Asian-Aust. J. Anim. Sci.
Vol. 19, No. 9 : 1283 - 1290
September 2006

www.ajas.info

Effect of Potato By-products Based Silage on Rumen Fermentation, Methane Production and Nitrogen Utilization in Holstein Steers

B. Pen, T. Iwama, M. Ooi[1], T. Saitoh[1], K. Kida, T. Iketaki, J. Takahashi and H. Hidari*

Department of Animal Science, Obihiro University of Agriculture and Veterinary Medicine
Obihiro Hokkaido 080-8555, Japan

ABSTRACT : The effect of substituting potato by-products based silage (PBS) for concentrates on ruminal fermentation, methane production and nitrogen utilization in Holstein steers was evaluated. Three growing Holstein steers (490±19 kg, initial body weight) were used in a 3×3 Latin square experiment with three experimental diets in which PBS was included at (1) 0, (2) 19 and (3) 27%, on a dry matter basis, replacing concentrates and wheat bran. Increasing replacement levels of PBS slightly increased dry matter (DM), organic matter (OM), NDF and ADF intakes by the steers (p<0.05). Inclusion of PBS at 19% increased crude protein (CP) digestibility of the experimental diets compared with the control (p<0.05). Substitution with PBS increased ADF digestibility and nitrogen retention (p<0.05), but did not affect energy retention. Energy loss as methane ranged between 5.0 and 6.1% of the total gross energy intake. There were no significant differences in carbon dioxide and methane production among all PBS levels, while daily methane production numerically increased with PBS inclusion. Substituting PBS for concentrates did not significantly affect ruminal pH and ammonia N concentration. Total VFA concentration, VFA molar proportions and blood metabolites were also unaffected by PBS replacement. These results suggest that substitution of PBS up to 27% of diet dry matter did not significantly increase methane production and was equal or superior to concentrates in ADF digestibility and nitrogen retention for growing steers. (**Key Words :** Potato By-products, Steers, Methane Production, Nitrogen Retention)

INTRODUCTION

Agricultural food processing industries such as potato processors yield a huge amount of by-products which need to be discarded. Disposal of these by-products is an economic and environmental problem. Ensiling potato by-products may benefit both commercial beef producers and potato processors. Potato by-products based silage (PBS) is produced commercially from potato by-products, which include culled potatoes and steam-peeled potato processing waste with grain by-products, and is used as feed for beef cattle in Hokkaido, Japan. In a previous study, Pen et al. (2005) reported that feeding growing Holstein steers with PBS did not negatively affect carcass characteristics but surpassed concentrate-fed beef in terms of producing beef that contained a higher proportion of linoleic acid (C18:2).

It has long been recognized that feeding high-fibrous diets to cattle increases ruminal methanogenesis (Blaxter, 1962) and ammonia accumulation (Annison, 1956) which are two processes that have been implicated in global warming (Duxbury et al., 1993) and N pollution (Yeck et al., 1975; Nolan et al., 1976), respectively. Potato by-products such as potato peelings and culled potatoes are attractive feedstuffs because of their availability, higher energy concentration and low cost (Monteils et al., 2002). Replacing concentrates with potato by-products such as PBS would be desirable, however, feeding PBS alone or in a partial replacement of concentrates may increase methane production due to its higher fiber content. There is limited research available on feeding potato by-products; either fresh or after ensiling to cattle. If this by-product is to be incorporated into diets, more knowledge about its digestive features is required. Therefore, the present study was conducted to determine the effect of increasing potato by-products based silage inclusion in diets on ruminal fermentation, methane production and nitrogen utilization and to determine the optimal replacement rate of potato by-products based silage (PBS) for concentrates in fattening diets of Holstein steers.

* Corresponding Author: H. Hidari. Tel: +81-155-49-5653, Fax: +81-155-49-5653, E-mail: hdr7142@m2.octv.ne.jp
[1] Hokkaido Animal Research Center, 5-39 Shintoku-nishi, Shintoku-cho, Hokkaido 081-0038, Japan.
Received October 11, 2005; Accepted March 25, 2006

Table 1. Chemical composition (% DM) and gross energy (Mcal/kg DM) of diet components

Items	Concentrates[1]	PBS[2]	Hay	Wheat bran
Dry matter	87.0	41.0	86.6	87.6
Organic matter	95.0	92.2	94.5	94.5
Ether extract	3.9	1.4	1.7	4.2
Crude protein	17.2	14.4	5.4	16.9
ADF	7.0	23.1	36.7	12.9
NDF	22.8	36.0	65.1	44.4
TDN	85.0	63.2	49.7	73.0
Gross energy	4.41	4.29	4.13	4.54

