

The Use of Apple Pomace in Rice Straw Based Diets of Korean Native Goats (*Capra hircus*)

J. H. Ahn*, I. H. Jo¹ and J. S. Lee²

Department of Dairy Science, Dairy Extension Service Center, Hankyong National University
Ansung, Kyonggi Province, Korea

ABSTRACT : In this study, three different experiments were conducted to evaluate the nutritional value of apple pomace produced in southern areas of the Republic of Korea (South Korea). The effects of combining apple pomace in different ratios with commercial concentrates and rice straw in the diets of Korean native goats (*Capra hircus*) were examined. In experiment I, *in situ* DM and CP disappearances from nylon bags incubated in the rumen of goats showed that greater amounts of DM and CP were released from apple pomace than those from concentrates at the later stages of incubation, but only after 48 h for DM and CP, respectively. This was reflected in the higher "b" value of the slowly degradable fraction of the apple pomace compared to the concentrates. Prior to these times the trend was reversed. In experiment II, Korean native goats were fed a diet containing apple pomace with either rice straw or rice straw and concentrates, and the *in vivo* nutrient digestibilities compared to animals receiving an alfalfa hay. DM digestibility in the animals given apple pomace plus concentrates with rice straw (66.86%) were similar to the goats given alfalfa hay only (69.09%) but significantly greater than for a diet of rice straw plus concentrates. In experiment III, an *in vivo* study was conducted to investigate the inclusion of 30 to 60% apple pomace pre-mixed with rice straw, rice bran and concentrates on the nutritional value for Korean native goats. Apple pomace mixed diets had higher DM intakes, nutrient digestibility and nitrogen retention than diets without apple pomace, which may have been due to the higher non-structural carbohydrates (NSC) and less ADF and NDF than those in other treatments. Replacement of concentrates with apple pomace in rice straw based diets of Korean native goats fed either separately (experiment II) or by pre-mixing (experiment III) gave satisfactory feed intake, digestibility, pH of ruminal fluid and production of NH₃-N and VFA in the rumen of goats. The results of this study infer that apple pomace can be included at levels of up to 60% in the diets of goats without dramatic effect on the animal. (*Asian-Aust. J. Anim. Sci.* 2002, Vol 15, No. 11 : 1599-1605)

Key Words : Digestibility, Apple Pomace, Korean Native Goats, Rice Straw, Agricultural Byproducts

INTRODUCTION

There has been a substantial increase in the production of goat meat in Korea in response to claims of its use as a health food and the consequent greater consumption. Goats have a greater capability than other herbivores to utilize low quality roughage (Seth et al., 1976). There is potential to complement low quality forages in the diet with high protein legumes for growth of goats (Ahn et al., 1989). However, South Korea has a limited production of forage for herbivores and therefore, the utilization of greater quantities of agricultural by-products is desirable. Although rice straw is a major available source of roughage for herbivores in South Korea, its nutritional value is known to be low due to its high fiber content and consequently reduced intake and digestibility in animals (Jackson, 1977).

A reasonable amount of apple pomace is currently produced in southern areas of South Korea (accurate statistics unavailable). Apple pomace contains abundant

NSC and energy, but low crude protein (Bae et al., 1994). However, the nutritional value of apple pomace for goats has not been studied especially for Korean native goats. The objective of this study was to investigate the utilization of apple pomace as a supplement for rice straw diets in goats.

MATERIALS AND METHODS

Animals and diets

Three experiments were conducted in this study. In *in situ* experiment I, two goats with the mean weight of 16±2.7 kg were surgically fitted with ruminal cannula and duplicate bags at each incubating time were incubated in the rumen of each animal. Animals were fed *ad libitum* a mixed diet of rice straw (30%), rice bran (30%), apple pomace (30%) and commercial concentrates (10%). In *in vivo* experiment II, four intact Korean native goats of mean weight 11±1.7 kg were fed alfalfa hay, rice straw+commercial concentrates (RS+CD), rice straw+apple pomace (RS+AP) or rice straw+commercial concentrates +apple pomace (RS+CD+AP) in a 4×4 Latin square design. The individual components were not pre-mixed, but rice straw was given *ad libitum*, apple pomace was also given *ad libitum* but only in the evenings and concentrates were fed at 90 g/d per animal. In experiment III, apple pomace

* Corresponding Author: Jong-Ho Ahn. Tel: +82-31-670-5124, Fax: +82-31-670-5238, E-mail: jhahn@hnu.hankyong.ac.kr

¹ Division of Life Resources, College of Natural Resources, Taegu University, Kyongsan, Kyungbuk, Korea.

