibility, % = 100 – [100 × (AIA% in feed) ÷ (AIA % in feces)]; Nutrient digestibility, % = 100 – [(100 × AIA% in feed ÷ AIA % in feces) × (nutrient % in feces ÷ nutrient % in feed)]. Organic matter (OM) or the loss in DM weight after incubated at 550 °C for 15 h was calculated as follows: OM = 100 – Ash %.

Values for metabolizable energy (ME) were calculated by prediction from digestible organic matter intake (DOMI) as follows: 1kg DOMI = 3.8 McalME/kgDM [20]. Net energy of lactation (NEL) was estimated at actual intake when feed EE content above 3% by equation as follows: NEL (Mcal/kg) =0.703 × ME – 0.19 + ([(0.097 × ME + 0.19)/97] × [EE – 3]) [15]. Values for feed protein truly digestible in the small intestine (PDIA) ; protein truly digestible in the small intestine where N is limiting microbial protein synthesis (PDIN); and protein truly digestible in the small intestine where energy is limiting microbial protein synthesis (PDIE) were calculated using the equations of Jarrige (1989) [21] as follows: PDIN (g/kgM) = PDIA + [0.64 × CP(g/kgDM) × (deg – 0.1)] where PDIA = CP(g/kgDM) × 1.11(1-deg) × dsi; PDIE =PDIA + PDIME where PDIME (g/kgDM) = 0.093 × [FOM – EE (g/kgDM)]. FOM is the fermentable organic matter content (g/kgDM) [21-22]. The deg value is theoretical degradability of feeds in *sacco* and dsi value is the true digestibility of undegraded dietary protein in the small intestine [21]. Both deg and dsi were obtained from published data [21-24].

Ruminal samples were taken by suction pump at 4 h post feeding and pH was measured immediately by portable pH (pHtestr 30®, EUTECH Instruments, Singapore). The 50 ml of rumen fluid were filtered through four layers of cheesecloth, with 5 mL of 6*N* H_2SO_4 added to stop fermentation, centrifuged at 3,000 rpm for 10 minutes and kept supernatant frozen at -20°C until later analyses for volatile fatty acid using an analytical High Performance Liquid Chromatography (HPLC, Agilent technologies 1100 series, Germany). 10 mL of blood samples were taken from the coccygeal vein and subsequently analyzed for glucose, urea nitrogen and electrolytes using enzymatic and kinetic methods (Synchron LXSystem/Lxi725, Beckman Coulter Inc.). Milk samples were collected during the morning and the afternoon milking at ratio of 60 to 40 for 4 consecutive days and composited to analyze for fat, protein, lactose, solid not fat, and total solid by Combi Foss 6000 (Foss Electric, Hillerød, Denmark).

2.2 Statistical Analysis

Data were analyzed using the general linear model procedure in which treatment means were compared by using Duncan's new multiple range test and significance was declared when P-value <0.05 [25]. The statistical model used was $Y_{ij(k)} = \mu + \rho_i + \gamma_j + \tau_{(k)} + \varepsilon_{ij}$ where $Y_{ij(k)}$ = dependent variable, μ = overall mean, ρ_i = effect of period (i=1,2,3,4), γ_j = effect of animal (j = 1,2,3,4), $\tau_{(k)}$ = effect of treatment, and ε_{ij} = random error [26].

3. Results and Discussion

The chemical composition of PL, CT and RS are presented in Table 1. The mean value for DM content of PL was 34.09 %. Previous studies (Datt *et al.*,(2008) [4]; Suksathit *et al*., (2011) [33]) reported that DM content of pineapple waste contained 13.85-16.87 %DM. The higher DM content of PL in this experiment is due to the moisture loss before packing and long transportation. The PL storage in sealed plastic bag could prevent mold growth and maintain nutritive quality throughout the experiment. The CT used in this study contained CP, NDF and ADF 18.78, 35.82 and 16.55 %DM, respectively. All mixed feeds contained adequate amounts of NDF (51.06-55.24 %DM) and ADF (24.13-28.85%DM) which were higher than those recommended by NRC (2001) [15] to maintain NDF and ADF at least 28 and 21 % DM in daily feed, respectively.