[1] Contained 24% corn, 17% rye, 19% wheat, 13% wheat bran, 9% corn gluten feed, 5.5% soybean meal, 1.5% rape seed meal, 4.4% beet pulp, 4.5% alfalfa meal, 1.10% calcium carbonate, 0.4% salt, 0.35% malt, 0.25% mineral and vitamin (Mn 126 mg; Fe 69 mg; Cu 33 mg; I 2.6 mg; Co 0.8 mg; Se 0.46 mg; vitamin A 34,350 IU; vitamin D_3 6,870 IU and vitamin E 46 mg/kg).

[2] PBS = Potato by-products based silage.

MATERIALS AND METHODS

Animals and diets

Three growing Holstein steers (490±19 kg, initial body weight) were used in a 3×3 Latin square design experiment. Before the experiment began steers were acclimated to metabolism stanchions to ensure that all steers maintained uniform patterns of feed intake during subsequent experimental measurements. After the acclimation period animals were weighed and randomly allocated to the 3 experimental diets, which PBS was included at 0, 19, or 27% of diet DM, in a different sequence. The PBS used in the experimental diets was ensiled from, on a fresh basis, 29% potato peelings, 29% culled potato, 17.4% potato gluten feed, 4.3% potato pulp, 8.7% corn cob, 2.9% beet pulp, and 8.7 culled bean. The chemical composition of the diet components and concentrates is shown in Table 1. The feed offered provided TDN and crude protein content at 130% of maintenance levels in accordance with the recommendations of the Japanese feeding standard for beef cattle (AFFRC, 1995).

Experimental procedure

Each of the 3 experimental periods lasted for 21 days, comprising 14 days of adaptation to the experimental diets and a 7-day period for collection and measurement. The steers were housed in an individual metabolism stanchion and were offered feed twice daily in equal amounts at 9:30 h and 16:30 h. Mineral blocks (Fe 1232, Cu 150, Co 25, Zn 500, I 50, Se 15 and Na 382 mg/kg) and clean drinking water were provided *ad libitum*. All animals were weighed at the beginning and end of each experimental period. The experimental protocol was approved by Obihiro University of Agriculture and Veterinary Medicine Committee for Animal Use and Care.

Digestion study

On days 1-5 of the collection and measurement period, total feces and urine were collected and weighed from each animal. Feces were collected into containers and urine was collected into separate containers and 300 ml of 15% H_2SO_4 was added to maintain urine pH below 4. Feed, feed refusal and water consumption were measured daily before morning feeding, and samples of feed and feed refusal were taken. Total feces were weighed and 3% of them were collected for chemical analysis. Daily samples of feed, feed refusal, and feces were dried in a forced-air oven at 60°C for 48 h, air-dried for 24 h at room temperature, and weighed. After being ground to pass through a 1-mm screen, the samples were composited for each animal and stored in air-tight containers until analysis. Urine output was filtered through filter papers to remove solids and weighed. A 5% aliquot was taken, then added to a composite sample, and frozen.

Gaseous exchange measurement

On days 1-6 of the collection and measurement period, oxygen consumption, carbon dioxide and methane production were monitored by a fully automated open-circuit respiratory system using a hood over the animal's head (Takahashi et al., 1998). Gas analyzers were calibrated against certified gases with known gas concentrations at the beginning of each measurement day. Methane gas volume was converted to energy values using the conversion factor 39.54 kJ/L and heat production of the steer was calculated using the equation (Brouwer, 1965): Heat production (kJ/d) = 16.18 O_2 (L/d)+5.02 CO_2 (L/d)-2.17 CH_4 (L/d)-5.99 N (g/d).

Blood and rumen fluid collections

On the last day of each collection and measurement period (day 7), blood and rumen fluid samples were collected at 0 and 5.5 h after morning feeding. Blood samples were collected into heparinized tubes from the jugular vein, placed on ice immediately and then centrifuged at 3,000×g for 10 min at 3°C. Plasma was decanted and stored at -30°C until analysis. Ruminal fluid samples were collected using a flexible stomach tube inserted into the rumen via the esophagus. The collected rumen fluid was immediately strained through 4 layers of cheesecloth and pH values were measured immediately (HM-21P, DKK TOA Electrics Ltd., Tokyo, Japan). The strained rumen juice samples were placed in conical tubes and stored at -30°C until analysis.