² Department of Biological Resource and Technology, College of Liberal Arts and Sciences, Yonsei University, Wonju, Korea.

Received March 15, 2002; Accepted July 24, 2002

was pre-mixed with rice bran, rice straw and concentrates in different ratios (rice straw:apple pomace:rice bran:concentrates, A 60:0:0:40, B 60:0:30:10, C 30:30:30:10, D 0:60:30:10) and given to ruminally cannulated Korean native goats (mean weight 16.1±2.1 kg). A 4×4 Latin square design was used to study the diets with periods of 31 days, 21 days for adaptation and 10 days for collection. Rice straw used in experiment II and III had been harvested and dried in the farm of Taegu University of Kyongsang Province, Republic of Korea. Dehydrated apple pomace was obtained from a local apple juice firm and rice bran and concentrates for goats were purchased from a feed mill.

Sample collection and chemical analysis

The disappearance of DM and CP for apple pomace and concentrates were determined *in situ* (experiment I). Apple pomace and concentrates were bulked for drying at 60°C in a forced draught oven and then, ground using a Wiley mill to pass through a 2 mm screen and 10 g of DM were weighed into nylon bags (5×15 cm, 45 µm pore size). Nylon bags were placed in the rumen for 0, 3, 6, 9, 12, 24, 48, and 72 h. Bags removed from the rumen were washed using fresh tap water until the effluent ran clear. Kinetics of dry matter (DM) and crude protein (CP) disappearance and effective ruminal degradabilities (ED) *in situ* were estimated by the following model of Orskov and McDonald (1979).

$$P = a + b(1 - e^{-ct})$$

P=DM or CP cumulative loss at given time (t)

a: quickly degradable fraction

b: slowly degradable fraction within given time

c: fractional rate of disappearance

t: time of incubation

$$ED = (a+b) \times c / (c+k)$$

k: fractional passage rate of 3, 5, 8% respectively that were assumed considering the general feed intake of animals (Orskov and McDonald, 1979)

In experiment II and experiment III, total fecal outputs from the animals were collected daily over a 10 day period, following a 21 day adaptation period to the experimental diets. Daily outputs of feces from each animal were measured and 10% sub-samples were bulked for drying at 60°C in a forced draught oven. Urine in experiment III was collected in 20 mL of concentrated HCl. Each day, a 10% aliquot of urine from the total volume measured was bulked for each animal over 10 days. At the end of the trial, rumen fluid samples (10 ml) were withdrawn through the cannula from each animal 3 h after the morning feed, acidified with

an equal volume of 0.3 M HCl and stored at 5°C prior to the determination of NH₃-N and volatile fatty acids.

DM contents of feed, feed refusals and feces were determined after drying the samples at 60°C for 48 h in a forced draught oven, and organic matter (OM) contents in this fraction were determined by ashing for 3 h at 550°C. Total nitrogen of feeds, feces and urine were determined by the Kjeldahl method (AOAC, 1990). NDF and ADF were measured by the method of Goering and van Soest (1970). Rumen NH₃-N was determined spectrophotometrically (Okuda and Fujii, 1966). Concentration and molar proportion of the volatile fatty acids were determined in the rumen fluid samples by gas chromatography (Varian star 3600cx) following deproteinization with 1% metaphosphoric acid (Erwin et al., 1961).

Statistical analysis

Data obtained from the experiments were analyzed using the SAS software package version 6.12 (SAS Inst Inc., Cary, NC, 1998) and differences were tested by Duncan's multiple range test.

RESULTS

Analysis of feed ingredients for experiment I, II and III are shown in Table 1. CP content in apple pomace in experiment I was 4.35% although, it was 6.25% in experiment II and III. Apple pomace that was used in the respective experiments of this study was produced in different years. Apple pomace and concentrates had similar NDF contents. However, apple pomace had a greater level of NSC than concentrates (55.74 vs 41.62%). Four different feed ingredients in experiment II showed that CP contents were 18.57, 5.25, 6.25 and 13.68% for alfalfa hay, rice straw, apple pomace and concentrates, respectively. Composition of experimental diets in experiment III showed that the proportion of NSC increased in the diets as the proportion of apple pomace increased.

