Journal of Animal and Veterinary Advances 12 (10): 996-999, 2013
ISSN: 1680-5593

Supplementation of Chicory and Jerusalem Artichoke in Sheep Diets on Ruminal Fermentation and Nitrogen Retention

S. Traiyakun and P. Paengkoum
School of Animal Production Technology, Institute of Agricultural Technology,
Suranaree University of Technology, Muang, 30000 Nakhon Ratchasima, Thailand

Abstract: The objective of this study was to evaluate the effects of chicory (*Cichorium intybus*) and Jerusalem artichoke (*Helianthus tuberosus* L.) on feed intake, digestibility, nitrogen retention and rumen fermentation of sheep fed with pangola (*Digitaria eriantha*) hay and pelleted concentrate. Four growing sheep between 2-3 years of age and pre-trial average body weight of 32.4±5.5 kg in a 4×4 Latin square design. The four concentrate treatments were control (T1), control plus 2% Chicory in concentrate (T2), control plus 2% Jerusalem artichoke (T3) and 4% Jerusalem artichoke (T4) in concentrate. The results showed that the addition of chicory and Jerusalem artichoke powder. There were no significant effects on the addition of chicory and Jerusalem artichoke powder of on feed intake and dry matter and organic matter and digestibility. Acid detergent fiber digestibility of sheep fed with chicory or Jerusalem artichoke was decreased ($p<0.05$) compared with the control diet. However, crude protein digestibility of sheep fed with chicory and Jerusalem artichoke were significantly higher ($p<0.05$) than that sheep fed with the control diet. Nitrogen (N) intake, urinary N, N absorption and N retention were not significantly different statistically ($p>0.05$) among treatments. The average ruminal pH values were ranged between 6.88-7.56 and were neither affected by sources of inulin are chicory and Jerusalem artichoke. Ruminal NH_3-N, Blood Urea Nitrogen (BUN ruminal bacteria and population of all dietary treatments were not significantly different statistically ($p>0.05$). Nitrogen retention of sheep fed with chicory and Jerusalem artichoke were significantly higher ($p<0.05$) than that sheep fed with the control diet. These results indicated that inulin from chicory and Jerusalem artichoke has the potential to improve nitrogen utilization.

Key words: Chicory, Jerusalem artichoke, fermentation, rumen, sheep

INTRODUCTION

Inulin is a non-starch polysaccharide naturally occurring as a storage carbohydrate in some 36,000 plant species. Inulin and oligo-fructose are present naturally in several fruits and vegetables, like Jerusalem artichoke, chicory, onion, garlic, banana and others.

Jerusalem artichoke (*Helianthus tuberosus* L.) is familiar to many people as a weed but it has some potential as a crop plant. Native to the central regions of North America, the plant can be grown successfully throughout the US under a variety of temperature and rainfall regimes. Jerusalem artichoke can be adapted to growing condition in Thailand and tend to increase planting both for human diet and also by-products or co-products for animals. Jerusalem artichoke contains 15-20% of inulin and Fructo-Oligosaccharide (FOS) and it is considered to be prebiotics which have been proposed to improve health by stimulation of beneficial bacteria in the intestine of humans and animals. Inulin is carbohydrate in the form of fructan. It is fiber source which is not digested in digestive system in (stomach and intestine) single stomach animal or human.

Therefore, inulin will fall into colon and it has benefit for body growth. It increases the number of beneficial microorganisms to health such as Lactobacillus and Bifidobacteria (Kaur and Gupta, 2002). Inulin is considered an archetypal prebiotic and it naturally occurs in many food plants. Inulin is industrially obtained from chicory roots by hot water extraction, followed by refining and spray drying and the degree of polymerization of inulin typically ranges from 3-60. It consists of chains of fructose units coupled by β (2, 1) bonds most often (though not always) terminated by a single glucose moiety (Havenaar *et al*., 1999).