Daily dry matter feed intake in this study ranged from 3.31-3.93 %BW (Table 2). Feed intake in all lactating cows was not affected by DF or $NaHCO_3$ supplementation (P>0.05). High dry matter intake indicated feed palatability in overall groups. It could be seen that all mixed diets have high palatability which may be influenced by some sugars and sour odor in PL. Average dry matter intake of cows supplemented with DF and $NaHCO_3$ tended to increase slightly when compared with those fed only the PL-CT mixed diet. Response to $NaHCO_3$ supplement on feed intake in this experiment was in accordance with many trials which reported the lack of response to $NaHCO_3$ supplement on feed intake [27-30]. In contrast, there were many trials that reported an increase in feed intake by $NaHCO_3$ supplement [31-32]. Dry matter intake also associates closely with dietary fiber or NDF concentration in the diet and dietary NDF concentration is negatively related to the energy concentration of feeds and positively related to the gut fill effect of the diet [34]. The NDF content in this study varied from 51.06-55.24% (Table 1). High dry matter intake may be a response to compensate body weight loss in early lactation and to promote animal growth in the first lactation.

The digestion coefficient in terms of DM, OM, CP, NDF and ADF was not affected by added DF or $NaHCO_3$ in PL-CT mixed diets for lactating cows (P>0.05) (Table 2). The digestion coefficients of DM and OM in this study were close to those reported by Suksathit *et al.*, (2011) [33] and Datt *et al.* (2008) [4]. The amount of digestible nutrients consumed by cows, including DM, OM, CP, NDF and ADF, was not affected by added DF or $NaHCO_3$ in PL-CT mixed diets (P>0.05) (Table 2). There are few data that have shown a positive effect on digestibility when pineapple waste was used as the sole roughage source compared with hay [33]. The ME content averaged 2.58 Mcal /kgDM ranging from 2.49 to 2.64 Mcal/kgDM (Table 2). By calculation based on ME concentration, it was found that NEL averaged 1.62 Mcal/kgDM ranging from 1.56 to 1.64 Mcal/kgDM (Table 2). The NEL content was higher averaged 0.2 Mcal/kgDM than the NEL requirement recommended by NRC, (2001)[15] which indicates that all cows have positive energy balance. The protein truly digested in the small intestine with nitrogen-limiting microbial protein synthesis in the rumen (PDIN) ranged from 74.00-77.48 g/kgDM and was not affected by added DF or $NaHCO_3$ in PL-CT mixed diets (P>0.05). The DF and $NaHCO_3$ supplement did not influence protein truly digested in the small intestine with energy-limiting microbial protein synthesis in the rumen (PDIE)

(P>0.05). The PDIE ranged from 78.33-81.34 g/kgDM (Table 2).

Influence of treatments on body weight, rumen pH, VFA concentration, blood metabolites, milk yield, and milk composition of dairy cows are shown in Table 3. Initial body weight of the cows ranged from 432.66-447.33 kg (P>0.05) while final body weight ranged from 439.66-453.00 kg (P>0.05). The average pH across treatments was 6.66 (P>0.05). Rumen pH was not significantly affected by DF and $NaHCO_3$ supplementation (P>0.05)(Table 3). Because physical PL had thick and long particle size containing 58.48 % NDF and 27.80 % ADF, this may stimulate chewing activity, saliva secretion, fluid dilution rate and pH in the rumen. The $NaHCO_3$ produced from saliva glands is also an extra buffering agent involving in ruminal pH control which can act effectively when rumen pH is above 5.7 [35].

The supplement of DF and $NaHCO_3$ did not significantly affect concentration of volatile fatty acids in ruminal fluid including acetic, propionic, and butyric acids (P>0.05) (Table 3). The ratio of acetic acid (A) to propionic acid (P) was in the range of 2.17 to 2.66 which was not significant (P>0.05) (Table 3). The ratio of acetic acid to propionic acid reflects the pattern of ruminal fermentation and ratio of roughage to concentrate in total feed. Normally, the ratio of acetic acid to propionic acid in cows fed 100 % hay is approximate 4.1 while that in cows fed 90 % concentrate is 2.2 [36].