Experiment I: *In situ* evaluation of apple pomace and concentrates

Table 2 presents the values of potentially degradable fraction, "A+B" from the data of DM disappearance in the rumen, which were significantly ($p < 0.05$) higher for apple pomace as 94.35% due to higher ($p < 0.05$) "B" value than 87.34% for concentrates. However the proportion of DM that disappeared from the nylon bags was greater ($p < 0.05$) for concentrates from 0 up to 24 h of incubation than for apple pomace. Although, those of apple pomace after 24 h tended to be greater than for concentrates afterwards. Degradation of the slowly degradable fraction was faster ($p < 0.01$) for concentrates than apple pomace (7.7 vs 4.8 %). The values in Table 2 of "A", "A+B" and "C" for CP

Table 1. Chemical composition of experimental feedstuffs (% DM basis)

Feedstuffs	Crude protein	ADF	NDF	Crude Ash	Ether extracts	NSC
Experiment I						
Apple pomace	4.35	26.44	31.63	1.85	6.43	55.74
Concentrates	13.68	7.43	35.54	6.51	2.65	41.62
Experiment II						
Alfalfa hay	18.57	34.13	46.67	10.67	2.57	21.52
Rice straw	5.25	52.12	71.71	12.45	2.29	8.30
Apple pomace	6.25	34.13	39.12	2.33	5.49	46.81
Experiment III						
A	8.20	32.20	65.80	11.30	1.90	12.79
B	8.50	33.20	62.41	11.89	7.69	9.49
C	9.00	25.69	49.21	8.59	8.49	24.60
D	9.50	18.30	36.50	5.30	9.20	39.50

A: Rice straw (60%)–Concentrates (40%).

B: Rice straw (60%)–Rice bran (30%)+Concentrates (10%).

C: Rice straw (30%)–Apple pomace (30%)+Rice bran (30%)–Concentrates (10%).

D: Apple pomace (60%)+Rice bran (30%)–Concentrates (10%).

Table 2. Dry matter and crude protein disappearance (%) and degradation parameters including effective rumen degradabilities

	Dry matter disappearance (%)		Crude protein disappearance (%)	
	Apple pomace	Concentrates	Apple pomace	Concentrates
Incubation time (h)				
0	48.50 ^b ±2.04	57.24 ^a ±3.16	31.16 ^b ±1.54	53.45 ^a ±0.70
3	57.29 ^b ±2.44	67.00 ^a ±3.09	34.04 ^b ±1.13	67.38 ^a ±0.65
6	59.81 ^b ±2.56	70.82 ^a ±1.46	35.05 ^b ±1.14	70.61 ^a ±0.84
9	62.65 ^b ±4.16	73.94 ^a ±2.74	37.26 ^b ±0.82	71.47 ^a ±0.82
12	71.94 ^a ±3.62	76.48 ^a ±1.62	48.10 ^b ±1.51	74.76 ^a ±1.10
24	78.71 ^a ±6.45	79.16 ^a ±2.40	62.76 ^b ±0.92	76.08 ^a ±1.39
48	90.40 ^a ±2.92	88.77 ^b ±0.64	87.48 ^a ±0.66	88.05 ^a ±0.78
72	92.74 ^a ±0.73	88.07 ^b ±0.81	92.28 ^a ±1.02	89.58 ^b ±0.76
Degradation parameters				
A	49.35 ^b	59.30 ^a	25.14 ^b	58.05 ^a
B	45.00 ^a	28.04 ^b	61.43 ^a	30.41 ^b
A+B	94.35 ^a	87.34 ^b	86.57	88.46
C	0.0477 ^b	0.0771 ^a	0.0345 ^b	0.0632 ^a
ED (%)				
k=0.03	76.82 ^a	79.49 ^a	58.00 ^b	78.67 ^a
k=0.05	71.15 ^b	76.31 ^a	50.22 ^b	75.03 ^a
k=0.08	66.00 ^b	73.06 ^a	43.65 ^b	71.47 ^a

Means separation within a row by Duncan's Multiple Range Test, 5% level. The same letters show non-significant difference at the 5% level.

A: Quickly degradable fraction.

B: Slowly degradable fraction within given time.

A+B: Potentially degradable fraction.

C: Fractional rate of disappearance.

ED: Effective degradability.

k: Fractional passage rate assumed to be 3, 5, and 8% respectively.

disappearance during incubation were consistent with the tendency of DM disappearance between apple pomace and concentrates but to wider extents of difference.