Prebiotics are used successfully in monogastric animals but not in ruminants. The process of fermentation that occurs in the colon of monogastric animal is

Corresponding Author: S. Traiyakun, School of Animal Production Technology, Institute of Agricultural Technology, Suranaree University of Technology, Muang, 30000 Nakhon Ratchasima, Thailand

essentially identical to that occurs in the fore-stomachs of ruminants. Inspection of the available literature shows that information on the degradation and fermentation of inulin in the rumen is limited. However, current opinion contends that inulin can be metabolized in the rumen ecosystem (Chesson and Forsberg, 1988). Addition of inulin to ruminant diets might be beneficial for ruminal fermentation and bacteria in rumen. The objective of the present study was to investigate the effects of chicory and Jerusalem artichoke on ruminal fermentation, feed intakes, nutrient digestibility and N balance in sheep fed with pangola hay as roughage.

MATERIALS AND METHODS

Animals and management: Four growing crossbred Thai long tail sheep between 2-3 years of age and pre-trial average body weight of 32.4±5.5 kg. The sheep were housed in individual pens and allowed 3 weeks to adapt to the experimental conditions. Sheep were fed a basal diet containing pangola (*Digitaria eriantha*) hay and pelleted concentrate supplemented with minerals and vitamins. The diet formulated to meet nutrient requirements for maintenance and 1.5% daily weight gains was offered twice daily at 07.00 and 17.00 h. Animals had free access to water and kept in individual pens. The chemical composition of the experimental diet is presented in Table 1. The four concentrate treatments were control (T1), control plus 2% Chicory in concentrate (T2), control plus 2% Jerusalem artichoke (T3) and 4% Jerusalem artichoke (T4) in concentrate.

Experimental procedure: To examine the role of chicory and Jerusalem artichoke powder on ruminal fermentation. The experiment consisted of 3 weeks of adaptation, following by four experimental periods. The duration of each period was 32 days, i.e., 3 weeks of adjustment followed by 11 days of measurements. The later consisted of 2 days of adaptation to the metabolic crates, 7 days of digestibility and N balance studies, 2 days of rumen fluid and blood sampling. Samples of feed refusals, feces and urine were collected before feeding in the morning to determine feed intake, digestibility and N balance.

Table 1: Chemical composition of experimental diets

Experimental diet	Concentrate	Chicory	Jerusalem artichoke	Roughage (Pangola grass hay)
DM	95.67	97.03	93.44	95.90
	---------- DM % ----------			
CP	15.63	0.40	5.78	6.91
Ash	9.09	0.00	8.08	7.88
OM	90.91	0.00	91.92	92.12
EE	2.03	2.20	0.17	0.03
ADF	25.20	2.02	9.67	47.07

DM = Dry Matter, CP = Crude Protein, OM = Organic Matter , EE = Ether Extract, ADF = Acid Detergent Fiber

Sampling methods: Diets were weekly sampled and feces samples were quantitatively collected based on total collection method were made in the last 7 days of each period. Concentrate, roughage and feces were analyzed of chemical composition in terms of DM, Ash, EE and CP (AOAC, 1990), ADF (Goering and Van Soet, 1970). Daily feces of each sheep were weighed and a 10% sub-sample collected and stored at -20°C. The sub-samples at the end of each period were bulked, dried (60°C) and ground through a 1 mm sieve and stored until analysis. Daily urine output was collected into a plastic container (containing 25 mL of 10% H_2SO_4). Approximately 10% of the volume was sampled and stored at -20°C pending energy and N analysis.

Rumen fluid samples from all sheep were collected by using a stomach tube at 0, 2 and 4 h post-feeding during the digestibility trial. It was strained through 4 layers of cheese cloth and pH measured immediately using a pH meter (Mettler Toledo MP 125) fitted with a combined electrode.

The rumen fluid was then acidified with H_2SO_4 (50%, v/v) and stored at -20°C for analyses of NH_3-N measurement (Bremner and Keeney, 1965) and Volatile Fatty Acids (VFAs) analysis. The rumen fluid was collected into 10% formaldehyde (1 mL rumen fluid to 9 mL of 10% formaldehyde) for total count bacteria and protozoa.

Blood samples were taken from the jugular vein at 0, 2 and 4 h post-feeding and after sampling of rumen fluid. The blood samples were centrifuged (3,500 g for 15 min) and the serum stored at -20°C for Blood Urea Nitrogen (BUN) analysis.

