



Fibrolytic Enzyme Supplementation on Growth Performance in Lambs

Sandeep et al.

Effect of Supplementation of Exogenous Fibrolytic Enzymes on Growth Performance of Lambs Fed Finger Millet Straw Based Diets

K.S. Sandeep^{1*}, B.C. Umashankar², T.M. Prabhu¹, K. Chandrapal Singh¹, N. Suma¹, Mahadevappa D, Gouri³ and Shankarappa Bhajantri⁴

¹Department of Animal Nutrition, Karnataka Veterinary Animal and Fishery Sciences University(KVAFSU), Hebbal, Bangalore ²Animal Husbandry Polytechnic, Konehalli, Tiptur

³Department of Livestock Production and Management, KVAFSU, Veterinary College Hebbal, Bangalore

⁴Department of Livestock Farm Complex, Veterinary College, KVAFSU, Hebbal, Bangalore

*Correspondence: sdvety91@gmail.com

ABSTRACT

This experiment was taken up to study the effect of supplementing fibrolytic enzymes on the growth performance of lambs fed finger millet straw based diets. In a growth trial of 8 weeks duration, three groups (T1, T2 and T3) of five male lambs each were fed diet comprising finger millet straw (40 per cent) and compounded feed mixture (60 per cent). Group T1 served as control with no enzyme supplementation, whereas groups T2 and T3 were supplemented with 1g and 2g of enzyme premix respectively per day. Digestion trial was conducted in the last week of growth trial. The supplementation of enzyme increased the digestibility (per cent) of neutral detergent fiber, acid detergent fiber and the digestible organic matter in dry matter content, of the diet with the digestibility of T3 group significantly higher than T1 or T2 groups ($P < 0.05$). There was no significant difference in the feed intake or average daily body weight gain of the lambs among the treatment groups, indicating that the supplementation of exogenous fibrolytic enzyme has no beneficial effect on the growth performance of lambs in the present study.

KEYWORDS: Cellulase, Exogenous fibrolytic enzymes, Finger millet straw, Xylanase

Article received: 16 February 2023; Article accepted: 01 August 2023

INTRODUCTION

A major constraint in the feeding management of sheep raising is the shortage of fodder resource, mainly due to lack of grazing land and diminishing area under green forage crops cultivation. The shortage of fodder in India is to the tune of 23 per cent of dry and 32 per cent of green forages, with more than 65 per cent of the farmers depending on the crop residues as a basal roughage for feeding animals (ICAR, 2019). Crop residues (straw) are poor quality roughage feeds, and different technologies like physical, chemical and biological methods have been attempted to improve the nutritional value (Abdel Yamid et al., 2013). However, none of these methods have been practically feasible due to the cost constraint, risk of toxicity, or extensive labour involved in these processes. Studies on supplementation of fibrolytic

enzymes to crop residue based diets have been promising (Morgavi et al., 2000), however the results have been inconsistent (Pinos Rodriguez et al., 2008; Bhasker et al., 2013). In this experiment, finger millet straw based diets were supplemented with exogenous fibrolytic enzymes to investigate the effect on growth performance and nutrient digestibility in lambs.

MATERIALS AND METHODS

Selection of experimental animals

Fifteen male lambs (Hassan breed) of about 4 to 6 months of age were selected. The lambs were divided into three groups consisting of five lambs each based on body weight and treatments were allocated randomly to individual group. The trial was conducted at Department of Livestock Farm Complex, Veterinary College, Hebbal, Bangalore,

Karnataka. The research station is a semi arid region located at an elevation of 891 m above mean sea level, 13°04' of North latitude and 77°59' of East longitude with mean annual rain fall of 970 mm. Permission for using the animals for the trial was duly taken from Institutional Animal Ethics Committee (IAEC) No. VCH/IAEC/2019/116 as per the Article No. 13 of the CPCSEA rules laid down by Government of India.

