academicJournals

Vol. 9(7), pp. 695-700, 13 February, 2014
DOI: 10.5897/AJAR2013.7976
ISSN 1991-637X ©2014 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Effect of Celmanax® on feed intake, live weight gain and nematode control in growing sheep

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Accepted 22 January, 2014

The role of yeast supplementation in small ruminants on rumen fermentation, animal performance, and nematode control is still unclear. The effect of Celmanax® (yeast culture product) in two diets using lambs on body weight gain, rectal temperatures and nematode loads were monitored. 24 sheep (17 ± 2.8 kg BW), housed in individual pens, were divided into four treatments and fed on four basal diets; lucerne meal (LC), lucerne meal plus Celmanax® (LCC), sunflower meal (SF), and 4 sunflower meal plus Celmanax (SFC), for 96 days including 14 days adaptation. Dry matter intake, average body weight gain and feed conversion efficiency were calculated. Rectal temperatures and nematode egg count/gram (EPG) were measured once a week. Feed intake was higher ($P < 0.05$) in LCC and SFC than in LC and SF, respectively. Overall, weight gain was higher in SFC ($P < 0.05$) than SF. Feed conversion efficiency was higher ($P < 0.05$) in LCC than LC. Nematode EPG were lower ($P < 0.05$) in Celmanax® supplemented diets (LCC and SFC) than in their controls. Rectal temperatures dropped ($P < 0.05$) in Celmanax® diets. These findings suggest that, Celmanax® has the potential of improving animal performance and may be used in conjunction with other anthelmintics to control nematodes.

Key words: Celmanax®, yeast, nematode, dry matter intake.

INTRODUCTION

Livestock contribute about 33 and 16% of the total protein and food energy consumption, respectively, in human diets globally (Chadd et al., 2002). The demand for meat could double (233 to 300 million tons) by the year 2020 due to changing food preferences, income growth, urbanization and increase in population growth (FAO, 2010; United Nations, 2010; WHO, 2011). Most African countries rely on livestock as a source of protein because of human preference since plant sources are scarce and are unevenly distributed. This implies that, livestock production needs to increase to sustain the ever-increasing human population. Attempts by small ruminant intensive livestock farming to optimize meat production are facing daunting challenges. The time taken to attain slaughter age is long due to poor quality diets and rangelands.

Sheep are largely fed on forages, crop residues, and agro-industrial by-products which often have low levels of energy, proteins and vitamins (Iñiguez, 2011; Krause et al., 2003; Powell and Unger, 1998). The energy of these fibrous feeds is locked up in the complex carbohydrate molecules which can only be unlocked by cellulolytic microbes (Bhat, 2000; Vuong and Wilson, 2009). Different strategies have been attempted to improve forage digestibility in ruminants. Examples of these methods include supplementation with foliage or legumes

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Table 1. Ingredient composition (g/kg) of the different meals.

Treatment	Sunflower meal (SF) diets		Lucerne meal (LC) diets	
	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Hominy chop (g)	812	812	812	812
SF or LC (g)	140	140	140	140
Vitamin and Mineral mix(g)	48	48	48	48
Urea (g)	0	0	7.8	7.8
Celmanax®	0	2	0	2
Crude protein	134	134	134	134

SF= Sunflower cake; LC = lucerne hay.