Experiment II : *In vivo* evaluation of separate feeding of apple pomace with rice straw and concentrates

DM intakes and digestibilities of nutrients are presented in Table 3. DM intakes per metabolic weight (DM g/kg BW^{0.75}) were greater ($p<0.05$) for animals given alfalfa hay only (60.45) than for other treatments, however those in RS+CD+AP (42.53) tended to be higher than in RS+CD

(35.62) and RS+AP (37.28). It is notable, that the intake of apple pomace (174.0 g/d) in RS+AP was comparable to that of RS+CD+AP (125.9 g/d).

Digestibilities of DM and OM were also highest ($p<0.05$) in goats fed alfalfa hay only, but there were no significant differences particularly when compared to those of RS+CD+AP. Digestibilities of NDF and ADF were highest ($p<0.01$) in RS+CD+AP, with the similar results in goats fed alfalfa hay only while those of RS+CD were significantly ($p<0.05$) lower.

Table 3. Dry matter intake and digestibility in Korean native goats fed alfalfa hay only or rice straw plus concentrates with or without apple pomace (Experiment II)

Items	Treatments			
	AH	RS+CD	RS+AP	RS+CD+AP
Dry matter intake(g/day)	358.10 ^a ±23.89	210.33 ^b ±35.34	228.33 ^b ±37.79	263.28 ^b ±62.12
(Rice straw)	(-)	(120.334±35.34)	(54.30±7.88)	(47.33±16.04)
(Apple pomace)	(-)	(-)	(174.03±38.85)	(125.95±71.69)
(Commercial diet)	(-)	(90.00)	(-)	(90.00)
DM Intake, g/kg of BW ^{0.75}	60.45 ^a ±3.54	35.62 ^b ±7.13	37.28 ^b ±5.35	42.53 ^b ±11.93
DM Intake/BW(%)	3.34 ^a ±0.24	1.97 ^b ±0.42	2.04 ^b ±0.29	2.32 ^b ±0.69
Digestibility (%)				
Dry matter	69.09 ^a ±1.89	55.39 ^c ±5.49	62.31 ^b ±4.13	66.86 ^{ab} ±3.06
Organic matter	70.72 ^a ±2.11	58.44 ^c ±5.51	63.90 ^{bc} ±4.52	68.83 ^{ab} ±3.34
Crude protein	67.74 ^a ±2.06	55.71 ^b ±5.69	64.95 ^a ±3.67	68.57 ^a ±3.05
ADF	71.13 ^a ±1.63	63.48 ^b ±4.78	69.67 ^a ±3.73	74.60 ^a ±2.43
NDF	68.87 ^b ±2.62	62.18 ^c ±4.79	72.66 ^{ab} ±3.68	75.69 ^a ±2.40
NSC	66.70 ^a ±2.12	47.23 ^b ±5.61	44.23 ^b ±6.31	52.01 ^b ±4.70

Means separation within a row by Duncan's Multiple Range Test, 5% level. The same letters show non-significant difference at the 5% level.

AH: Alfalfa hay only.

RS+CD: Rice straw-Concentrates.

RS+AP: Rice straw-Apple pomace.

RS+CD-AP: Rice straw+Apple pomace+Commercial diet of concentrates.

Experiment III : *In vivo* evaluation of premixed rice straw based diets containing apple pomace, rice bran and concentrates in different ratios.

Apple pomace increased ($p<0.01$) intake of the rice straw diets to levels comparable to the high concentrate diet (Table 4). Digestibilities of DM, OM, CP, ADF and NDF also increased ($p<0.01$) with higher levels of apple pomace. Nitrogen retention was increased ($p<0.01$) by higher levels of apple pomace in the diet.

Table 5 shows the results of pH, NH₃-N and VFA production in the rumen of goats fed the diets mixed with or

without addition of apple pomace in different ratios. Rumen pH was significantly ($p<0.05$) lower for the diets with the highest levels of apple pomace and was consistently lower over the time of sampling (Figure 1a). NH₃-N concentrations in goats fed apple pomace mixed diets (C and D) were not significantly ($p>0.05$) different with those of A and B. Concentrations of NH₃-N were similar for all diets and were highest 3 h after feeding (Figure 1b). Concentration of total VFA followed the same trend of NH₃-N production in all treatments except B, in which no increase in total VFA production was demonstrated, even at

Table 4. Dry matter intake, digestibility and nitrogen balance of Korean native goats fed apple pomace mixed with other agricultural by-products (Experiment III)