Preparation of enzyme premix:

The enzymatic activity of pure crystalline extract of cellulase and xylanase specified were 8,00,000 U/g and 75,00,000 U/g respectively, procured from Adventis Biolabs, Bangalore (Source: Indian Advanced Enzymes Ltd., Thane, Maharashtra). An enzyme premix was prepared by mixing 7.6 g of pure crystalline cellulase and 1.6 g of pure crystalline xylanase with 1 kg of calcium carbonate (carrier), to obtain a cellulase concentration of 6,000 U of cellulase and 12,000 U of xylanase per gram of premix. This enzyme premix was used for feeding the experimental lambs.

Dietary treatments and feeding management

The experimental lambs were offered with diet containing finger millet straw (FMS) and compounded feed mixture (CFM) (Table 1). Treatment T1 (control) group of animals received no enzyme supplement while the lambs in Treatment 2 (T2) received 1 g of the premix (to provide 6,000 U of cellulase and 12,000 U of xylanase) and the lambs in Treatment 3 (T3) received 2 g of the premix (to provide 12,000 U of cellulase and 24,000 U of xylanase) per day. All the experimental lambs were housed in individual pens and provided similar feeding and management care. The diets for lambs were provided with adequate energy and protein (to gain 100 g body weight per day) as per the standards of ICAR (2013). Finger millet straw was offered *ad libitum* while the calculated quantities of CFM was fed in two equal portions at 09:00 and 16:00 hours of the day. The specified quantities of enzyme for T2 and T3 groups (1 g or 2 g per day) was supplemented

in the morning with the enzyme premix mixed in about 50 g of the CFM, offered to the lambs and ensured complete consumption, before the remainder quantities of the CFM was fed. The duration of feeding trial was eight weeks. To assess the digestibility of nutrients, digestion trial was conducted with faecal samples collected for five days during the last week of the experiment.

Sampling, analyses and calculations

Representative samples of FMS, CFM and ort were collected for analyses. Faecal pellets voided by each lamb over 24 hours was weighed at 08:30 hours. After proper crushing and mixing, 1/5th of total collection was sub sampled and kept in deep freezer. The five days pooled sample from individual lambs was thawed and dried in a forced hot air oven at 60°C, air equilibrated and ground in a willey mill to pass through 1 mm size sieve. Samples of feed ingredients, ort and faeces were analyzed for dry matter (DM), crude protein (CP), ether extract, neutral detergent fibre (NDF), acid detergent fibre (ADF) and total ash (TA) as per the procedures of AOAC (2005) and Van Soest et al. (1992).

Statistical analysis

Experimental data on DMI, nutrient intake, body weight gain and digestibility were subjected to Analysis of Variance (ANOVA) using statistical software and SPSS (Version 26). Individual differences between means were tested using Tukey 't' test and results interpreted accordingly.

RESULTS AND DISCUSSION

Dry matter and nutrient intake

The mean intake of DM and nutrients in different treatment groups are presented in Table 2. Dry matter intake *per se* or as per cent body weight or g per kg metabolic weight were not significantly different among treatment groups. Mean DMI values of experimental lambs corroborated with the findings of Ajit et al. (2017), who reported similar intake of feed DM in growing lambs.

The results observed in present study were in agreement with Wahyuni et al. (2012) who reported that when goats fed with palm leaves based diet supplemented with exogenous fibrolytic enzymes (EFE) did not affect the DMI, however improved the efficiency of feed utilization of the diet. Similarly, Torres et al. (2013) reported no change in DMI observed with the supplementation of EFE to the lambs fed lucerne hay based diet. In contrast, Beauchemin et al. (2001) reported significant improvement in DMI with sheep fed guinea hay supplemented with fibrolytic enzymes.