(Undi et al., 2001), concentrates (Cherdthong et al., 2010; Izadifard and Zamiri, 2007), urea (Aregheore, 2005; Cherdthong et al., 2011), chemical treatment of forages (Chen et al., 2008), specific or composite cellulases (Hristov et al., 1998; Shekhar et al., 2010; Yang et al., 2011), specific microbial strains (Paul et al., 2011) and microbial inocula (Singh et al., 1994, 1997; Wanapat et al., 2003). Celmanax® is a yeast culture product that has been shown to improve milk yield and milk protein production, attachment of sporozoites to bovine epithelial cells, ability of cows to withstand heat stress and decreased *Escherichia coli* colonization of bovine cells and feed associated cytotoxicity (Baines et al., 2011a, b) and reduced rectal temperatures (Bruno et al., 2009). Although, it has widely been suggested that, yeast could have a nematophagous effect (Larsen, 2000, 2006; Ojeda-Robertos et al., 2005; Waghorn et al., 2003; Waller and Faedo, 1993; Waller et al., 2006; Waller and Thamsborg, 2004), little, if any, evidence is available. The objective of the current study was therefore, to determine the effect of Celmanax® in diets of lambs on body weight gain, rectal temperatures, and nematode loads. It was hypothesized that, Celmanax inclusion in sheep diets improves animal performance and decrease nematode loads.

MATERIALS AND METHODS

Study site

The study was conducted at Ukulinga Research Farm, University of KwaZulu-Natal, Pietermaritzburg. The site lies in a subtropical hinterland approximately 700 m above sea level. The climate is characterized by annual rainfall of 735 mm, which falls mostly between October and April. The maximum and minimum mean annual temperatures are 25.7 and 8.9°C, respectively. Light to moderate frost occurs occasionally during the cool-dry season.

Animals, diet, experimental design, and feeding management

24 lambs (17 ± 2.8 kg) were divided into four treatments of six based on stratification. Each group was assigned one of four treatments randomly. All animals were placed in individual pens (140 × 80 cm). Body weights were recorded weekly. Lambs were fed twice daily with hominy chop concentrates supplemented with sunflower cake (Treatment 1) or lucerne (Treatment 3) (Table 1). The control diets (Treatment 1 and 3) had no Celmanax® while the experimental diets had Celmanax® (Treatments 2 and 4, Table 1). All diets were mixed manually for each treatment. The animals were given hay *ad libitum* an hour after being fed with 300 g concentrates daily. Vitamin and mineral mix were also included in the diet (Table 1). Clean drinking water was provided *ad libitum*. The experiment ran for 82 days, plus an adaptation period of 14 days.

Dry matter intake, body weight gain, and feed conversion ratio

Hay was offered every day, and refusals were recorded weekly. Samples offered and refused were collected weekly, composited, oven dried (60°C) for 48 h and dry matter intake (DMI) was determined. Body weight gain was calculated by subtracting mean initial body weights of animals from the final mean weights. Feed conversion ratio (FCR) for each animal was calculated as body weight gained divided by feed intake.

Rectal temperature

Rectal temperatures were measured at 0700, 1200, and 1600 h once every week to the nearest 0.1°C using a digital thermometer for two months. The thermometer was inserted rectally to full depth until a stable automated reading was obtained. The ambient temperature was also recorded.

Faecal sample collection and parasitological analysis

All animals were initially treated (Abamectin and Praziquantel) for worms before commencing the trial. However, the animals were dozed (with Abamectin and Praziquantel) again on Day 14 in response to high eggs count to prevent animals from being sick (because of slow response of Celmanax®). Rectal faeces samples were collected on Days 0, 14, 28, 42, 56, 70, and 84 post-treatment, placed in plastic bags bearing the animal's identification number and then conveyed to the Laboratory of Animal and Poultry Science. Faecal nematode egg count was done using the McMaster Technique (Hansen and Perry, 1994) and the process was usually complete within a day. Briefly, 56 ml of saturated salt solution was added to 4 g of faeces in a beaker. The faecal suspension was filtered into another beaker. Both wells of the McMaster counting chamber were filled with the suspension, allowed to stand for 5 min, and examined under a light microscope at 100 × magnification. The number of nematode eggs counted in both wells of the McMaster chamber was multiplied by 50 to get egg per gram (EPG) count.

Table 2. Dry matter intake, body weight gain and feed conversion ratio of grass hay fed to lambs inoculated with Celmanax®.