	A	B	C	D
Dry matter intake (g/day)	455.6 ^a ±27.0	313.1 ^b ±34.9	446.5 ^a ±18.5	418.0 ^a ±47.6
DM Intake, g/kg of BW ^{0.75}	48.4 ^a ±5.9	35.1 ^b ±4.2	49.7 ^a ±4.7	45.4 ^a ±1.9
Digestibility (%)				
Dry matter	53.7 ^c ±4.1	43.1 ^c ±1.8	62.1 ^b ±1.9	71.6 ^a ±1.2
Organic matter	55.6 ^c ±1.2	55.9 ^c ±2.0	67.8 ^b ±2.0	78.8 ^a ±1.4
Crude protein	62.4 ^b ±2.3	59.7 ^b ±3.2	76.3 ^a ±1.9	74.6 ^a ±2.1
ADF	58.2 ^c ±2.8	62.3 ^{bc} ±3.7	66.4 ^b ±0.6	73.4 ^a ±3.3
NDF	65.1 ^b ±3.5	67.7 ^b ±2.6	68.4 ^b ±3.6	73.6 ^a ±2.2
NSC	65.0 ^b ±3.2	58.3 ^c ±1.0	72.6 ^a ±0.5	71.2 ^a ±1.8
Nitrogen balance				
Total N intake (g/day)	6.0 ^a ±1.13	4.3 ^b ±0.62	6.4 ^a ±0.61	6.4 ^a ±1.20
Fecal N loss (g/day)	2.3±0.74	1.7±0.43	1.5±0.70	1.6±0.64
Urinary N loss (g/day)	3.9 ^a ±1.21	3.7 ^{ab} ±0.61	2.9 ^{bc} ±0.52	2.0 ^c ±0.14
Nitrogen retention (g/day)	-0.2 ^b ±0.80	-1.1 ^b ±0.32	2.0 ^a ±0.81	2.8 ^a ±0.94
Nitrogen retention (%)	-0.04 ^c ±0.24	-0.3 ^c ±0.82	31.6 ^b ±0.90	43.3 ^a ±0.81

Means separation within a row by Multiple Range Test, 5% level. The same letters show non-significant difference at the 5% level.

A: Rice straw (60%)–Concentrates (40%)

B: Rice straw (60%)–Rice bran (30%)–Concentrates (10%)

C: Rice straw (30%)–Apple pomace (30%)–Rice bran (30%)–Concentrates (10%)

D: Apple pomace (60%)–Rice bran (30%)–Concentrates (10%)

Table 5. Ruminal pH, NH₃-N, VFA concentration in Korean native goats fed apple pomace mixed with other agricultural by-products¹

	A	B	C	D
pH	6.7 ^a ±0.13	6.8 ^a ±0.12	6.5 ^b ±0.21	6.1 ^c ±0.34
NH ₃ -N (mg/100ml)	24.4 ^{ab} ±5.02	25.8 ^a ±6.12	24.3 ^{ab} ±6.34	22.6 ^b ±6.62
Total VFA (mM) ²	126.2 ^{ab} ±61.10	80.6 ^b ±14.6	144.8 ^a ±60.10	127.1 ^{ab} ±52.30
Acetic acid (mM)	86.1 ^a ±40.70	54.3 ^b ±8.40	86.4 ^a ±31.50	68.5 ^{ab} ±18.80
Propionic acid (mM)	27.4 ^{ab} ±14.70	20.4 ^b ±5.10	48.1 ^a ±24.70	39.9 ^{ab} ±23.40
Butyric acid (mM)	11.0 ^{ab} ±5.61	4.6 ^b ±1.10	8.4 ^{ab} ±4.72	15.2 ^a ±10.13
Iso-butyric acid (mM)	0.8±0.60	0.5±0.23	0.5±0.42	0.6±0.41
Valeric acid (mM)	0.5 ^b ±0.44	0.3 ^b ±0.14	0.8 ^b ±0.62	2.4 ^a ±0.61
Iso-valeric acid (mM)	0.8±0.60	0.5±0.22	0.7±0.31	0.5±0.14
Acetate/propionate ratio	3.3 ^a ±0.54	2.8 ^a ±0.53	2.0 ^b ±0.62	1.9 ^b ±0.43

¹ Means in the same row with different superscripts differ ($p < 0.05$).

² Mean values 0, 3, 6, 9 hr post-feeding.

A: Rice straw (60%)–Concentrates (40%).

B: Rice straw (60%)–Rice bran (30%)–Concentrates (10%).

C: Rice straw (30%)–Apple pomace (30%)–Rice bran (30%)–Concentrates (10%).