Blood metabolites including glucose and blood urea nitrogen (BUN) were unaffected by DF or $NaHCO_3$ supplementation (P>0.05) (Table 3). Blood glucose ranged from 64.00-67.50 mg/dl while BUN ranged from 6.66-9.33 mg/dl. Kronfeld *et al*.,(1982) [37] reported nutritional status of dairy cows indicated by analysis of blood and suggested that normal glucose and BUN should range between 43-69 and 2-22 mg/dl, respectively. Electrolytes showed no significant differences among treatments (P>0.05) (Table 3). Serum sodium concentration was not altered by added $NaHCO_3$. In addition, there was no significant difference in blood chloride, bicarbonate and potassium among treatments (P>0.05). The normal ranges of serum sodium, chloride, bicarbonate and potassium are 0.70-157 meq/l, 93-152 meq/l, 11-26 meq/l and 1.7-4.5 meq/l, respectively [37].

The supplementation of DF and $NaHCO_3$ did not influence milk yield of dairy cows (P>0.05) (Table 3). Daily milk production ranged from 9.40-9.76 kg/cow. As a result, a lower mean in milk production was observed in this study because all cows were in the first lactation and midlactation. The composition of milk including fat, protein, lactose, solid not fat and total solid was also not affected by added DF and $NaHCO_3$, (P>0.05) (Table 3). The DF and $NaHCO_3$ supplementation resulted in a trend towards higher milk composition including fat, protein, lactose, solid not fat and total solid. These data agree with previous reports by Erdman *et al.,* (1982) [27] and Rogers *et al.,* 1985) [31].

Table1. Ingredients, chemical composition of diets and nutrient requirement of cows.

Items				Mixed Feed		
				T1	**T2**	**T3**
Ingredients, kg/100kgDM						
PL				70.00	50	69.16
CT				30.00	30	29.64
RS				-	20	-
$NaHCO_3$				-	-	1.2
Total				100	100	100
Chemical composition, %DM						
	PL	**CT**	**RS**	**T1**	**T2**	**T3**
DM	34.10	95.85	94.96	92.94	93.59	91.82
OM	90.85	88.55	84.93	90.16	88.97	89.07
CP	7.38	18.78	4.43	10.80	10.21	10.67
EE	2.33	5.24	1.65	3.20	3.06	3.16
NDF	58.48	35.82	76.31	51.68	55.24	51.06
ADF	27.80	16.55	46.97	24.42	28.85	24.13
Ash	9.15	11.45	15.07	9.84	11.02	9.72
Ca	0.82	1.69	0.41	1.08	0.99	1.06
P	0.20	0.85	0.08	0.39	0.37	0.39
pH	3.55	-	-	-	-	-
Nutrient requirement				**T1**	**T2**	**T3**
NEL, Mcal/d				14.79	15.86	15.02
NEL, Mcal/kgDM				1.39	1.45	1.42
CP, kg/d				1.13	1.26	1.16
NDF,kg/d				2.98	3.07	2.96
ADF, kg/d				2.23	2.30	2.22
Ca, g/d				47.26	52.10	48.22
P, g/d				30.80	33.80	31.39

PL = pineapple peel, CT = concentrate pellet, RS = rice straw**.** T1 = PL to CT ratio of 70:30, T2= PL to CT ratio of 50:30 with 20 % RS, T3= PL to CT ratio of 70:30 with 1.2 % $NaHCO_3$ supplement**.**

Table2. Influence of treatments on intake, digestion coefficient, digestible nutrient intake and nutritive values.

Items	**T1**	**T2**	**T3**	**SE**	***P-value***
Feed Intake					
kgDM	14.88	15.79	17.10	1.17	0.270
%BW	3.31	3.53	3.93	0.29	0.225
Digestion coefficient, %					
DM	69.48	75.68	73.51	4.74	0.431
OM	72.84	78.48	76.13	4.98	0.508
CP	52.58	64.56	57.85	7.72	0.355
NDF	68.18	75.00	71.85	5.16	0.433
ADF	66.36	71.67	69.19	5.17	0.558
Digestible nutrient intake, kgDM/d					
DM	10.34	11.95	12.60	1.34	0.307
OM	9.79	11.01	11.79	1.37	0.380
CP	0.79	1.00	0.97	1.26	0.385
NDF	5.36	6.42	6.60	0.76	0.303
ADF	2.47	2.98	3.01	0.378	0.339
Nutritive value					
ME[1], Mcal/kgDM	2.49	2.64	2.61	0.20	0.681
NEL[2], Mcal/kgDM	1.56	1.67	1.64	0.13	0.679
NEL[2], Mcal/d	23.32	26.42	28.25	3.47	0.393
PDIN[3], g/kgDM	77.48	74.80	74.00	1.52	0.190
PDIE[4], g/kgDM	81.34	79.29	78.33	1.48	0.238