Laboratory analysis

Feed, feed refusal, and fecal samples were analyzed for dry matter (DM), crude protein (CP), ether extract (EE), and organic matter (OM) according to the procedures of AOAC

Table 2. Ingredient, chemical composition, and gross energy of diets

Item	PBS inclusion (% diet DM)		
	0	19	27
Ingredients (% DM)			
Concentrates	61.1	56.2	48.2
PBS[1]	0.0	18.6	27.1
Hay	26.2	25.2	24.7
Wheat bran	12.7	0.0	0.0
Chemical composition			
DM (%)	87.0	71.7	66.4
OM (% DM)	94.8	94.4	94.1
EE (% DM)	3.4	2.9	2.7
CP (% DM)	14.0	13.7	13.5
ADF (% DM)	15.7	17.7	18.8
NDF (% DM)	36.8	36.1	36.9
Hemicelluose (%DM)	21.1	18.4	18.1
TDN (% DM)	74.1	71.9	70.2
GE (Mcal/kg DM)	4.35	4.32	4.31

[1] PBS = Potato by-products based silage.

(1990). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were analyzed according to the method of Van Soest (1967). Urinary samples were analyzed for nitrogen content by the micro-Kjeldahl method. The gross energy (GE) in feeds, feed refusal, feces, and urine was determined by Bomb calorimeter (CA-4P, Shimadzu, Tokyo, Japan) as described by Mwenya et al. (2004). Urinary samples were prepared by freezing a mixture of 2 g of urine and 1 g of cellulose powder in a bomb capsule overnight and then freeze-dried. The combustion heat of urine was calculated by subtracting the total combustion heat with the combustion heat of cellulose. Blood plasma samples were analyzed for blood urea nitrogen (BUN), glucose and non-esterified fatty acids (NEFA) according the procedure described by Toharmat et al. (1998). Rumen fluid samples were analyzed for NH_3-N concentration according to the procedures of Conway and O' Malley (1942) and volatile fatty acid (VFA) concentrations. The VFA concentrations were analyzed by gas-liquid chromatography (Shimadzu GC-14A, Kyoto, Japan) equipped with a flame-ionization detector and a capillary column (Ulbon HR-52, 0.53 mm ID ×30 m, 3.0 μm) by using 2-Ethyl-n-butyric acid as an internal standard. The operation conditions were: injector temperature, 190°C; detector temperature, 280°C; column temperature 50-90°C (5°C/min). The VFA concentrations were calculated using a Chromatopac data processing system (C-R 4A, Shimadzu, Kyoto, Japan).

Statistical analysis

Data from digestion and metabolism trials were analyzed as a 3×3 Latin square using GLM procedure of SAS (Ver. 6.12; SAS Inst., Inc., Cary, NC). The model included effects for steers, experimental periods and diets. Treatment means were compared using Duncan's multiple range tests. An orthogonal contrast was used to compare the effect of control with PBS substitution diets (o vs. others). Significance was declared at $p<0.05$, and trend was determined at $0.05<p<0.1$, unless otherwise stated.

RESULTS AND DISCUSSION

Feed and feed intake

The chemical composition of the diet components and ingredient composition of concentrates are presented in Table 1. The PBS was lower in dry matter (DM), ether extract (EE), crude protein (CP) and TDN, and was higher in ADF and NDF than concentrates. The ingredients,

Table 3. Feed intake and nutrient digestibility of steers fed 0, 19 and 27% PBS diets

Items	PBS inclusion (% diet DM)			SEM	p value	
	0	19	27		Diet	0 vs. other[1]
Intake (kg/d)						
TDN	4.80	4.84	4.85	0.032	0.523	0.315
DM	6.46[c]	6.71[b]	6.89[a]	0.021	0.010	0.006
OM	6.13[c]	6.34[b]	6.49[a]	0.019	0.011	0.007
EE	0.22[a]	0.20[b]	0.19[c]	0.002	0.008	0.004
CP	0.91	0.92	0.93	0.008	0.275	0.172
ADF	1.01[c]	1.17[b]	1.29[a]	0.004	0.001	0.001
NDF	2.37[b]	2.41[b]	2.53[a]	0.010	0.014	0.016
Hemicellulose	1.36[a]	1.23[b]	1.24[b]	0.010	0.019	0.010
Digestibility (%)						
DM	74.31	77.06	75.17	0.752	0.222	0.189
OM	75.60	78.27	76.30	0.710	0.208	0.192
EE	79.20	78.93	77.80	1.380	0.775	0.669
CP	68.26[b]	70.93[a]	68.48[b]	0.292	0.038	0.056
ADF	56.75[b]	61.77[a]	60.64[a]	0.531	0.039	0.021
NDF	64.29	67.59	64.87	1.074	0.271	0.279
Hemicellulose	69.88	73.24	69.27	1.605	0.360	0.555

[1] Contrast 0% vs. 19% and 27% PBS substitution.