Mean intake of organic matter, NDF, ADF, and CP over 8 weeks of growth trial are presented in

Table 2. Intake of organic matter, NDF, ADF and CP were not significant among treatment groups. In all the three groups the levels of NDF and ADF intake was adequate, for optimum ruminal fermentation (Van Soest et al., 1992). The CP intake of all the groups was also adequate (Table 2 and 4) to meet the requirement of 100 g daily body weight gain as specified by the ICAR (2013). Similarly, the ME intake among experimental groups were similar (Table 3) with sufficient energy provided (more than 6.70 MJ per day, Table 4) to meet the requirement of 100 grams daily body weight gain as stipulated by ICAR (2013).

Table 1. Chemical composition¹ (percent DM), fiber fractions and energy² of the Finger millet straw and compounded feed mixture

| Parameter | Finger millet straw | Compounded feed mixture [#] |
|--------------------------|---------------------|--------------------------------------|
| Dry matter | 95.8 | 96.2 |
| Organic matter | 91.4 | 94.9 |
| Crude protein | 4.55 | 20.1 |
| Ether Extract | 0.75 | 3.44 |
| Total Ash | 8.56 | 5.11 |
| Acid insoluble ash | 3.32 | 0.36 |
| Neutral detergent fiber | 77.5 | 23.6 |
| Acid detergent fiber | 61.3 | 9.37 |
| Acid detergent lignin | 6.20 | 2.11 |
| ME(MJ/KgDM) ² | 5.46 | 13.6 |

¹Variations in duplicate measurements were within $\pm 3\%$ of the mean

²Determined by RIVIGP Technique (Menke and Steingass, 1988) [#]Compounded feed mixture contained maize 67 parts, wheat bran 14 parts, soybean meal 14 parts, common salt 1 part, urea 2 parts and mineral mixture 2 parts

Table 2. Daily mean intake of dry matter and nutrients of experimental lambs in growth trial

| Parameter | T1 (Control) | T2 | T3 | SEM | P |
|--------------------------------|--------------|------|------|------|-------|
| Finger millet straw | | | | | |
| g per day | 230 | 247 | 241 | 8.99 | 0.772 |
| percent of body weight | 1.10 | 1.09 | 1.15 | 0.28 | 0.059 |
| g per Kg Metabolic body weight | 23.4 | 23.7 | 24.5 | 0.32 | 0.351 |
| Compounded feed mixture | | | | | |
| g per day | 520 | 558 | 543 | 15.9 | 0.702 |
| per-cent of body weight | 2.50 | 2.48 | 2.60 | 0.03 | 0.085 |
| g per Kg Metabolic body weight | 53.2 | 53.9 | 55.5 | 0.48 | 0.130 |
| Total DMI | | | | | |
| g per day | 750 | 805 | 785 | 24.8 | 0.702 |
| per-cent of body weight | 3.60 | 3.57 | 3.75 | 0.04 | 0.085 |
| g per Kg Metabolic body weight | 76.6 | 77.6 | 80.1 | 0.72 | 0.130 |
| Organic matter | | | | | |
| g per day | 704 | 755 | 737 | 23.3 | 0.701 |
| Crude protein | | | | | |
| g per day | 69.6 | 74.7 | 73.0 | 2.51 | 0.741 |
| Neutral detergent fiber | | | | | |
| g per day | 301 | 323 | 315 | 10.7 | 0.734 |
| Acid detergent fiber | | | | | |
| g per day | 190 | 204 | 199 | 6.99 | 0.749 |

T1 : Control group fed diet with no enzyme supplement

T2 : Diet fortified with Cellulase and Xylanase at 6,000 U and 12,000 U respectively /animal

T3 : Diet fortified with Cellulase and Xylanase at 12,000 U and 24,000 U respectively /animal

SEM: Standard error of means

Body weight gain

The average daily body weight gain (g) for T1, T2 and T3 groups during growth trial period was 93.8, 97.8 and 101 g, respectively (Table.3). There was no significant difference in the mean body weight or average daily gain among T1 (control), T2 and T3 groups. These results were in agreement with Almaraz et al.(2010) who reported that the fibrolytic enzymes mixture did not change body weight in lambs fed 70 per cent concentrate diets. Eun and Beauchemin (2007) and also reported that

supplementation of Fibrozyme (60 IU glucanase and 110 xylanase activities/g) supplied by feeding 2 g/kg DM did not affect the growth performance of steers fed on total mixed ration consisting of corn or barley based silage diets. However, Beauchemin et al. (2003) reported that the response of supplementing fibrolytic enzymes was highly variable on body weight gain in sheep fed high-grain diets. In contrast, Beauchemin et al.(1995) reported increase in growth rate of steers fed alfalfa hay based diet supplemented with xylanase enzymes.

