Indian Journal of Animal Sciences **88** (2): 210–214, February 2018/Article

Growth performance and economics of pre-weaner lambs fed gelatinized and non-gelatinized milk replacer

R S BHATT[1], A SAHOO[2], S K SANKHYAN[3] and M C MEENA[4]

ICAR-Central Sheep and Wool Research Institute, Avikanagar, Rajasthan 304 501 India

Received: 15 July 2017; Accepted: 21 August 2017

ABSTRACT

Influence of milk replacer feeding to lambs was assessed on pre-weaning growth and nutrient utilization. Seven day old Malpura lambs (45) were divided into three groups of fifteen lambs in each group and were fed *ad lib.* creep mixture and roughage (C-0; Control) along with free suckling of dam. Unlike control (C-0), the lambs in two treatment groups were additionally fed with gelatinized (MR-G) and non-gelatinized (MR-Ng) milk replacer with limited suckling from their dam, which were manually milked once in the afternoon (4.00 PM). The MR was fed at 100 ml/lamb/day for first fifteen days and thereafter at 250 ml/lamb/day. The experimental feeding including a digestibility trial was continued until weaning at 3 months of age. Weaning weight, total gain and ADG was higher in MR-G compared to MR-Ng and control and there was 15.25% improvement in MR-G than the control. A lower value of FCR indicated 10.5% improvement in MR-G than the control. The plane of nutrition and digestibility of DM, OM, CP, NDF, hemicellulose was similar in all the three groups. The total milk collected/ewe in MR-G and MR-Ng group was 9.0 kg each that fetched ₹ 360 and it reduced the production cost to ₹ 51.0 in MR-G, 53.1 in MR-Ng compared to ₹ 68.1 in C-0. One time milking of ewes and replenishment with additional milk replacer to lambs promises higher gain and introduction of the gelatinization procedure ensures further improvement in FCR and ease in delivery to lambs.

Key words: Economic analysis, Lamb performance, Milk replacer, Rumen fermentation

Milk replacer feeding promoted faster rate of growth (average daily gain of 154 g, Bhatt *et al*. 2009) during pre-weaning phase. In young ruminants (during first 4 weeks of life), milk proteins, butter fat / fat of vegetable and animal origin, sugars including lactose and glucose are satisfactorily utilized however, non-milk proteins (above 20% of the total protein) and starch cause depression and food refusal and starch digestion can be facilitated by cooking or gelatinization. Feeding cooked grain mixture as gruel rather than in dry form is an effective way to improve starch digestion in pre-ruminants (Krishnamoorthy and Moran 2011). Feeding restricted quantity of milk, stimulates solid food intake which results in faster rumen development. Restricted milk feeding encourages solid feed consumption and has been viewed as a key contributor to the metabolic and physical development of the rumen (Baldwin *et al*. 2004). Calves maintained on reducing milk feeding frequency from twice to once in a day accelerate intake of starter feeds without adversely affecting body weight gain (Hussain *et al*. 2009) or glucose metabolism (Stanley *et al*. 2002).

Therefore, the present experiment was aimed at assessing the effect of two types of milk replacers (i.e. gelatinized and non-gelatinized) with limited suckling (after afternoon milking of dams) on pre-weaning performance of lambs and its economic analysis.

Present address: [1]Principal Scientist (bhatt_rs @yahoo.com), [2]Principal Scientist & Head (sahooarta1 @gmail.com), [3]Principal Scientist (sankhyan1964@yahoo.com), Division of Animal Nutrition; [4]Senior Technical Officer (mcmeena72@gmail.com).

MATERIALS AND METHODS

The experiment was carried out in semi-arid Rajasthan during the period of October to December (2014). During the experiment, minimum and maximum ambient temperature ranged from 8.02 to 16.40°C and 24.90 to 35.24°C . Relative humidity varied from 39.02 to 81.74%.

Seven days old Malpura lambs (45) were divided into three groups of fifteen lambs comprising 7 males and 8 females in each group. The animals were penned in well ventilated enclosure during the day time and let loose with their dam during night. Lambs of control group (C-0) were allowed to suckle their dams at 7.00 h in the morning and at 16.00 h in the evening and were offered standard concentrate mixture, dry cowpea hay and dry Pala (*Ziziphus nummularia*) leaves, and fresh Ardu (*Ailanthus excelsa*) leaves. The two treatment groups (MR-G and MR-Ng) were fed additionally with gelatinized and non-gelatinized milk replacer (MR), respectively and their suckling from the mother was limited by allowing the lambs to suckle only after manual milking of respective dams once at 16.00 h. All other feeding protocol in MR-G and MR-Ng remained similar to C-0. The milk intake of individual lamb was determined by lambs suckling method twice a week.