Parameter	Sunflower meal	Sunflower Meal + Celmanax®	Lucerne meal	Lucerne meal + celmanax®	*P*-value	SEM (df=19)
Concentrate DM (kg/d	0.23[a]	0.23[a]	0.26[b]	0.26[b]	0.05	0.000
Roughage intake (kg/d)	0.13[a]	0.18[b]	0.16[b]	0.19[b]	0.05	0.01
Total DM intake (kg/d)	0.36[a]	0.42[b]	0.43[b]	0.45[b]	0.05	0.01
Initial live weight (kg/wk)	17[a]	17[a]	17[a]	17[a]	NS	0.02
Final live weight (kg/wk)	18.28[a]	18.9[ab]	18.67[ab]	19.77[b]	0.05	0.02
Average weight gain (kg/d)	0.18[a]	0.27[ab]	0.24[ab]	0.31[b]	0.05	0.02
Feed conversion ratio	0.53[a]	0.63[a]	0.46[a]	0.69[b]	0.05	0.064

[a, b]Values in the same rows with different superscripts are different ($P < 0.05$).

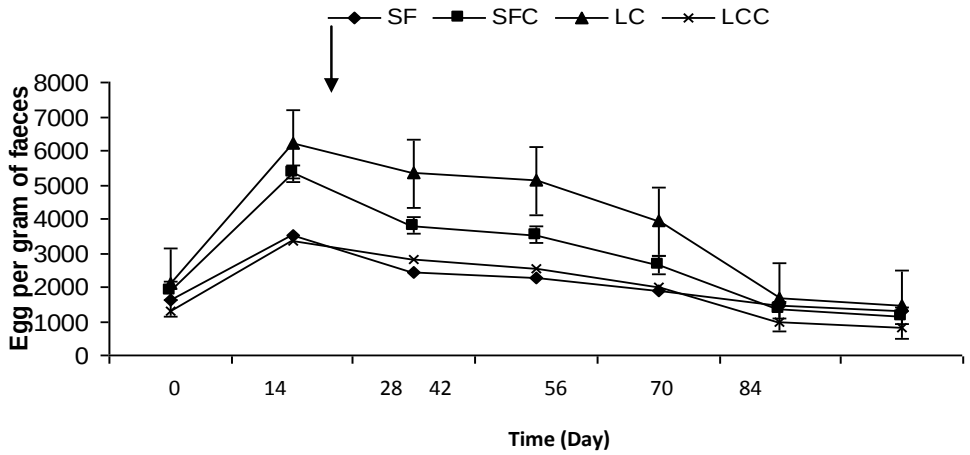

Figure 1. Effects of treatments on nematodes egg counts. SF, SFC, LC, LCC stand for Sunflower, Sunflower/Celmanax, Lucerne, Lucerne / Celmanax. Arrow indicates time of Anthelminthic dosed.

Statistical analysis

DMI, body weight gain, feed conversion ratio and rectal temperatures were analysed using the general linear model of SAS (2002). The model was given as follows:

$Y_{ij} = \mu + T_i + C_j + T \times C_{ij} + e_{ijk}$

Where Y is the individual observation, μ is the overall mean, T_i is the effect of the supplement, C is the effect of Celmanax®, $(T \times C)_{ij}$ is the interaction between supplement and Celmanax® and e_{ijk} is the residual error.

RESULTS

Total DM and daily roughage intake differed ($P < 0.05$) between treatments but not within treatments. Celmanax® addition increased ($P < 0.05$) both roughage and total DMI in animals fed with sunflower diet but tended to increase both intakes in lucerne diets (Table 2). Weekly live weight gains tended ($P > 0.05$) to increase in lambs fed with Celmanax® for both diets. Feed conversion ratios also tended ($P > 0.05$) to increase upon Celmanax® addition in both diets.