D: Apple pomace (60%)–Rice bran (30%)–Concentrates (10%).

3 h after feeding (Figure 1c). Acetate/Propionate (A/P) ratios of rumen fluid were significantly ($p < 0.05$) lower in diets C and D containing apple pomace than those of other treatments (Figure 1d).

DISCUSSION

Crude protein contents in apple pomace in experiment I were 4.35% although, it was 6.25% in experiment II, which indicates a possible yearly variation of chemical composition in apple pomace. However, NSC content of apple pomace was always high from 46.81 (experiment II) to 55.74% (experiment I). The results of *in situ* DM disappearance from nylon bags incubated in the rumen (experiment I) indicated a large increase in the amounts of DM and CP from apple pomace released at the later stages of incubation (Table 2) and ultimately higher overall levels of DM and CP degradation in the rumen from apple pomace. Disappearance after 48 h for DM and CP of apple pomace respectively were greater than those from concentrates. *In vivo* digestibility trials in experiments II and III with goats given apple pomace either separately (experiment II) or by pre-mixing (experiment III) with rice straw, rice bran (in experiment III only) and concentrates have also shown apple pomace was palatable and well digested through the total digestive tract of goats.

In experiment II, separate feeding of apple pomace (RS+AP+CD) to the goats given rice straw based diets has shown similar digestibilities of DM, OM, CP, ADF, NDF, crude ash, ether extracts, and NSC compared to those in goats fed alfalfa hay only. Furthermore, if the addition of apple pomace to the rice straw based diets (RS+AP, RS+AP+CD) is compared just to RS+CD, digestibilities became significantly higher in apple pomace added treatments. DM digestibilities of goats given the diets containing apple pomace in this study (RS+AP 62 %, RS+AP+CD 67 % in experiment II and C 62%, D 71% in

experiment III) were close to the DM digestibility of goats fed alfalfa hay (66 %) reported by Antoniou and Hadjipanayiotou (1985). Alibes et al. (1984) reported high OM digestibility (78 %) when apple pomace silage was fed to goats, and it was very similar to OM digestibility in D containing 60 % apple pomace in this study of experiment III. Digestibilities of CP and fiber fractions in experiment II and III also showed the same trend for DM and OM (Tables 3 and 4), presumably in association with higher contents of NSC in apple pomace and its influence on increased efficiency of fermentation in the rumen (Beever et al., 1990).

In experiment II, the NSC digestibility values from goats receiving apple pomace (RS+AP 44.2%; RS+AP+CD 52.0%) were lower than in the goats fed alfalfa hay only (66.7%). However in experiment III the goats receiving 30 and 60% apple pomace mixed diets demonstrated higher NSC digestibilities, comparable to those goats fed alfalfa hay only in experiment II. Replacement of rice straw and concentrates with 30 or 60% of apple pomace and rice bran, as a mixed diet in experiment III, did indeed increase the NSC contents and it nevertheless still maintained the protein level in the diet as 9.0–9.5 percent similarly to the other treatments.

Daily intakes of digestible crude protein (DCP) were 27, 40, 40 g in B, C and D respectively in experiment III and those were enough to meet the maintenance level (26 g/d) recommended by NRC (1989). DM intakes per metabolic weight were particularly lower in B (35.1 g) than 48.4, 49.7, 45.4 of A, C and D respectively and it indicates that replacement of concentrates with rice bran only on rice straw based diet was not enough to recover the intakes of the animals, but was enough with the addition of apple pomace on rice straw or rice bran (C and D). However, liveweight change of the animals between treatments throughout the experimental period was not statistically different partly due to variations to which extent animals

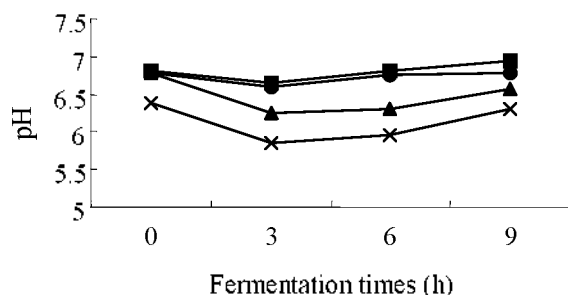


Figure 1a. Change of ruminal pH in Korean Native Goats fed four experimental diets (Experiment III).

