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Effects of Dietary Vegetable Oils on Intake, Digestibility and Methane Emission from Black Goats

[1]W.Y. Jeong, [1]O.H. Yi, [1]H.J. Choi, [2]K.T. Nam, [1]B.G. Kim and [1]S.R. Lee
[1]Department of Animal Science and Technology, Konkuk University, 143-701 Seoul, Republic of Korea
[2]Department of Animal Life and Environmental Science, Hankyong National University, 456-749 Gyeonggi-do, Republic of Korea

Abstract: This study was carried out to investigate the effects of dietary vegetable oils on the nutrient digestibility and methane production of black goats. Four castrated hybrid black goats (mean body weight: 44.07±0.16 kg) were fed four experimental diets each in a 4×4 Latin square design. A control diet consisting of tall fescue hay (56%) and a mixture (44%) of corn and soybean meal was prepared and added with 3% each of soybean, coconut and palm oil, respectively for 3 treatment diets. Each experimental period consisted of a 10 days adaptation period and 4 days for the measurement of apparent digestibility of Dry Matter (DM) and of methane and carbon dioxide emissions using an open-circuit chamber system. Supplemental vegetable oil did not affect DM intake and digestibility of DM, Organic Matter (OM), crude protein and Neutral Detergent Fiber (NDF) but the addition of the oils significantly decreased daily methane production and metabolic weight-based methane production ($p<0.05$). Methane production per kg intake of DM, OM and NDF was reduced by dietary coconut oil or palm oil ($p<0.05$). Supplemental palm oil decreased methane production per digested DM intake or digested OM intake ($p<0.05$). In conclusion, supplementing diets with 3% of palm oil most effectively reduced methane gas generation without affecting digestibility.

Key words: Vegetable oils, feed intake, digestibility, methane production, ruminants

INTRODUCTION

Methane gas has been known to have a 23 times greater impact on global warming than carbon dioxide. Many studies have attempted to reduce methane gas generated during the intestinal fermentation process of ruminants. Vegetable oils are widely used to raise the energy values of livestock feeds (Schauff *et al*., 1992). Also medium-chain fatty acids and long-chain fatty acids rich in vegetable oils are known to inhibit methane emissions by restraining the activities of methane gas-producing microorganism in the rumen (Machmuller and Kreuzer, 1999; Hristov *et al*., 2009; Hook *et al*., 2010). Reduced methane emission from ruminants have been observed by dietary supplementation of coconut oil (Machmuller and Kreuzer, 1999), soybean oil (Jordan *et al*., 2006a) and linseed oil (Martin *et al*., 2008).

However, supplementation of some vegetable oils to ruminant feeds was also found to reduce Dry Matter Intake (DMI) and Dry Matter (DM) digestibility (Manso *et al*., 2006; Bhatt *et al*., 2011). An *in vitro* experiment of adding fatty acids revealed that each fatty acid affected a DM digestibility reduction of 1.9-9.3% units (Davison and Woods, 1960). And feeding beef heifers diets supplemented with 3% coconut oil resulted in a decline of DMI by 17% units (Jordan *et al*., 2006b). The reduced feed intake and digestibility can decrease productivity in livestock and thus economic profit. Therefore, this study was conducted to investigate effects of various vegetable oil sources on feed intake, nutrient digestibility and methane production in black goat.

MATERIALS AND METHODS

Experimental animals and management: Four castrated hybrid black goats (mean body weight = 44.78±0.15 kg) were used in this study. Each goat was adapted in a respiration-metabolism chamber (0.53×1.47×1.37 m) installed in a metabolism laboratory, equipped with temperate control (23.34±0.22°C) and humidity

Corresponding Author: S.R. Lee, College of Animal Bioscience and Technology, Konkuk University, 143-701 Seoul, Republic of Korea

(62.75±1.67%) for 3 months. The animals were fed once daily at 11:00 and allowed free access to fresh water and mineral salts *ad libitum*.