Means within a row with different superscript differ significantly by the p value in that row.

Table 4. Nitrogen and energy partition in steers fed 0, 19 and 27% PBS diets

Item	PBS inclusion (% diet DM)			SEM	p value	
	0	19	27		Diet	0 vs. other[1]
Nitrogen partition						
Nitrogen intake (g/d)	145.23	147.63	149.43	1.313	0.280	0.177
Fecal N (%N intake)	31.74[a]	29.07[b]	31.52[a]	0.292	0.038	0.056
Urinal N (% N intake)	39.64	37.79	34.97	0.578	0.057	0.044
Digested N (% N intake)	68.26[a]	70.93[b]	68.48[a]	0.292	0.038	0.056
Retained N (g/d)	28.63[b]	33.14[a]	33.52[a]	0.288	0.011	0.006
Energy partition						
GE intake (Mcal/d)	28.15[b]	29.01[a]	29.70[a]	0.130	0.027	0.017
Fecal energy (% GEI)	26.34	24.06	26.12	0.719	0.246	0.292
Urinal energy (% GEI)	1.84	1.94	2.06	0.107	0.491	0.358
Methane energy (% GEI)	4.98	6.14	5.59	0.283	0.192	0.125
Heat production (% GEI)	49.41	51.54	50.97	0.453	0.145	0.080
Metabolizable energy (%)	66.84	67.86	66.24	0.871	0.529	0.866
Retained energy (%)	17.44	16.32	15.27	0.646	0.263	0.174

[1] Contrast 0% vs. 19% and 27% PBS substitution.

Means within a row with different superscript differ significantly by the P value in that row.

chemical composition, and gross energy (GE) of the experimental diets are presented in Table 2. Dry matter and EE of diets decreased as PBS replacement levels increased from 19 to 27% of diet DM due to higher moisture and lower EE in PBS than in concentrates.

Substituting PBS for concentrates up to 27% on a DM basis in diets did not affect TDN or CP intakes, but increased DM, OM, NDF and ADF intakes (p<0.05) and decreased intakes of EE (p<0.01) and hemicellulose (p<0.05), however, the increases were small (Table 3). These effects were due to PBS being higher in DM, OM, NDF and ADF, and lower in EE and hemicellulose (on a TDN basis) than concentrates. Onwubuemeli et al. (1985) reported that DM intake was not affected in steers fed a diet with potato waste inclusion at 10, 15, and 20% (*ad libitum*). However, increasing levels of potato by-product in diets from 0 to 40% (Radunz et al., 2003) and from 0 to 60% (Stanhope et al., 1980) significantly decreased DM intake in steers. In a previous study, Pen et al. (2005) reported that feeding steers with PBS up to 75% did not affect overall DM intake during the 6-month feeding period, although DM intake was decreased at a later stage.

Apparent digestibility

Substitution of PBS in diets did not affect nutrient digestibility, except for CP and ADF digestibility (Table 3). Stanhope et al. (1980) reported that DM digestibility was not affected by levels of potato processing residue in the diets. However, decreases in OM and NDF digestibility in lactating cows has been reported when potato meal was included at ensiling (Schneider et al., 1985). Steers fed 19% PBS diet had greater CP digestibility compared with steers fed other diets (p<0.05). This effect could reflect a decrease in fecal N in steers fed 19% PBS diet compared with the control and 27% PBS diets (Table 4). However, it is not clear why CP digestibility was increased with PBS replacement at 19% but not at 27%. Onwubuemeli et al. (1985) reported that inclusion of wet potato wastes up to 20% in the ration (on a DM basis) did not affect CP digestibility in steers. Inclusion of PBS in diet increased ADF digestibility compared with the control diet (p<0.05). This effect could be attributed to higher energy intake in steers fed PBS diets (29-30 Mcal/d) compared with the control diet (28 Mcal/d). Potato by-products such as potato peelings, culled potatoes and potato pulp contain a relatively high amount of fermentable carbohydrates, and the fermentation of these PBS carbohydrates would enable ruminal microorganisms to digest fiber more efficiently in feed-restricted steers. Furthermore, the differences in ADF digestibility might be due to PBS fiber being easier to digest than wheat bran, which was included only in the control diet. In contrast, Onwubuemeli et al. (1985) found a decline in ADF digestibility in steers fed *ad libitum* a diet with potato waste substitution at 20%.