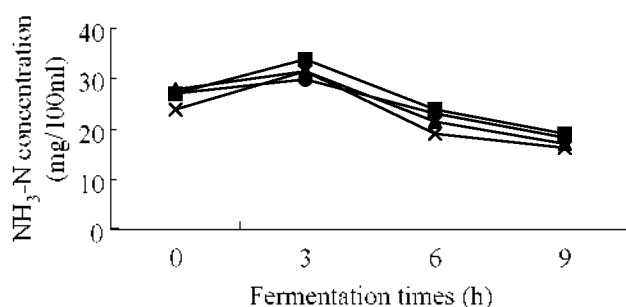


Figure 1b. Change of ruminal NH₃-N concentration in Korean Native Goats fed four experimental diets (Experiment III).

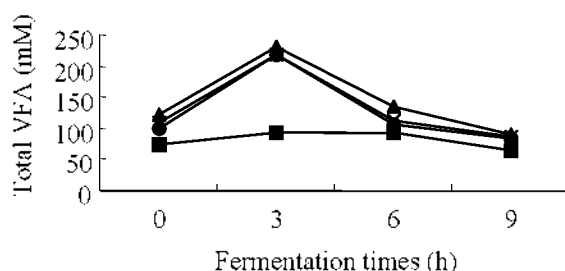


Figure 1c. Change of total volatile fatty acid (VFA, mM) concentration in Korean Native Goats fed four experimental diets (Experiment III).

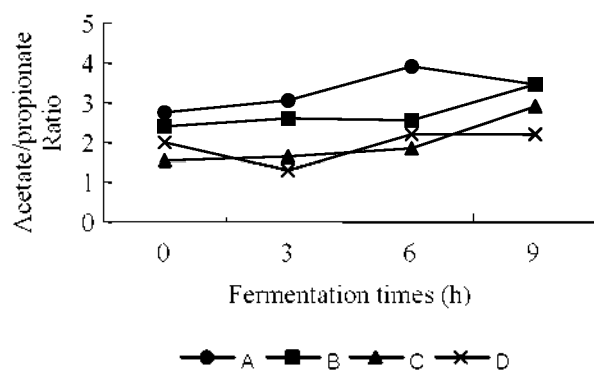


Figure 1d. Change of acetate to propionate ratio in Korean Native Goats fed four experimental diets (Experiment III).

A: Rice straw (60%)+Concentrates (40%), B: Rice straw (60%)+Rice bran (30%)+Concentrates (10%), C: Rice straw (30%)+Apple pomace (30%)+Rice bran (30%)+Concentrates (10%), D: Apple pomace (60%)+Rice bran (30%)+Concentrates (10%)

were accustomed to the cannula fitted to the rumen. Nitrogen retention of apple pomace in experiment III was higher than other diets due to lower loss of urinary nitrogen (Table 4). Ruminal NH₃-N may have been used more efficiently for the production of microbial protein due to greater energy intake which would provide for greater energy fermented in the rumen of goats given apple pomace. Acetate to propionate ratio was reduced in diets with the higher levels of apple pomace, likely a consequence of the higher NSC of these diets (Schauff and Clark, 1992). Although acetate concentration in the rumen of goats fed D diet (60% apple pomace) was in a decreasing trend compared to the others and may have influenced the lower ruminal pH (6.1) in D, this was still within a range which would maintain normal rumen function.

We concluded that replacement of concentrates with apple pomace in the rice straw based diets of Korean native goats given separately or by pre-mixing gave satisfactory results of feed intake, digestibility, pH of ruminal fluid and production of NH₃-N and VFA in the rumen. Despite low protein content in apple pomace in experiment II, similar DM digestibilities and even higher digestibilities for fiber fractions of NDF and ADF were shown compared to those in goats fed alfalfa hay only. It may be probable that the protein requirements for goats could be different according to the types of diets. Fu et al. (2001) reported that rumen degradable protein (RDP) was less required for NSC-fermenting bacteria than that found in many usual diets. This may indicate the rumen microbial population in the goats fed apple pomace was more efficient at scavenging nitrogen from the feed than other diets.

The maximum content of apple pomace investigated in this study was 60% in the diets for goats and it still showed high digestibilities of nutrients in experiment II and III, and also high nitrogen retention in experiment III. One of the main reasons for good performance of animals given apple pomace was due most probably to its high NSC content of slowly degradable fraction (experiment I) and its influence on the stable fermentation of microbes in the rumen (experiment III). Combination of apple pomace with low quality roughage of rice straw as a diet for Korean native goats were comparable to the goats fed alfalfa hay only in respect of digestibility in this study. However, care should be taken when apple pomace is intensively fed to animals. Fontenot et al. (1977) reported that the mortality of calves and abortion rate of cows may increase if apple pomace is over fed. If too much apple pomace is fed, it may be required to supply more protein, particularly for the growing animals.