Chemical analysis and calculations: Feed samples were collected twice a week. Representative samples of feed and feces collected during the digestibility trial were analyzed according to AOAC (1990) for DM, ash and CP and for fiber components according to Van Soest *et al.* (1991).

Apparent digestibility was calculated using equations of Schneider and Flatt. Total direct count of bacteria and protozoa were determined by microscopic direct count (Galyean, 1989). Serum urea was determined by using a urea test kit (Sigma Diagnostics INFINITY™ BUN Reagent).

Statistical analysis: Data were analyzed as a 4×4 Latin square design using the General Linear Model (GLM) procedure of the Statistical Analysis System Institute. Duncan's new multiple range test was used to compare treatment means. Unless otherwise noted, significance was declared at $p<0.05$.

RESULTS AND DISCUSSION

The effects of supplementation of chicory and Jerusalem artichoke powder in sheep diets on feed intake are showed in Table 2. The feed intake parameters of sheep were not significantly different statistically ($p>0.05$) among treatments. Table 3 shows the amount of nutrient digestibility in sheep fed with the four experimental treatments. The digestibility of DM, OM and EE were not statistically differ ($p>0.05$) among treatments. Acid detergent fiber digestibility of sheep fed with 2% chicory and 4% Jerusalem artichoke were lower significant ($p>0.05$) than those of sheep fed the control diet and 2% Jerusalem artichoke. It possible that inulin is resistant to enzymatic hydrolysis, especially cellulose and hemicellulase enzymes. Moreover, inulin from chicory and Jerusalem artichoke has the potential to improve nitrogen utilization. The finding from this study agreed with Ozturk (2008). The nitrogen intake of sheep fed with chicory and Jerusalem artichoke were not significantly different statistically ($p>0.05$) among treatments. While feces N and total N output of sheep fed the control was higher ($p<0.05$) than sheep in those sheep fed with chicory and Jerusalem artichoke. Moreover, sheep fed with all chicory and Jerusalem artichoke was significantly higher ($p<0.05$) than that sheep fed with the control diet. The finding from this study also agreed with Ozturk (2008), it indicated that chicory and Jerusalem artichoke has the potential to improve nitrogen utilization (Table 4).

Results in Table 5 shows ruminal pH of rumen fluid in sheep. The average pH values ranged between 6.88-7.56 and were neither affected by sources of inulin are chicory and Jerusalem artichoke. Before feeding, 2 and 4 h after feeding were not significant difference ($p>0.05$) among treatments. The pH value was higher than that reported by Ozturk (2009, 2008) and Umucalilar *et al.* (2010) which were study effect of inilin on ruminal fermentation *in vitro*. However, pH was considered to be high than in the normal level which it ranges between 6.2-7.0 (Ozturk, 2008).

On the other hand, the addition of chicory and Jerusalem artichoke resulted was not-significant in ammonia nitrogen (NH_3-N) concentrations at the 4 h. Ozturk (2008) reported that NH_3-N was range between 5.89-6.36 mmol day^{-1} and similar with Ozturk (2009) reported that the NH_3-N in the rumen in sheep is between 5.26-6.37 mmol day^{-1}. Umucalilar *et al.* (2010) reported that appropriate concentrations of NH_3-N in the rumen should be ranged between 10.51-15.93 mmol day^{-1} on ruminal fermentation *in vitro*. Blood urea nitrogen (Table 6) and

Table 2: Feed intake of sheep fed with chicory and Jerusalem artichoke

	Treatments					
Items	T1	T2	T3	T4	SEM	p-value
Roughage						
gDM day^{-1}	482.11	515.07	495.02	493.50	11.09	0.77
BW (%)	1.38	1.61	1.43	1.53	0.06	0.60
g/kg BW$^{0.75}$ (%)	33.64	38.28	34.80	36.49	1.23	0.60
Concentrate						
gDM day^{-1}	446.26	441.06	449.74	449.74	3.91	0.84
BW (%)	1.29	1.36	1.29	1.40	0.04	0.76
g/kg BW$^{0.75}$ (%)	31.35	32.60	31.45	33.36	0.79	0.77
Total intake						
gDM day^{-1}	928.38	956.12	944.76	943.24	11.42	0.86
BW (%)	2.68	2.97	2.73	2.93	0.10	0.66
g/kg BW$^{0.75}$ (%)	64.99	70.88	66.25	69.86	1.85	0.65