Nitrogen and energy metabolism

The nitrogen and energy metabolism is presented in Table 4. Steers fed PBS at a 19% inclusion level had lower (p<0.05) fecal N than the control and the 27% PBS level, which resulted in increased (p<0.05) digestible N. Urinary N tended to decrease (p = 0.06) when PBS replacement levels increased from 19 to 27%. These results are consistent with Onwubuemeli et al. (1985) who reported that inclusion of potato processing residue at 20% of diet DM decreased fecal N and had no effect on urinary N in steers. The daily fecal and urinary N excretions as percentage of N intake ranged between 29.1 and 31.7% and between 35.0 and 39.6%, respectively, which were similar

Table 5. Oxygen Consumption and carbon dioxide and methane production of steers fed 0, 19 and 27% PBS diets

Items	PBS inclusion (% diet DM)			SEM	p value	
	0	19	27		Diet	0 vs. other[1]
O_2 (L/d)	2,672.1	2,943.6	2,994.3	66.37	0.128	0.067
CO_2 (L/d)	3,102.1	3,101.5	3,074.1	128.47	0.985	0.936
CH_4 (L/d)	148.1	189.6	176.4	8.91	0.151	0.086
CH_4 (L/kg DMI[2])	22.9	28.1	25.5	1.25	0.190	0.127
CH_4 (L/kg DOMI[3])	32.0	38.0	35.4	1.93	0.292	0.185

[1] Contrast 0% vs. 19% and 27% PBS substitution. [2] DMI: Dry matter intake. [3] DOMI: Digestible organic matter intake.