Eggs per gram (EPG) of faeces increased up to day 14. On this day all animals were administered one dose of a combination of Abamectin and Praziquantel (Figure 1) and then EPG consistently decreased through time for all treatments. However, Celmanax® treatments [lucerne meal plus Celmanax® (LCC); sunflower meal plus Celmanax (SFC)] caused lower ($P < 0.05$) EPG. Rectal temperatures decreased ($P < 0.05$) with Celmanax® supplementation between diets but tended ($P > 0.05$) to decrease within diets. Mean temperature maximum and minimum were 30.31 and 15.05°C, respectively (Table 3).

DISCUSSION

The current study evaluated the effect of Celmanax® in diets (sunflower and lucerne meal) of lambs on roughage and total DM intake, live weight gain, FCR, rectal

Table 3. Rectal temperatures of sheep fed inoculated with Celmanax®.

Parameter	Sunflower Meal	Sunflower meal + Celmanax®	Lucerne meal	Lucerne meal + Celmanax®	*P*-value	SEM
n	6	6	6	6		
Mean rectal T (°C)	39.17[b]	39.01[ab]	39.03[ab]	38.96[a]	0.05	0.036
Mean environmental T (°C)						
Maximum	30.31	30.31	30.31	30.31	-	10.460
Minimum	15.05	15.05	15.05	15.05	-	2.551

[a b] Values in the same rows with different superscripts are different ($P < 0.05$) and T is temperature, n = number of animals per treatment.

temperatures, and nematode egg counts. The expectations were that all parameters might be improved with the addition of Celmanax® as some yeast species have been shown to increase animal performance and health due to some special characteristics (oxygen depletion from the rumen, stimulation of cellulolytic bacteria, increase ruminal pH, and nematophagous effect).

Celmanax® supplementation increased weekly roughage intake (14 to 45%) and total DM intake (4 to 15%) in lambs fed with lucerne and sunflower meal. Increased intakes have been obtained in other studies on goats, Awassi lambs, Maghraby camel calves and horses (Haddad and Goussous, 2005; Hristov et al., 2010; Kawas et al., 2007; Mohamed et al., 2009). Increased DMI might have been influenced by increased in fibre digestibility due to increased total bacteria number, viable bacteria and total cellulolytic bacteria stimulated by Celmanax® supplementation (Abd El-Ghani, 2004; Putnam and Schwab, 1994). In contrast, Haddad and Goussous (2005), Mohamed et al. (2009), Proudfoot et al. (2009) found no difference in DMI but reported an increase in animal performance.

Celmanax® supplementation tended to increase weekly and total live weight gain in both diets while feed conversion was improved in the lucerne meal (LC) only. Increased live weight gain and feed conversion upon supplementation with Celmanax® was associated to improved efficiency of fermentation (stimulation of microbial growth, activity and increased proportion of available carbon towards microbial protein synthesis), that might have diverted balanced supply of nutrient towards cell growth Tripathi and Karim, 2011). Others have observed increased live weight gain and feed conversion due to supplementation with yeast (Abdelrahman and Hunaiti, 2008; Lesmeister et al., 2004; Tripathi and Karim, 2011), while others have not (Titi et al., 2008; Tripathi et al., 2008). This study demonstrated that Celmanax® supplementation have the potential of improving intake, live weight gain and feed conversion efficiency, hence its application as possible feed additives in small ruminants.

Decreased DMI and milk yield has been associated with increasing air temperatures, temperature humidity index and rising rectal temperatures above critical threshold in ruminants (West, 2003), making attempt to regulate heat stress in ruminants imperative. Enhanced passive ventilation, fans, sprinklers and shaded pens are some of the physical methods that have been exploited to decrease body temperatures, improve DMI and live weight gain in ruminants (Blaine and Nsahlai, 2011). Genetic selection of heat tolerant ruminant species is the most widely used application. However, yeast cultures fed to dairy animals exposed to heat stress tended to decrease rectal temperatures, respiration rate and enhanced lactation performance (Bruno et al., 2009; Huber et al., 1994). Although, Celmanax® supplementation tended to decrease the rectal temperature it is right to suggest that this tendency may be a contributing factor for the increased in DMI and improved animal performance (West, 2003). The growing demand for livestock products offers an opportunity for the 675 million rural poor who depend on livestock to improve their livings (Perry, 2002). Nematode infestation in small ruminants (e.g. goats and sheep) is a major constrain on small ruminant production, as lower out puts of animal products and by-products characterized these animals globally (Soto-Barrientos et al., 2011; Waller and Thamsborg, 2004).