IMPLICATIONS

The effect of combining apple pomace with

concentrates and rice straw in the diets of Korean native goats (*Capra hircus*) was investigated. Apple pomace was able to provide the rumen with abundant energy with the evidence that disappearances of DM and CP from *in situ* incubation of apple pomace contained in nylon bags in the rumen of goats were greater than those from concentrates at the later stages of incubation after 48 h for DM and CP, respectively. In experiment II and III where apple pomace was fed separately or by pre-mixing (30-60% apple pomace) to Korean native goats, it gave satisfactory feed intake, digestibility, pH of ruminal fluid and production of $\text{NH}_3\text{-N}$ and VFA in the rumen of goats. Apple pomace is considered a good source of feedstuffs that can be included in TMR (Total Mixed Ration) or as a supplement when feeding low quality roughage for goats. The primary effects of supplementing apple pomace into rice straw based diet of goats in this study could have been attributed to its higher content of non-structural carbohydrates (NSC). Regarding the type of apple pomace before used, a dried form or silage is preferred in order to reduce the probability of deterioration.

REFERENCES

- Ahn, J. H., B. M. Robertson, R. Elliott, R. C. Gutteridge and C. W. Ford. 1989. Quality assessment of tropical browse legumes: tannin content and protein degradation. *Animal Feed Science and Technology*. 27:147-156.
- Alibes, X., F. Munoz and J. Rodriguez, 1984. Feeding value of apple pomace silage for sheep. *Anim. Feed Sci. Technol.*, 11:189-197.
- AOAC. 1990. Official Methods of Analysis (15th Ed.). Association of Official Analytical Chemists, Washington, DC.
- Antoniou, T., and M. Hadjipanayiotou. 1985. The digestibility by sheep and goats of five roughages offered alone or with concentrates. *J. Agric. Sci., Camb.* 105:663-671.
- Beever, D. E., M. Gill, J. M. Dawson and P. J. Buttery. 1990. The effect of fish meal on the digestion of grass silage by growing cattle. *Brit. J. Nutr.* 63:489-502.
- Bae, D. H., C. N. Shin and K. H. Ko. 1994. Effect of total mixed ration including apple pomace for lactating cows. *Korean J. Dairy Sci.* 16(4):295-302.
- Erwin, E. S., C. J. Macro and E. W. Emergy. 1961. Volatile fatty acid analysis of blood and rumen fluid by gas chromatography. *J. Anim. Sci.* 44:1768.
- Fontenot, J. P., K. P. Bovard, R. R. Oltjen, T. S. Rumsey and B. M. Priode. 1977. Supplementation of apple pomace with non-protein nitrogen for gestating beef cows. I. Feed intake and performance. *J. Anim. Sci.* 45:513-522.
- Fu, C. J., E. E. D. Felton, J. W. Lehmkuhler and M. S. Kerley. 2001. Ruminal peptide concentration required to optimize microbial growth and efficiency. *J. Anim. Sci.* 79:1305-1312.
- Goering, H. K. and P. J. van Soest. 1970. Forage fiber analysis. USDA Agric. Handbook No. 379, Washington, DC.
- Jackson, M. G. 1977. Rice straw as livestock feed. *World Anim. Rev.* 23:25.
- NRC. 1989. Nutrient Requirements of Dairy Cattle. 6th rev. ed. Natl. Acad. Sci. Washington DC.
- Okuda, H. and S. Fujii. 1966. Determination of blood ammonia by the spectrophotometric method. *Saishin Igaku.*, 21:622-627.
- Orskov, E. R., and I. McDonald. 1979. The estimation of protein degradability in the rumen. *J. Agric. Sci. Cambridge*. 96:251-252.
- SAS. 1998. SAS User's Guide Statistics, SAS Inst. Inc., Cary, NC.
- Seth, D. N., G. S. Rai, P. C. Yadav and M. D. Pandey. 1976. A note on the rates of secretion and chemical composition of parotid saliva in sheep and goat. *Indian J. of Anim. Sci.* 46:660-663.
- Schauff, D. J. and J. H. Clark. 1992. Effects of feeding diets containing calcium salts of long-chain fatty acids to lactating dairy cow. *J. Dairy Sci.* 75:2990.