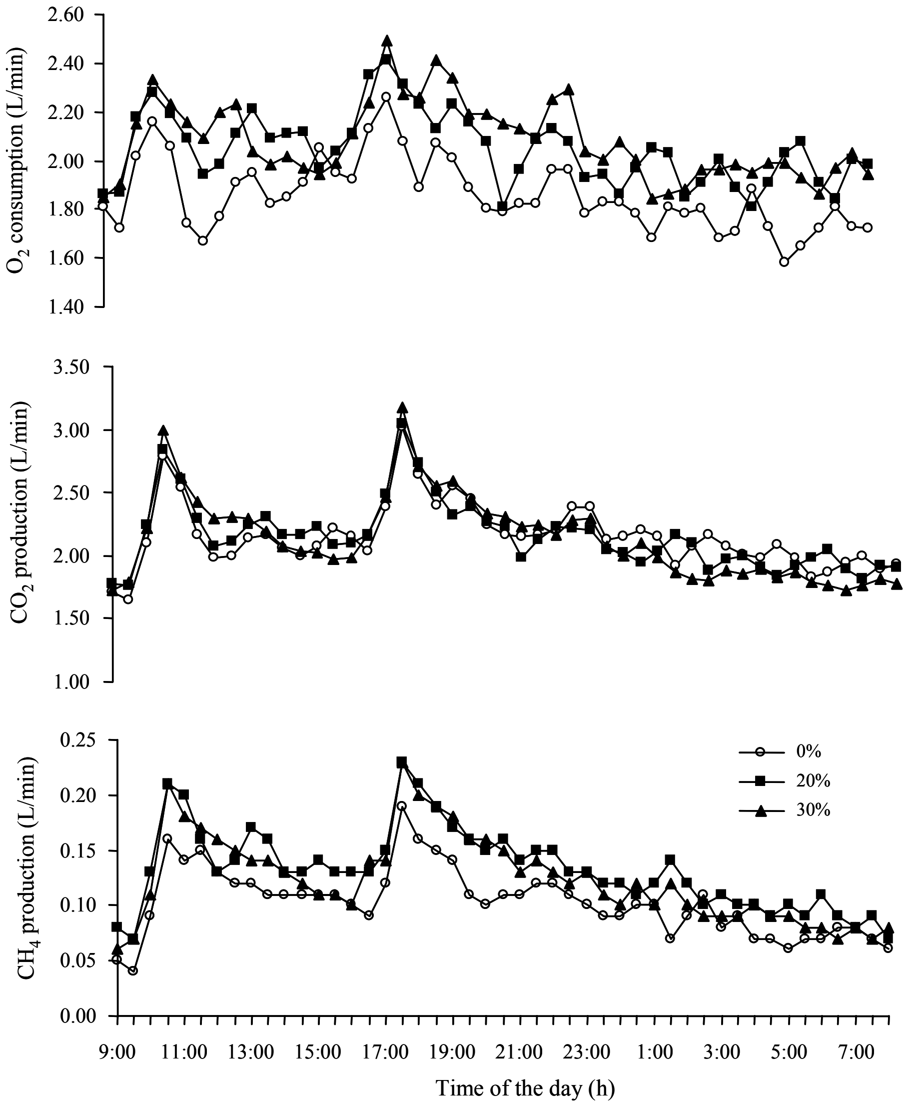

Figure 1. Diurnal variation in rate of oxygen consumption, carbon dioxide and methane production of steers fed diets with 0 (○), 19 (■), and 27% (▲) PBS. Feeding time: morning (9:30) and afternoon (16:30).

to those reported by Onwubuemeli et al. (1985), but were slightly higher than those found by Hoover et al. (1976). Inclusion of PBS at levels of 19% and 27% of diet DM increased N retention ($p<0.05$). These data suggest that either more dietary nitrogen was digested in the rumen or that rumen ammonia was utilized more effectively in the presence of the PBS. These results are consistent with Schneider et al. (1985) who found metabolized nitrogen was higher for lactating cows consuming silage with potato meal inclusion than without.

Steers fed diets with PBS inclusion had higher total GE intake compared to steers fed the control diet ($p<0.05$). This might be attributed to higher GE in PBS than concentrates (6.78 vs. 5.19 Mcal/kg TDN). Inclusion of PBS in diets did not affect energy losses in feces, urine, and heat production. The energy loss in feces and urine as percentage of GE intake ranged between 24.0 and 26.3% and between 1.8 and 2.1%, respectively. Numerical increase in energy loss as methane when concentrates were replaced with PBS at 19 and 27% (5.0 vs. 5.6-6.1% of GEI, control vs. 19 and 27% PBS diets) was observed. This effect might be due to increased ADF digestibility (Table 3). Hoover et al. (1976) reported that energy losses in urine and methane were lower in steers fed potato silage compared to corn silage. Inclusion of PBS in diets did not affect metabolized energy but energy retention was numerically decreased, which might be due to a numerical increase in energy loss as methane.

Methane production

The respiratory gaseous exchange of steers fed 0, 19, and 27% PBS diets is shown in Table 5. Replacing concentrates with PBS in diets did not affect carbon dioxide production. Numerical increases in methane production and oxygen intake were observed with PBS replacement. These numerical increases in methane production and O_2 intake might be reflected by higher DM intake in steers receiving diets with PBS inclusion. It has long been recognized that feeding high-fibrous diets to cattle increases methane production in the rumen (Blaxter, 1962). The diurnal changes in oxygen uptake, carbon dioxide and methane production of the steers are presented in Figure 1. In all PBS levels, methane and carbon dioxide production and oxygen intake increased immediately after morning and afternoon feedings.

Rumen fermentation characteristics

The effect of increasing levels of PBS inclusion on ruminal fermentation is shown in Table 6. It is expected that rapid fermentation of readily available carbohydrates in PBS may reduce ruminal pH, however, ruminal pH was unaffected by PBS inclusion. The inefficacy of PBS inclusion on ruminal pH in steers fed diets with up to 40% of potato waste of diet DM has also been reported (Radunz et al., 2003). In contrast, an increase in ruminal pH with the addition of steam-peeled potato wastes in diets has been reported (Onwubuemeli et al., 1985). In the present study, PBS inclusion did not affect ruminal NH_3-N concentration in steers. Radunz et al. (2003) reported increased ruminal NH_3-N concentration in steers fed diets with potato waste inclusion, while Onwubuemeli et al. (1985) reported a decrease in ruminal NH_3-N concentration when potato waste replaced high-moisture corn in feed.

There were no significant differences in total VFA concentration and VFA molar proportions among all diets, but only butyrate molar proportion declined ($p<0.05$) in steers fed a 19% PBS diet compared to those fed the control diet (Table 6). Radunz et al. (2003) reported an increase in total VFA concentration and butyrate molar proportion and a decrease in propionate molar proportion as replacement levels of potato by-products was increased. Onwubuemeli et al. (1985) reported decreases in total VFA and acetate concentration, and acetate to propionate ratio, and an increase in propionate molar proportion when wet potato by-products replaced high-moisture corn. Schneider et al. (1985) found a decrease in acetate molar proportion and an increase in propionate molar proportion when potato meal was ensiled with forage.