In the past, nematode infestation was successfully controlled by anthelmintics drugs but nowadays there has been a development of drug resistance by the adult stage (Soto-Barrientos et al., 2011; Torres-Acosta et al., 2012). In most goats and sheep in tropical and sub-tropical regions, total failure of broad spectrum anthelmintics is a reality of rapidly increasing dimensions. Therefore, studies on bio-control methods such as plant extracts (Ahmed et al., 2013; Eguale et al., 2011, 2007) and nematophagous fungi (Chandrawathani et al., 2003) predating soil nematodes (Ahrén et al., 1998) are gaining popularity, particularly in organic systems of production. Celmanax® additive decreased EPG consistent with results from other experiments (Larsen, 2006; Ojeda-Robertos et al., 2005; Soto-Barrientos et al., 2011; Waghorn et al., 2003; Waller et al., 2006; Waller and Thamsborg, 2004). The slightly increased EPG after administration of Celmanax® (day 14), can be associated to the slow effect of biocontrol agent. After 14 days, EPG

decreased consistently with all diets but much lower in LCC than in SFC. However, at the end of the trial both LCC and SFC EPG were relatively lower than observed in sunflower meal (SF) and LC diets. Egg count per gram of feces was suppressed from day 14 by Celmanax® supplementation. This is associated to nutrient availability to nematodes as suggested by Waller et al. (2006). It has been observed that, nutrient (solubles) availability restricts the drop of EPG in feces as the decrease in worm's population is slower.

Therefore, it is possible that, SFC may be supplying more solubles to the worms than LCC. The result of this study indicates that, Celmanax® has a nematophagous effect which can be very useful in controlling nematodes infections. Celmanax® potency could be better if applied in combination with other control anthelmintics.

Conclusions

Supplementing diets with Celmanax® improved DMI and sheep performance. In addition, lower rectal temperatures, and nematode faecal egg counts observed with supplemented animals, shows that Celmanax® has a temperature regulatory effect as well as a biological control effect on nematode parasitology. Therefore, the application of Celmanax® as a feed additive can stimulate rumen fermentation and control nematode population in lambs. Further experimentation on the nematophagous effect of Celmanax® on a larger-scale in animals grazing on the fields where they are vulnerable to re-infection is imperative.

ACKNOWLEDGMENTS

We would like to acknowledge Charlie Elrod from Varied Industries Corporation (Vi-COR®) for providing the feed additive (Celmanax®)

REFERENCES

Abd El-Ghani AA (2004). Influence of diet supplementation with yeast culture (*Saccharomyces cerevisiae*) on performance of Zaraibi goats. Small Rum. Res. 52:223-229.

Abdelrahman MM, Hunaiti DA (2008). The effect of dietary yeast and protected methionine on performance and trace minerals status of growing Awassi lambs. Livest. Sci. 115:235-241.

Ahmed M, Laing M, Nsahlai I (2013). *In vitro* anthelmintic activity of crude extracts of selected medicinal plants against *Haemonchus contortus* from sheep. J. Helminthol. 87:174-179.

Ahrén D, Ursing BM, Tunlid A (1998). Phylogeny of nematode-trapping fungi based on 18S rDNA sequences. FEMS Microbiol. Lett. 158:179-184.

Aregheore EM (2005). Effect of Yucca schidigera saponin on the nutritive value of urea-ammoniated maize stover and its feeding value when supplemented with forage legume (*Calliandra calothyrsus*) for goats. Small Rum. Res. 56:95-102.