Table 3. Mean body weight gain of experimental lambs during the growth trial

| Parameter | T1 (Control) | T2 | T3 | SEM | P |
|----------------------------|--------------|------|------|------|-------|
| Initial body weight (kg) | 18.0 | 18.4 | 18.2 | 0.81 | 0.988 |
| Final body weight (kg) | 23.9 | 24.6 | 24.6 | 1.04 | 0.469 |
| Body weight gain (kg) | 5.9 | 6.2 | 6.4 | 0.49 | 0.188 |
| Average daily gain (g/day) | 93.8 | 97.8 | 101 | 2.84 | 0.167 |

T1 : Control group fed diet with no enzyme supplement

T2 : Diet fortified with Cellulase and Xylanase at 6,000 U and 12,000 U respectively /animal

T3 : Diet fortified with Cellulase and Xylanase at 12,000 U and 24,000 U respectively /animal

Table 4. Daily mean intake of energy and protein in experimental lambs in growth trial

| Diets | T1 (Control) | T2 | T3 |
|--------------------------|--------------|-------------|-------------|
| ME intake (MJ) | 6.80 (6.91) | 7.41 (7.20) | 7.63 (7.31) |
| Crude protein intake (g) | 69.6 (64.5) | 74.7 (64.5) | 73.0 (63.7) |

T1 :Control group fed diet with no enzyme supplement

T2 :Diet fortified with Cellulase and Xylanase at 6,000 U and 12,000 U respectively /animal.

T3 :Diet fortified with Cellulase and Xylanase at 12,000 U and 24,000 U respectively /animal..

Values in parenthesis indicate the requirement as specified by ICAR (2013)

DIGESTION TRIAL

Apparent digestibility of dry matter and organic matter

The apparent digestibility of DM, OM, NDF ADF and CP are presented Table 5. Supplementing EFE to FMS based diet had no significant effect on digestibility of DM among the treatment groups. Findings of the digestibility of DM are in agreement with findings of Pinos Rodriguez et al.(2008) who reported that fibrozyme (100 units of xylanase/g) supplemented at 2g supplementation to concentrate portion of total mixed ration (Forage:Concentrate; 60:40, 50:50, and 40:60) had no effect on dry matter digestibility in lambs. Similarly, Bhasker et al. (2013) also reported that supplementation of EFE had no effect on the digestibility of DM in the diets. In contrast, Titi and Tabbaa (2004) observed significant increase ($P < 0.05$) in DM digestibility in awassi lambs fed on wheat straw based ration supplemented with cellulase at 150g/ton of forage. Pinos Rodriguez et al.(2008) also reported an increase ($P < 0.05$) in DM digestibility in lambs fed on alfalfa hay and rye grass with intra-ruminal supplementation of Fibrozyme at 5g/lamb/day.

Supplementing EFE in the diet had no influence on the digestibility of OM (Table5). Previous studies of Hristov et al.(2008) also reported no change in the digestibility of OM in Holstein cows fed total mixed

ration (hay: concentrate; 40:60) supplemented with EFE at 10g/cow/day. Nevertheless, Titi and Tabbaa (2004) reported a significant increase ($P < 0.05$) in OM digestibility in awassi lambs fed on wheat straw based ration supplemented with cellulase at 150g/ton of forage. The digestible organic matter in dry matter (DOMDM, Table5) was higher in diet of T3 group (69.4) compared to T2 (65.7) or T1 (64.7)group ($P < 0.05$). The DOMDM values correspond to total digestible nutrients in ruminants (Van Soest et al., 1992). In the present study, the diet comprised of finger millet straw (40 per cent) and compounded feed mixture (60 per cent) and for this combination of diet, supplementation of EFE (at a concentration of cellulase : xylanase :: 12000:24000 per animal per day) was beneficial in increasing the DOMDM content of the diet.