T1 = Control, T2 = 2% Chicory of concentrate, T3 = 2% Jerusalem artichoke of concentrate, T4 = 4% Jerusalem artichoke of concentrate

Table 3: Nutrient digestion of sheep fed with chicory and Jerusalem artichoke

	Treatments					
Items	T1	T2	T3	T4	SEM	p-value
Digestion (Intake %)						
DM	41.98	37.52	45.41	39.02	1.37	0.27
OM	47.76	44.72	50.09	46.51	1.41	0.61
CP	53.39^{b}	59.50^{a}	59.02^{a}	59.68^{a}	1.85	0.04
EE	93.44	97.92	91.60	94.80	1.20	0.37
ADF	30.29^{ab}	18.55^{b}	35.38^{a}	20.25^{b}	1.79	0.06

^{a,b}Means within a row with different superscripts differ ($p<0.05$), DM = Dry Matter, OM = Organic Matter, CP = Crude Protein, EE = Ether Extract, ADF = Acid Detergent Fiber, T1 = Control, T2 = 2% Chicory of concentrate, T3 = 2% Jerusalem artichoke of concentrate, T4 = 4% Jerusalem artichoke of concentrate

Table 4: Nitrogen balance of sheep fed with chicory and Jerusalem artichoke

	Treatments					
Nitrogen	T1	T2	T3	T4	SEM	p-value
N intake (g day^{-1})	17.38	17.63	17.62	17.61	0.16	0.92
Feces N (g day^{-1})	8.10^{a}	7.14^{b}	7.22^{b}	7.10^{b}	0.27	0.05
Urine N (g day^{-1})	1.00	0.69	0.60	1.07	0.29	0.87
N output (g day^{-1})	9.10^{a}	7.83^{b}	8.32^{b}	8.17^{b}	0.33	0.66
N absorption (g day^{-1})	9.28^{b}	10.49^{a}	10.40^{a}	10.51^{a}	0.15	0.49
N absorption (%)	53.39^{b}	59.50^{a}	59.02^{a}	59.68^{a}	1.85	0.04
N retention (g day^{-1})	8.26^{b}	9.80^{a}	9.80^{a}	9.44^{a}	0.29	0.05
N retention (%)	47.64^{b}	55.59^{a}	55.68^{a}	53.60^{a}	1.79	0.04

^{a,b}Means within a row with different superscripts differ ($p<0.05$). T1 = Control, T2 = 2% Chicory of concentrate, T3 = 2% Jerusalem artichoke of concentrate, T4 = 4% Jerusalem artichoke of concentrate

Table 5: Rumen fermentation of sheep fed with chicory and Jerusalem artichoke

	Treatments					
Ruminal parameters	T1	T2	T3	T4	SEM	p-value
pH						
0 h	7.54	7.29	7.38	7.56	0.05	0.33
2 h	7.10	7.07	7.05	7.02	0.05	0.95
4 h	6.94	7.10	7.14	6.88	0.05	0.22
NH_3-N (mg%)						
0 h	4.04	3.09	3.14	4.79	0.47	0.06
2 h	4.39	3.04	4.39	4.04	0.22	0.06
4 h	4.84	3.89	4.19	3.84	0.14	0.06

T1 = Control, T2 = 2% Chicory of concentrate, T3 = 2% Jerusalem artichoke of concentrate, T4 = 4% Jerusalem artichoke of concentrate

Table 6: Blood Urea Nitrogen (BUN) of sheep fed with chicory and Jerusalem artichoke

	Treatments					
Items	T1	T2	T3	T4	SEM	p-value
BUN (mg dL^{-1})						
0 h	18.60	18.60	18.15	19.37	0.39	0.84
2 h	18.83	19.81	18.60	19.66	0.33	0.52
4 h	18.60	19.66	18.22	19.89	0.33	0.31