Baines D, Erb S, Turkington K, Kuldau G, Juba J, Masson L, Mazza A, Roberts R (2011a). Mouldy feed, mycotoxins and Shiga toxin – producing *Escherichia coli* colonization associated with Jejunal Hemorrhage Syndrome in beef cattle. BMC Veter. Res. 7:24.

Baines D, Erb S, Lowe R, Turkington K, Sabau E, Kuldau G, Juba J, Masson L, Mazza A, Roberts R (2011b). A prebiotic, Celmanax, decreases *Escherichia coli* O157:H7 colonization of bovine cells and feed-associated cytotoxicity *in vitro*. BMC Res. Notes 4:110.

Bhat MK (2000). Cellulases and related enzymes in biotechnology. Biotechnol. Adv. 18:355-383.

Blaine K, Nsahlai I (2011). The effects of shade on performance, carcass classes and behaviour of heat-stressed feedlot cattle at the finisher phase. Trop. Anim. Health Prod. 43:609-615.

Bruno R, Rutigliano H, Cerri R, Robinson P, Santos J (2009). Effect of feeding *Saccharomyces Cerevisiae* on performance of dairy cows during summer heat stress. Anim. Feed Sci. Technol. 150:175-186.

Chadd AS, Davies WP, Koivisto MJ (2002). Practical production of protein for food animals, in: FAO (Ed.), FAO animal production and health proceedings, Bangkok, ftp://ftp.fao.org/docrep/fao/007/y5019e/y5019e00.pdf.

Chandrawathani P, Jamnah O, Waller PJ, Larsen M, Gillespie AT, Zahari WM (2003). Biological control of nematode parasites of small ruminants in Malaysia using the nematophagous fungus *Duddingtonia flagrans*. Vet. Parasitol. 117:173-183.

Chen XL, Wang JK, Wu YM, Liu JX (2008). Effects of chemical treatments of rice straw on rumen fermentation characteristics, fibrolytic enzyme activities and populations of liquid- and solid-associated ruminal microbes *in vitro*. Anim. Feed Sci. Technol. 141:1-14.

Cherdthong A, Wanapat M, Wachirapakorn C (2011). Influence of urea calcium mixture supplementation on ruminal fermentation characteristics of beef cattle fed on concentrates containing high levels of cassava chips and rice straw. Anim. Feed Sci. Technol. 163:43-51.

Cherdthong A, Wanapat M, Kongmun P, Pilajun R, Khejornsart P (2010). Rumen Fermentation, Microbial Protein Synthesis and Cellulolytic Bacterial Population of Swamp Buffaloes as Affected By Roughage to Concentrate Ratio. J. Anim. Vet. Adv. 9:1667-1675.

Eguale T, Tadesse D, Giday M (2011). *In vitro* anthelmintic activity of crude extracts of five medicinal plants against egg-hatching and larval development of *Haemonchus contortus*. J. Ethnopharmacol. 137:108-13.

Eguale T, Tilahun G, Debella A, Feleke A, Makonnen E (2007). *In vitro* and in vivo anthelmintic activity of crude extracts of Coriandrum sativum against *Haemonchus contortus*. J. Ethnopharmacol. 110:428-33.

FAO (2010). Animal genetic resources. Food and Agriculture Organization.

Haddad SG, Goussous SN (2005). Effect of yeast culture supplementation on nutrient intake, digestibility and growth performance of Awassi lambs. Anim. Feed Sci. Technol. 118:343-348.

Hansen J, Perry B (1994). The epidemiology, diagnosis and control of helminth parasites of ruminants. Animal Diseases Press, Nairobi, Kenya. Electronic version available in www.fao.org/wairdocs/ILRI/x5492E/x5492E00.HTM accessed on 11/4/2008.

Hristov ANA, McAllister T, Cheng KJ (1998). Stability of exogenous polysaccharide-degrading enzymes in the rumen. Anim. Feed Sci. Technol. 76:161-168.