Crude protein digestibility

Supplementing EFE in diet had no effect on the digestibility of CP (Table 5). The results were in agreement with findings of Titi and Tabbaa (2004), who reported no significant increase in CP digestibility in Awassi lambs fed wheat straw based ration supplemented with cellulase at 150g/ton of forage. Similarly, Avellaneda et al.(2009) reported no effect of supplementing xylanase enzyme on CP digestibility in Suffolk lambs fed on guinea grass. However, Malik

and Bandla (2010) reported a significant increase in CP digestibility in buffalo calves fed on wheat straw based diet supplemented with 4000 IU cellulase and 12500 IU xylanase/kg DM. On the other hand Bhasker et al.(2013) reported decreased CP digestibility in lambs fed with maize and sorghum stover based total mixed ration supplemented with EFE containing 12800 IU of cellulase and 12800 IU of xylanase.

Digestibility of fiber fractions

Supplementation of cellulose (12000IU) and xylanase (24000IU) enzymes in T3 group of animals fed finger millet straw based diet significantly increased the digestibility of NDF and ADF ($P < 0.05$) (Table 5). These results corroborated with the observations of Morgavi et al.(2000) who reported an increase in digestibility of fibre fractions and ascribed it to increased

hydrolytic activity in the rumen and the synergistic effect of exogenous enzymes with the hydrolases of the ruminal microorganisms. Wang et al.(2001) postulated that EFE enhanced the attachment of rumen microorganisms to the feed particles thereby increasing the hydrolytic activity of cellulase in the rumen. In contrast, Rode et al.(1999), Reddish and Kung (2007) and Pinos Rodriguez et al.(2008) reported no effect on digestibilities of NDF or ADF due to supplementation of EFE in diets based on hay or total mixed rations. Variable responses in digestibility have been attributed to many factors such as mode of application, type, activity and dosage of the enzyme, composition of the basal diet, application level and stability of the enzymes in the rumen (McAllister et al.,2001). In the present study, supplementation of exogenous fibrolytic enzyme has increased the digestibility of NDF and ADF content of the diet (Table 5).

Table5. Daily mean intake and apparent digestibility of nutrients (percent) in experimental lambs during the digestion trial

| Parameter | T1 (Control) | T2 | T3 | SEM | P |
|-------------------------|-------------------|-------------------|-------------------|-------|-------|
| Dry matter | | | | | |
| Intake (g per day) | 819 | 748 | 826 | 42.82 | 0.178 |
| Digestibility (%) | 67.1 | 69.1 | 71.7 | 1.14 | 0.065 |
| Organic matter | | | | | |
| Intake (g per day) | 767 | 702 | 775 | 40.03 | 0.179 |
| Digestibility (%) | 68.2 | 70.1 | 73.9 | 1.17 | 0.077 |
| Crude protein | | | | | |
| Intake (g per day) | 119 | 115 | 126 | 6.02 | 0.220 |
| Digestibility (%) | 69.6 | 70.8 | 70.3 | 0.84 | 0.131 |
| Neutral detergent fiber | | | | | |
| Intake (g per day) | 446 | 391 | 437 | 24.31 | 0.157 |
| Digestibility (%) | 45.9 ^a | 47.1 ^a | 52.6 ^b | 0.89 | 0.038 |
| Acid detergent fiber | | | | | |
| Intake (g per day) | 228 | 185 | 211 | 13.81 | 0.131 |
| Digestibility (%) | 42.1 ^a | 42.9 ^a | 48.2 ^b | 1.21 | 0.041 |
| *DOMDM (%) | 64.7 ^a | 65.7 ^a | 69.4 ^b | 1.923 | 0.643 |

T1 :Control group fed diet with no enzyme supplement

T2 :Diet fortified with Cellulase and Xylanase at 6,000 U and 12,000 U respectively /animal.