Table 6. Changes in ruminal pH, NH_3-N concentration and VFA proportion of steers fed 0, 19, and 27% PBS diets

Item	PBS inclusion (% diet DM)			SEM	p value	
	0	19	27		Diet	0 vs. other[1]
pH	6.71	6.64	6.76	0.042	0.293	0.299
NH_3-N (mg/L)	128.03	122.47	123.65	8.257	0.367	0.176
Total VFA (mmol/L)	50.43	48.88	51.59	2.754	0.788	0.954
Molar proportion (%)						
Acetate (A)	68.50	69.78	68.23	0.588	0.187	0.500
Propionate (P)	16.50	15.94	16.72	0.446	0.471	0.754
Butyrate	13.00[a]	11.98[b]	12.89[a]	0.217	0.015	0.061
Isobutyrate	0.79	0.86	0.79	0.056	0.612	0.610
Isovalerate	0.29	0.53	0.39	0.119	0.408	0.280
Valerate	0.92	0.79	0.99	0.078	0.227	0.791
A:P	4.21	4.46	4.14	0.147	0.313	0.638

Means within a row with different superscript differ significantly by the P value in that row.

Table 7. Blood metabolites of steers fed 0, 19, and 27% PBS diets

Item	PBS inclusion (% diet DM)			SEM	p value	
	0	19	27		Diet	0 vs. other[1]
Glucose (mg/dl)	78.42	85.23	77.18	3.195	0.220	0.497
NEFA (μEq/L)	173.44	198.44	170.11	27.279	0.734	0.754
BUN (mg/dl)	8.90	8.70	8.52	0.149	0.250	0.147

[1] Contrast 0% vs. 19% and 27% PBS substitution.

Blood metabolites

PBS substitution in diets did not significantly affect the concentration of plasma glucose, NEFA and blood urea-N (BUN) (Table 7). Onwubuemeli et al. (1985) found no effects of potato by-products on plasma glucose concentration. The plasma glucose concentration in the present study was relatively higher than that found in lactating cows receiving silage with up to 20% of potato by-products (Onwubuemeli et al., 1985) and non-lactating cows receiving grass silage alone (Santoso et al., 2003). This could be attributed to the higher proportion of concentrates ingested by steers in this study (Dhiman et al., 1991). Plasma glucose and BUN are considered a reflection of the amount of ingested starch and protein or the ratio of these nutrients consumed (Blowery et al., 1973). Pethick and Dunshea (1993) suggested that NEFA entry into the plasma pool reflect fat mobilization.

CONCLUSIONS

Data from this study suggest that substitution of potato by-products based silage for concentrates up to 27% of diet dry matter did not significantly increase methane production and improved ADF digestibility and nitrogen retention. Further study is required with a larger number of cattle and more PBS replacement levels before it can be recommended that it be incorporated into diets. However, in general, potato by-products based silage has lower protein content and an equal energy value compared with concentrates on a dry matter basis. Therefore, potato by-products based silage may be used as a substitute for concentrates as an energy source in growing and finishing diets for beef cattle. Utilization of potato by-products for animals feed may eliminate a substantial pollution problem for the potato industry and provide a feedstuff which might be beneficial to cattle production.

ACKNOWLEDGEMENT

This study was partly supported by Grants from the 21st Century COE program (A-1), Ministry of Education, Science, Sports and Culture of the Japanese government.

REFERENCES

Agriculture Forestry and Fisheries Research Council Secretariat (AFFRC). 1995. Standard tables of feed composition in Japan. Central association of livestock industry, Tokyo.

Annison, E. F. 1956. Nitrogen metabolism in the sheep. Biochem. J. 64:705-714.

AOAC. 1990. Official Methods of Analysis. 15th ed. Association of Official and Agricutual Chemists, Arlington, Virginia, USA.

Blaxter, K. L. 1962. The energy Metabolism of ruminants. Charles C Thomas, Springfield, IL.

Blowey, R. W., D. W. Wood and J. R. Davis. 1973. A nutritional monitoring system for dairy herds based on blood glucose, urea and albumin levels. Vet. Rec. 92:691-696.