Hristov AN, Varga G, Cassidy T, Long M, Heyler K, Karnati SKR, Corl B, Hovde CJ, Yoon I (2010). Effect of *Saccharomyces cerevisiae* fermentation product on ruminal fermentation and nutrient utilization in dairy cows. J. Dairy Sci. 93:682-692.

Huber J, Higginbotham G, Gomez-Alarcon R, Taylor R, Chen K, Chan S, Wu Z (1994). Heat Stress Interactions with Protein Supplemental Fat, and Fungal Cultures. J. Dairy Sci. 77:2080-2090.

Iñiguez L (2011). The challenges of research and development of small ruminant production in dry areas. Small Rum. Res. 98:12-20.

Izadifard J, Zamiri MJ (2007). Effects of supplementary feeding on growth and carcass characteristics of fat-tailed lambs grazing cereal stubble. Iran J. Veter. Res. 8:123-130.

Kawas JR, García-Castillo R, Fimbres-Durazo H, Garza-Cazares F, Hernández-Vidal JFG, Olivares-Sáenz E, Lu CD (2007). Effects of sodium bicarbonate and yeast on nutrient intake, digestibility, and

ruminal fermentation of light-weight lambs fed finishing diets. Small Rum. Res. 67:149-156.
Krause DO, Denman SE, Mackie RI, Morrison M, Rae AL, Attwood GT, McSweeney CS (2003). Opportunities to improve fiber degradation in the rumen: microbiology, ecology, and genomics. FEMS Microbiol. Rev. 27:663-693.
Larsen M (2000). Prospects for controlling animal parasitic nematodes by predacious micro fungi. Parasitology 120:121-131.
Larsen M (2006). Biological control of nematode parasites in sheep. J. Anim. Sci. 84:E133-E139.
Lesmeister K, Heinrichs A, Gabler M (2004). Effects of Supplemental Yeast (*Saccharomyces cerevisiae*) Culture on Rumen Development, Growth Characteristics, and Blood Parameters in Neonatal Dairy Calves. J. Dairy Sci. 87:1832-1839.
Mohamed MI, Maareck YA, Abdel-Magid SS, Awadalla IM (2009). Feed intake, digestibility, rumen fermentation and growth performance of camels fed diets supplemented with a yeast culture or zinc bacitracin. Anim. Feed Sci. Technol. 149:341-345.
Ojeda-Robertos N, Mendoza-de Gives P, Torres-Acosta J, Rodríguez-Vivas R, Aguilar-Caballero A (2005). Evaluating the effectiveness of a Mexican strain of *Duddingtonia flagrans* as a biological control agent against gastrointestinal nematodes in goat faeces. J. Helminthol. 79:151-157.
Paul SS, Deb SM, Punia BS, Das KS, Singh G, Ashar MN, Kumar R (2011). Effect of feeding isolates of anaerobic fungus Neocallimastix sp CF 17 on growth rate and fibre digestion in buffalo calves. Arch. Anim. Nutr. 65:215-228.
Perry BD (2002). Investing in animal health research to alleviate poverty. ILRI (aka ILCA and ILRAD).
Powell JM, Unger PW (1998). Alternatives to crop residues for sustaining agricultural productivity and natural resource conservation. J. Sustain. Agric. 11:59-84.
Proudfoot K, von Keyserlingk M, Weary D, Nocek JE (2009). The Effect of Enzymatically Hydrolyzed Yeast (EHY, Celmanax) on Production Performance in Dairy Cattle. CELMANNAX Research Bulletin D49.
Putnam D, Schwab C (1994). Mode of action of yeast culture. J. Anim. Sci. 72:2-5.
SAS (2002). Statiscal Analysis System user's guide (version 8). SAS Institude Inc., SAS CampusDrive, Cary, N.C., USA.
Shekhar C, Thakur SS, Shelke SK (2010). Effect of exogenous fibrolytic enzymes supplementation on milk production and nutrient utilization in Murrah buffaloes. Trop. Anim. Health Prod. 42:1465-1470.