Experimental design and sampling: An experiment was conducted with 4 treatment groups:

- Control (no vegetable oils)
- Soybean oil (3%)
- Coconut oil (3%)
- Palm oil (3%)

The control diet was consisted of 43.6% concentrate (corn and soybean meal) and 56.4% forage (tall fescue hay: 2-5 cm length). Vegetable oil diets were consisted each 56:41:3 forage:concentrate:vegetable oil (Table 1). And goats were fed four experimental diets each in a 4×4 Latin square design (Kim and Kim, 2010). Each experimental period consisted of a 10 days adaptation period and 4 days for the measurement of apparent digestibility of DM and of methane and carbon dioxide emissions using an open-circuit chamber system. Fecal sample were collected every day using a total collection method and stored in a freezer at -20°C prior to analysis.

Measurement of methane gas and carbon dioxide production: Production of methane and carbon dioxide were measured using respiration metabolism chamber system which was established by Li *et al.* (2010). Before the experiment, a recovery test was performed using standard methane gas. Values for recovery rate of methane ranged from 96.2-97.3%. Production of methane and carbon dioxide were calculated based on the analysis of air flowing into the respiration-metabolism chamber and that of the exhausted air (Klein and Wright, 2006). Air flow rate was measured using a mass flow meter (GFM57, Aalborg Instruments and Controls Inc., Orangeburg, NY, USA) and concentrations of methane and carbon dioxide in the exhausted air were measured using a non-dispersive infrared gas analyzer (VA-3000, Horiba Stec Co., Kyoto, Japan).

Table 1: Ingredients and chemical composition of experimental diets, dry matter basis

Items	Control	Soybean oil	Coconut oil	Palm oil
Ingredient (%)				
Corn	33.1	31.0	31.0	31.0
Soybean meal	10.5	10.0	10.0	10.0
Tall fescue	56.4	56.0	56.0	56.0
Soybean oil	-	3.0	-	-
Coconut oil	-	-	3.0	-
Palm oil	-	-	-	3.0
Chemical composition (%)				
DM	89.4	89.8	89.8	89.8
OM	95.9	96.0	96.0	96.0
CP	11.5	11.1	11.1	11.1
NDF	46.1	45.4	45.4	45.4

DM: Dry Matter, OM: Organic Matter, CP: Crude Protein, NDF: Neutral Detergent Fiber

Analysis: Samples of each experimental feed and collected fecal sample were ground in 1 mm using micro fine mill (ABTF-3002, Culatti AG, Zurich, Swiss). And chemical components were analyzed according to the method suggested by AOAC (1995) while the content of Neutral Detergent Fiber (NDF) was analyzed in accordance with the method suggested by Van Soest *et al.* (1991).

Statistical analysis: All data from the experiment were analyzed using MIXED procedure of SAS (SAS 9.2 Inst., Inc., Cary, NC). The model's independent variables included dietary treatment as fixed effect while animal and period as random effect. Dependent variables included feed intake, digestibility and methane gas production. The significant levels were declared at $p<0.05$.

RESULTS AND DISCUSSION

The fact that vegetable oils have significant effects on the reduction of DMI and digestibility of ruminants has been verified through numerous studies (Sutton *et al*., 1983; Jordan *et al*., 2006b). Vegetable oils reduced the number of protozoa and methanogenic bacteria within rumen. This reduction in microorganism lowered degradation rate of fibers and digestibility (Dohme *et al*., 1999). Decrease in digestive speed of feed has been known reducing to increase in the volume of rumen and feed intake (Allen, 2000).

But according to this study, feeding black goats diets supplemented with 3% of vegetable oils did not affect DMI or digestibility of black goats (Table 2). Ueda *et al.*

Table 2: Effects of dietary vegetable oils on feed intake, digestibility and CH_4 production in black goats[1]