T3 :Diet fortified with Cellulase and Xylanase at 12,000 U and 24,000 U respectively /animal..

SEM: Standard error of means.*DOMDM= Digestible organic matter in dry matter

^{ab} Mean values within a row bearing different superscripts differ ($P < 0.05$)

CONCLUSION

Supplementation of cellulase and xylanase enzymes increased the *in vivo* digestibility of NDF and ADF, and the DOMDM content of the diet. However, these effects of fibrolytic enzyme supplementation were not reflected in the feed intake or daily body weight gain of growing lambs. It was concluded that supplementation of cellulase: xylanase :: 12000:24000 units per day per lamb had no beneficial effects on the growth performance of lambs fed finger millet straw based diets. Future studies may be taken up on supplementing the EFE in diets containing other forage based diets, or supplementing EFE at much higher concentrations than used in this experiment.

REFERENCES

- Abdel Yamid, A.M., Solbiati, J.O. and Cann, I.R.O. 2013. Advances in Applied Microbiology. 82:1-9.
- Almaraz, I., Gonzalez, S.S., Pinos Rodriguez, J.M. and Miranda, L.A. 2010. Effects of exogenous fibrolytic enzymes on *in sacco* and *in vitro* degradation of diets and on growth performance of lambs. Italian Journal of Animal Science. 9(1):2-10
- A.O.A.C. 2005. Official Method of Analysis. 18th Edn. Association of Official Analytical Chemists. National Academy of Sciences, National Academy Press, Washington, D.C, USA.
- Ajit, K. S., Arpitha, R., Madhura, Y., Prabhu, T. M., Gloridoss, R. G., Narasimhamurthy, H. N. and Chandrapal Singh, K. 2017. Effect of feeding spineless cactus (*Opuntia ficus indica*) on intake, digestibility and growth performance in lambs. International Journal of Livestock Research. 7(12). 101-110.
- Avellaneda, J. H., Pinos Rodriguez, J. M., Gonzalez, S. S., Barcena, R., Hernandez, A., Cobos, M., Hernandez, D. and Montanez, O. 2009. Effects of exogenous fibrolytic enzymes on ruminal fermentation and digestion of Guinea grass hay. Animal Feed Science Technology. 149(1-2): 70-77.
- Beauchemin, K.A., Rode, L.M. and Sewalt, V.J.H. 1995. Fibrolytic enzymes increase fiber digestibility and growth rate of steers fed dry forages. Canadian Journal of Animal Science. 75(4):641-644.
- Beauchemin, K.A., Morgavi D.P., Mcallister T.A., Yang W.Z. and Rode L.M. 2001. The use of enzymes in ruminant diets. Recent Advances in Animal Nutrition. Loughborough (UK): Nottingham University Press. p. 297-322.
- Beauchemin, K.A., Colombatto, D., Morgavi, D.P. and Yang, W.Z. 2003. Use of exogenous fibrolytic enzymes to improve feed utilization by ruminants. Journal of Animal Science. 81(14 suppl 2):E37-E47.
- Bhasker, T. V., Nagalakshmi, D. and Rao, S. 2013. Development of appropriate fibrolytic enzyme combination for maize stover and its effect on rumen fermentation in sheep. Asian Australian Journal of Animal Science. 26: 945-951.
- Eun, J. S. and Beauchemin, K. A. 2007. Enhancing *in vitro* degradation of alfalfa hay and corn silage using feed enzymes. International Journal of Dairy Science. 90(6): 2839-2851.
- I.C.A.R. 2013. Nutrient Requirements of Animals- Sheep, Goat and Rabbit (ICAR-NIANP). Indian Council of Agricultural Research, New Delhi.
- I.C.A.R. 2019. Revisiting national forage demand and availability scenario. Indian fodder scenario: Redefining state wise status. ICAR-AICRP on Forage Crops and Utilization, Jhansi, India, pp.1-21.
- Hristov, A. N., Basel, C. E., Melgar, A., Foley, A. E., Ropp, J. K., Hunt, C.W. and Tricarico, J. M. 2008. Effect of exogenous polysaccharide-degrading enzyme preparations on ruminal fermentation and digestibility of nutrients in dairy cows. Animal Feed Science Technology. 145(1-4): 182-193.
- Malik, R. and Bandla, S. 2010. Effect of source and dose of probiotics and exogenous fibrolytic enzymes (EFE) on intake, feed efficiency,