Singh S, Pradhan K, Bhatia SK (1994). The effect of trans-inoculation of rumen contents in microflora concentration in the rumen of cattle and buffalo. Indian J. Anim. Nutr. 11:133-138.
Singh S, Pradhan K, Bhatia SK (1997). Effect of transinoculation of rumen contents between cattle and buffalo on feed intake, nutrient digestibility and rumen metabolites. Indian J. Anim. Nutr. 14:25-30.
Soto-Barrientos N, de Oliveira J, Vega-Obando R, Montero-Caballero D, Vargas B, Hernandez-Gamboa J, Orozco-Solano C (2011). *In-vitro* predatory activity of nematophagous fungi from Costa Rica with potential use for controlling sheep and goat parasitic nematodes. Rev. Biol. Trop. 59:37-52.
Titi HH, Dmour RO, Abdullah AY (2008). Growth performance and carcass characteristics of Awassi lambs and Shami goat kids fed yeast culture in their finishing diet. Anim. Feed Sci. Technol. 142:33-43.
Torres-Acosta JFJ, Molento M, de Gives PM (2012). Research and implementation of novel approaches for the control of nematode parasites in Latin America and the Caribbean: Is there sufficient incentive for a greater extension effort. Vet. Parasitol. 186:132-142.
Tripathi M, Karim S, Chaturvedi O, Verma D (2008). Effect of different liquid cultures of live yeast strains on performance, ruminal fermentation and microbial protein synthesis in lambs. J. Anim. Physiol. Anim. Nutr. 92:631-639.
Tripathi MK, Karim SA (2011). Effect of yeast cultures supplementation on live weight change, rumen fermentation, ciliate protozoa population, microbial hydrolytic enzymes status and slaughtering performance of growing lamb. Livest. Sci. 135:17-25.
Undi M, Kawonga KC, Musendo RM (2001). Nutritive value of maize stover/pasture legume mixtures as dry season supplementation for sheep. Small Rum. Res. 40:261-267.
United Nations (2010). United Nations Population Information Network. http://www.un.org/popin/.
Vuong TV, Wilson DB (2009). Processivity, Synergism, and Substrate Specificity of Thermobifida fusca Cel6B. Appl. Environ. Microbiol. 75:6655-6661.
Waghorn T, Leathwick D, Chen LY, Skipp R (2003). Efficacy of the nematode-trapping fungus *Duddingtonia flagrans* against three species of gastro-intestinal nematodes in laboratory faecal cultures from sheep and goats. Vet. Parasitol. 118:227-234.
Waller P, Faedo M (1993). The potential of nematophagous fungi to control the free-living stages of nematode parasites of sheep: screening studies. Vet. Parasitol. 49:285-297.
Waller P, Ljungstrom B-L, Schwan O, Martin LR, Morrison D, Rydzik A (2006). Biological Control of Sheep Parasites using *Duddingtonia flagrans*: Trials on Commercial Farms in Sweden. Acta Vet. Scand. 47:23-32.
Waller PJ, Thamsborg SM (2004). Nematode control in green'ruminant production systems. Trends Parasitol. 20:493-497.
Wanapat M, Nontaso N, Yuangklang C, Wora-anu S, Ngarmsang A, Wachirapakorn C, Rowlinson P (2003). Comparative study between swamp buffalo and native cattle in feed digestibility and potential transfer of buffalo rumen digesta into cattle. Asian-Australas. J. Anim. Sci. 16:504-510.
West JW (2003). Effects of Heat-Stress on Production in Dairy Cattle. J. Dairy Sci. 86:2131-2144.
WHO (2011). World Health Statistics 2011, Geneva.
Yang HE, Son YS, Beauchemin KA (2011). Effects of Exogenous Enzymes on Ruminal Fermentation and Degradability of Alfalfa Hay and Rice Straw. Asian-Australas. J. Anim. Sci. 24:56-76.