PL = pineapple peel, CT = concentrate pellet, RS = rice straw**.** T1 = PL to CT ratio of 70:30, T2= PL to CT ratio of 50:30 with 20 % RS, T3= PL to CT ratio of 70:30 with 1.2 % $NaHCO_3$ supplement**.**
Within rows, means followed by different letters are significantly different at (P<0.05).
[1]1kg DOMI = 3.8 McalME/kgDM (Kearl, 1982) [20].
[2]NEL (Mcal/kg) $=0.703 \times \text{ME} - 0.19 + ([(0.097 \times \text{ME} + 0.19)/97] \times [\text{EE} - 3])$ (NRC, 2001) [15].
[3]PDIN = protein truly digested in the small intestine with nitrogen-limiting microbial protein synthesis in the rumen (Jarrige, 1989) [21].
[4]PDIE = protein truly digested in the small intestine with energy-limiting microbial protein synthesis in the rumen (Jarrige, 1989) [21].

Table3. Influence of treatments on body weight, rumen pH, VFA , blood metabolites and milk of dairy cows.

Items	**T1**	**T2**	**T3**	**SE**	***P-value***
Initial BW, kg	447.33	440.16	432.66	1.16	0.008
Final BW, kg	449.33	453.00	439.66	9.53	0.390
Rumen fermentation					
Rumen pH	6.68	6.62	6.70	0.36	0.992
Acetic, *mmol/l*	95.23	98.63	81.90	16.06	0.524
Propionic, *mmol/l*	35.69	42.91	37.60	4.46	0.321
Butyric, *mmol/l*	3.51	3.95	2.61	1.03	0.431
A:P ratio	2.66	2.29	2.17	0.80	0.306
Blood metabolites					
Glucose, *mg/dl*	67.50	64.00	64.33	4.33	0.698
BUN, *mg/dl*	8.33	9.33	6.66	2.33	0.500
Blood electrolytes					
Sodium, *meq/l*	141.00	143.33	142.00	1.20	0.260
Chloride, *meq/l*	101.00	105.33	95.33	9.06	0.521
Bicarbonate , *meq/l*	23.00	23.66	24.00	1.76	0.800
Potassium, *meq/l*	4.33	4.73	4.26	0.20	0.177
Milk production					
Milk yield, kg/d	9.40	9.76	9.44	2.42	0.980
4%FCM, kg/d	8.81	9.83	9.22	2.36	0.875
Milk composition					
Fat, %	3.56	4.05	3.89	0.27	0.295
Protein,%	2.61	2.81	2.88	0.38	0.712
Lactose, %	4.68	5.04	5.11	0.65	0.732
Solid not fat,%	7.99	8.56	8.71	0.68	0.524
Total solid, %	11.56	12.61	12.61	0.96	0.457

PL = pineapple peel, CT = concentrate pellet, RS = rice straw**.** T1 = PL to CT ratio of 70:30, T2= PL to CT ratio of 50:30 with 20 % RS, T3= PL to CT ratio of 70:30 with 1.2 % $NaHCO_3$ supplement**.** Within rows, means followed by different letters are significantly different at ($P<0.05$).

4. Conclusion

The supplement of DF as saliva secretion stimulant and $NaHCO_3$ had no significant impact or major physiological changes on performance of lactating dairy cows. The PL-CT mixed feed with or without DF and $NaHCO_3$ can be effectively used by dairy cows without adversely affecting digestive efficiency, metabolites and productive performance. Further research should be conducted to examine these effects with larger number of milking cows in the long run.

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