Items	Control	Soybean oil	Coconut oil	Palm oil	SEM	p-value
BW (kg)	43.97	44.49	44.67	43.16	1.44	0.280
DMI (g/day)	646.82	599.14	576.28	638.68	62.21	0.900
Fecal output (g/day)	180.56	173.70	185.33	191.90	14.31	0.809
Digestibility (%)						
DM	72.08	71.09	66.40	69.03	3.43	0.607
OM	73.53	72.68	68.08	70.56	3.34	0.614
CP	73.63	69.47	71.78	70.58	2.16	0.563
NDF	56.47	54.32	45.23	49.75	6.09	0.523
CH_4 production						
CH_4 (l/h/day)	26.77^a	20.70^b	17.99^b	19.14^b	3.22	0.005
CH_4 (l/kg/day $BW^{0.75}$)	1.58^a	1.20^b	1.05^b	1.14^b	0.20	0.004
CH_4 (l/kg/day DMI)	41.24^a	35.35^{ab}	31.21^b	29.99^b	4.98	0.007
CH_4 (l/kg/day OMI)	48.11^a	41.02^{ab}	36.22^b	34.81^b	5.79	0.006
CH_4 (l/kg/day NDFI)	89.56^a	77.79^{ab}	68.68^b	66.00^b	10.95	0.010
CH_4 (l/kg/day DDMI)	56.97^a	49.45^{ab}	47.56^{ab}	43.99^b	6.88	0.036
CH_4 (l/kg/day DOMI)	68.07^a	58.62^{ab}	57.02^{ab}	52.58^b	8.17	0.045

[a, b]Within a row, means without a common superscript differ ($p<0.05$); [1]SEM: Standard Error of the Means, BW: Body Weight; DMI: Dry Matter Intake; DM: Dry Matter; OM: Organic Matter; CP: Crude Protein; NDF: Neutral Detergent Fiber; OMI: Organic Matter Intake; NDFI: Neutral Detergent Fiber Intake; DDMI: Digested Dry Matter Intake; DOMI: Digested Organic Matter Intake

(2003) found that feeding lactating cow diets supplemented with 3% of flax seed oil did not influence on digestion within rumen. These results indicate that a low level of oil addition to does not affect to the feed intake and digestibility.

Daily and metabolic weight-based methane production was significantly reduced in all oil treatment groups (17.99-20.69 l/h/day and 1.05-1.20 l/kg/day $BW^{0.75}$) than in that of the control group (26.77 l/h/day and 1.58 l/kg/day $BW^{0.75}$) ($p<0.01$). This was consistent with the results of earlier *in vitro* and *in vivo* studies (MachMueller *et al*., 1998; Hristov *et al*., 2009). Methane production was also decreased in all oil treatment groups. This is expected to be attributable to the impacts of vegetable oils on methanogens within the rumen. According to the *in vitro* study of Machmuller and Kreuzer (1999) that used sheep, coconut oil lowered the metabolic rate of methanogens. In the study here found that DM, OM and NDF intake-based methane production was diminished in the treatment groups which fed coconut oil and palm oil-supplemented diets ($p<0.01$). On the other hand, the studies of Jordan *et al*. (2006b) and Hook *et al*. (2010) reported that coconut oil and palm kernel oil were effective in reducing methane generation. This reduction is expected to be attributable to the impacts of coconut oil and palm oil on the number of ciliate, protozoa and methanogenic bacteria within the rumen.

Methane production from digestion in ruminants created with hydrogen, carbon dioxide and acetate which is derived in the digestive process of microorganism inside the rumen. Therefore, evaluation of the effect of methane emissions should be based on digestion rather than feed intake. DM digestibility and OM digestibility-based methane production was significantly reduced in the treatment group fed diets supplemented with palm oil compared to the control ($p<0.05$). Palm oil affected to reduce methane emissions. It seems that oleic acid had influence on rumen microbes. Three vegetable oils (soybean oil, coconut oil and palm oil) which used in this study, contain medium and long-chain fatty acids such as 49.70% of linoleic acid, 47.15% of lauric acid and 43.30% of oleic acid, respectively. Lauric acid, oleic acid and linoleic acid are known as effective materials to decreasing methane production in the ruminants (Czerkawski *et al*., 1966; Machmuller, 2006). The *in vitro* study of Davison and Woods (1960) found that oleic acid was more effective in digestibility than lauric acid. This result suggests that oleic acid affects more on microbial flora rumen than lauric acid. However, this study did not investigate the change in microorganism composition of rumen by supplementation of diets or the effect of each fatty acid on reducing methane generation.

CONCLUSION

Dietary supplementation of vegetable oils (3%) to black goats' feed is an effective way to lower methane emissions without affecting DMI or digestibility on black goats. Especially, palm oil decreased the amount of digestion-based methane emissions. Therefore, more research is needed on the specific impacts of each fatty acid on the relevant microorganisms within the rumen.

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