Brouwer, E. 1965. Report of sub-committee on constants and factors. In: Proceedings of the 3rd EAAP Symposium on Energy Metabolism (Ed. K. L. Blaxter). Troon, Publ. 11. Academic Press, London, pp. 441-443.

Conway, E. J. and E. O'Malley. 1942. Microdiffusion methods: ammonia and urea using buffered absorbents (revised methods for ranges greater than 10 g N). Biochem. J. 36:655-661.

Dhiman, T. R., J. Kleinmans, N. J. Tessmann, H. D. Radloff, P. Van Everet and L. D. Satter. 1991. Effect of dietary forage:grain ratio on blood constituents in dairy cows. J. Dairy Sci. 74:2691-2695.

Duxbury, J. M., L. A. Harper and A. R. Mosier. 1993. Contributions of agroecosystems to global climate change. In: L.A. Harper, R.

Hoover, W. H., C. J. Sniffen and E. E. Wildman. 1976. Nutritive value of potato-based silages for dairy bulls. J. Dairy Sci. 59:1286-92.

Mwenya, B., X. Zhou, B. Santoso, C. Sar, Y. Gamo, T. Kobayashi and J. Takahashi. 2004. Effects of probiotic-vitacogen and β1-4 galacto-oligosaccharides supplementation on methanogenesis and energy and nitrogen utilization in dairy cows. Asian-Aust. J. Anim. Sci. 17:349-354.

Monteils, V., S. Jurjanz, O. Colin-Schoellen, G. Blanchart and F. Laurent. 2002. Kinetics of ruminal degradation of wheat and potato starches in total mixed rations. J. Anim. Sci. 80:235-241.

Nolan, J. V., B. W. Norton and R. A. Leng. 1976. Further studies of the dynamics of nitrogen metabolism in sheep. Br. J. Nutr. 35:127-147.

Onwubuemeli, C., J. T. Huber, K. J. King and Cole Johnson. 1985. Nutritive value of potato processing wastes in total mixed rations for dairy cattle. J. Dairy Sci. 68:1207-1214.

Pethick, D. W. and F. R. Dunshea. 1993. Fat metabolism and turnover. In: Qualitative aspexts of ruminant digestion and metabolism (Ed. J. M. Forbes and J. France). CAB International, Willingford, UK. pp. 291-311.

Pen, B., T. Oyabu, S. Hidaka and H. Hidari. 2005. Effect of potato by-products based silage on growth performance, carcass characteristics and fatty acid composition of carcass fats in Holstein steers. Asian-Aust. J. Anim. Sci. 18:490-496.

Radunz, A. E., G. P. Lardy, M. L. Bauer, M. J. Marchello, E. R. Loe and P. T. Berg. 2003. Influence of steam-peeled potato-processing waste inclusion level in beef finishing diets: Effects on digestion, feedlot performance, and meat quality. J. Anim. Sci. 81:2675-2685.

Santoso, B., S. Kume, K. Nonaka, K. Kimura, H. Mizukoshi, Y. Gamo and J. Takahashi. 2003. Asian-Aust. J. Anim.Sci. 16(4): 534-540.

Schneider, P. L., M. R. Stokes, L. S. Bull. and C. K. Walker. 1985. Evaluation of potato meal as feedstuff for lactating dairy cows. J. Dairy Sci. 68:1738-1743.

Stanhope, D. L., D. D. Hinman, D. O. Everson and R. C. Bull. 1980. Digestibility of potato processing residue in beef cattle finishing diets. J. Anim. Sci. 51:202-206.

Takahashi, J., M. Ikeda, S. Matsuoka and H. Fujita. 1998.

Prophylactic effect of L-cysteine to acute and subclinical nitrate toxicity in sheep. Anim. Feed Sci. Technol. 74:273-280.

Toharmat, T., I. Nonaka, M. Shimizu, K. K. Batajoo and S. Kume. 1998. Effect of prepartum energy intake and calving season on blood composition of periparturient cows. Asian-Aust. J. Anim. Sci. 11: 739-745.

Van Soest, P. J. and R. H. Wide. 1967. Use of detergents in analysis of fibrous feeds. IV. Determination of plant cell wall constituents. J. Ass. Off. Analy. Chem. 50:50-55.

Yeck, R. G., L. W. Smith and C. C. Calvert. 1975. Recovery of nutrients from animal wastes. An overview of existing options and potentials for use in feed. Pro. 3rd . Int. Symp. Livest. Wastes. 193-194.