Table 7: Rumen microbial population of sheep fed with chicory and Jerusalem artichoke

	Treatments					
Items	T1	T2	T3	T4	SEM	p-value
Bacteria (×10^{10} cell mL^{-1})						
0 h	7.39	7.54	7.50	7.42	0.04	0.59
4 h	7.90	7.82	7.83	7.87	0.05	0.87
Mean	7.87	7.90	7.93	7.86	0.05	0.93
Protozoa (×10^{6} cell mL^{-1})						
0 h	5.85	5.98	6.03	5.91	0.05	0.62
4 h	5.61	5.45	5.78	5.69	0.05	0.17
Mean	5.75	5.81	5.92	5.82	0.05	0.63

T1 = Control, T2 = 2% Chicory of concentrate, T3 = 2% Jerusalem artichoke of concentrate, T4 = 4% Jerusalem artichoke of concentrate

direct count bacteria and protozoa populations of to all treatments was not significantly different statistically ($p>0.05$) (Table 7).

CONCLUSION

The results from this study indicated that the supplementation of chicory and Jerusalem artichoke had no effected on ruminal bacteria/protizoa, ruminal pH value, ruminal NH_3-N and BUN concentrations. However, supplementation of chicory and Jerusalem artichoke has the potential to improve nitrogen utilization (N balance and CP digestibility). More studies might be needed to understand the effects of chicory and Jerusalem artichoke on rumen bacterial strains and performance of ruminants. In conclusion, supplementation of chicory and Jerusalem artichoke has a potential for industrial application as a feed additives to improve the digestion of plant materials and more clarify the potentially beneficial effect of inulin as prebiotic sources on rumen metabolism, immunology system and productive performances.

ACKNOWLEDGEMENTS

This research was supported by Suranaree University of Technology Animal Nutrition and Feed Technology Research and Development Group (SUT-RU) and the Higher Education Promotion and National Research University Project of Thailand (NRU), Office of the Higher Education Commission.

REFERENCES

AOAC, 1990. Official Methods of Analysis. 15th Edn., Association of Official Analytical Chemists, Washington, DC., USA.

Bremner, J.M. and D.R. Keeney, 1965. Steam distillation methods of determination of ammonium, nitrate and nitrite. Anal. Chem. Acta, 32: 485-495.

Chesson, A. and C.W. Forsberg, 1988. Polysaccharide Degradation by Rumen Microorganisms. In: The Rumen Microbial Ecosystem, Hebson, P.N. (Ed.). Elsevier Applied Science, London, UK., pp: 251-284.

Galyean, M., 1989. Laboratory Procedure in Animal Nutrition Research. Lab Safety from Science Related Materials Inc., USA., Pages: 189.

Goering, H.K. and P.J. Van Soet, 1970. Forage fiber analyses (apparatus, reagents, procedures and some applications). Agriculture Handbook No. 379, ARS-USDA, Washington, DC., USA., pp: 1-20. http://naldc.nal.usda.gov/download/CAT87209099/PDF.

Havenaar, R., S. Bonnin-Marol, W. Van Dokkum, S. Petite and G. Schaafsma, 1999. Inulin: Fermentation and microbial ecology in the intestinal tract. Food Rev. Int., 15: 109-120.

Kaur, N. and A.K. Gupta, 2002. Applications of inulin and oligofructose in health and nutrition. J. Biosci., 27: 703-714.

Ozturk, H., 2008. Effects of inulin on rumen metabolism *in vitro*. Ankara Univ. Vet. Fak. Derg., 55: 79-82.

Ozturk, H., 2009. Effects of chicory inulin on ruminal fermentation *in vitro*. Ankara Univ. Vet. Fak. Derg., 56: 171-175.

Umucalilar, H.D., N. Gulsen, A. Hayirli and M.S. Alatas, 2010. Potential role of inulin in rumen fermentation. Revue de Medecine Veterinaire, 161: 3-9.

Van Soest, P.J., J.B. Robertson and B.A. Lewis, 1991. Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583-3597.