- and growth of male buffalo (*Bubalus bubalis*) calves. *Tropical Animal Health and Production*. 42(6): 1263-1269.
- Mcallister, T.A., Hristov, A.N., Beauchemin, K.A., Rode, L.M. and Cheng, K.J. 2001. Enzymes in ruminant diets. *Enzymes in Farm Animal Nutrition*. pp.273-298.
- Menke, K.H. and Steingass, H. 1988. Estimation of the energetic feed value obtained from chemical analysis and *in vitro* gas production using rumen fluid. *Animal Research and Development*. 28:7-55.
- Morgavi, D.P., Beauchemin, K.A., Nsereko, V.L., Rode, L.M., Iwaasa, A.D., Yang, W.Z., Mcallister, T.A. and Wang, Y. 2000. Synergy between ruminal fibrolytic enzymes and enzymes from *Trichoderma longibrachiatum*. *Journal of Dairy Science*. 83(6):1310-1321.
- Pinos Rodriguez, J.M., Moreno, R., Gonzalez, S.S., Robinson, P.H., Mendoza, G. and Alvarez, G. 2008. Effects of exogenous fibrolytic enzymes on ruminal fermentation and digestibility of total mixed rations fed to lambs. *Animal Feed Science and Technology*. 142(3-4):210-219.
- Reddish, M. A. and Kung Jr, L. 2007. The effect of feeding a dry enzyme mixture with fibrolytic activity on the performance of lactating cows and digestibility of a diet for sheep. *Journal of Dairy Science*. 90(10): 4724-4729.
- Rode, L. M., Yang, W. Z. and Beauchemin, K. A. 1999. Fibrolytic enzyme supplements for dairy cows in early lactation. *Journal of Dairy Science*. 82(10): 2121-2126.
- Titi, H. H. and Tabbaa, M. J. 2004. Efficacy of exogenous cellulase on digestibility in lambs and growth of dairy calves. *Livestock Production Science*. 87(2-3): 207-214.
- Torres, N., Mendoza, G.D., Barcena, R., Loera, O., Gonzalez, S., Aranda, E., Hernandez, P.A. and Crosby, M. 2013. Effects of various fibrolytic enzyme extracts on digestibility and productive performance of lambs fed a forage-based diet. *Animal Nutrition and Feed Technology*. 13(3):381-389.
- Van Soest, P.J., France, J. and Siddons, R.C. 1992. On the steady-state turnover of compartments in the ruminant gastrointestinal tract. *Journal of Theoretical Biology*. 159(2):135-145.
- Wahyuni, R.D., Ngampongsa, W., Wattanachant, C., Visessanguan, W. and Boonpayung, S. 2012. Effects of enzyme levels in total mixed ration containing oil palm frond silage on intake, rumen fermentation, and growth performance of male goat. *Songklanakarinn Journal of Science and Technology*. 34(4).
- Wang, Y., Mcallister, T.A., Rode, L.M., Beauchemin, K.A., Morgavi, D.P., Nsereko, V.L., Iwaasa, A.D. and Yang, W. 2001. Effects of an exogenous enzyme preparation on microbial protein synthesis, enzyme activity and attachment to feed in the Rumen Simulation Technique (Rusitec). *British Journal of Nutrition*. 85(3):325-332.