The lambs of MR-G and MR-Ng groups were offered MR at 100 ml/lamb for first fifteen days thereafter 250 ml/ lamb daily at 11.00 AM. The MR was boiled for 5 min to make the carbohydrate moiety gelatinized to form a homogenous solution for easy delivery and then cooled to 42°C temperature prior to feeding the lambs. Milk replacer was blended with warm water (42°C) to have total solid 17% simulating that of sheep milk. Daily records of green leaves, dry hay and leaves, creep mixture and MR intake were maintained during entire pre-weaning phase of experiment. Metabolizable energy (ME) intake was calculated according to ARC (1990) as ME (MJ/kg DM) = [(digestible OM, g/kg DM)/1000] × 18.5×0.81]. Water was available freely to lambs during experiment. The creep ration offered to experimental lambs consisted of maize 33, barley 38, soyaflakes 7, groundnut cake 14, mustard cake 3, til cake 4, mineral mixture 2 and salt 1 kg per 100 kg.

The growth trial lasted from 7 days to 91 days of age, during which weekly body weights (BW) were recorded prior to feeding and these values were used to determine BW gain. Pattern of growth was calculated on the basis of the 7 d periods. Roughage, creep mixture and MR samples were collected once in a week, which were pooled after dry matter (DM) estimation for further chemical analysis. A digestibility trial was conducted after 75 d of experimental feeding on six representative lambs of each group by double indicator method (Shinde *et al*. 2000). Samples of feed and feces were analyzed for DM by drying at 70°C till constant weight. The OM was determined by ashing at 550°C for 4 h and CP by a Kjeldahl technique (AOAC 1995). Neutral detergent fiber (NDF) was determined as per Van Soest *et al*. (1991) with α-amylase, whereas acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to the method described by Robertson and Van Soest (1981). The chromium concentration in the feces was determined by the method of Shinde *et al*. (2000).

At 84th day of age, rumen liquor (50 ml) samples were withdrawn from six representative intact lambs of each group after 4 h post feeding using a stomach tube. Each sample was placed in a 100 ml glass jar for pH determination using a portable pH meter within 4–5 min of sampling. Thereafter, rumen fluid was strained with four layer of muslin cloth and the strained rumen liquor (SRL) samples were preserved in labelled polypropylene bottles by adding a few drops of saturated mercuric chloride solution at –20°C for further analysis. The SRL samples were analyzed for total nitrogen (Total-N; Micro Kjeldahl), ammonia nitrogen (NH_3- N) and total volatile fatty acids (TVFA; Gas chromatography). Ciliate protozoa numbers in SRL were enumerated following the procedure described by Sahoo *et al*. (1999).

Input cost included cost of creep ration, milk replacer, dry Cowpea hay, Pala leaves and fresh Ardu leaves. The cost took care of harvesting charges of leaves, local market price of ingredients and their processing to prepare creep ration and MR. Cost of rearing (feeding, health care etc) included deployment of contractual services by the institute for rearing the lambs up to three months. Output cost included the cost of milk which was collected from the ewes of test lambs and supplied to Livestock Product Technology Section at ₹ 40/kg. Cost per kg weight gain was calculated after deducting the cost of milk collected from the ewes of test lambs from the total input cost involved in that group and divided by total gain attained by the lambs of that particular group.

Data were subjected to analysis of variance using SPSS Base 14.0 (SPSS Inc. Chicago, USA). Significance among the mean values for three dietary treatments were tested using Tukey's test.

RESULTS AND DISCUSSION

Chemical composition of milk replacer revealed 24.67% CP and 11.23% EE and 8.46% total mineral matter and that of lamb ration 11.94% CP, 2.12% EE and 11.94% mineral matter. The composition of milk replacer (Table 1) was similar to those reported earlier (Bhatt *et al*. 2009).

Plane of nutrition during early age of lamb influences entire growth performance of lambs (Karim *et al*. 2008). Lambs during their early age deposit more muscle and require higher amount of protein, while older lambs deposit more fat and require higher energy in the diet. Milk replacer feeding in pre-ruminant animals aims to supplement dams milk to support better growth of early weaned lambs, whereas, early feeding of creep mixture to young lambs promotes early rumen development and better growth (Ryan *et al*. 2007). High and prolonged milk feeding delays early rumen development. However, the recommended feeding strategy involving modified milk supplement and creep ration promote early establishment of rumen microflora and functional rumen (Sahoo *et al*. 2005). Weaning weight, total gain and ADG was higher ($P<0.05$) in MR-G compared to MR-Ng and control, whereas the difference between C-0 and MR-Ng was non-significant (Table 2). Findings of the present study were in agreement with the observations of Diaz *et al*. (2001), Brown *et al*. (2005) and Bartlett *et al*.

Table 1. Chemical composition (g/100g of dry matter) of milk replacer, creep ration, pala leaves and cowpea hay fed to experimental lambs

	Milk replacer	Creep ration	Pala leaf	Cowpea hay
Chemical composition (%)				
Crude protein	24.67	14.05	16.67	9.97
Dry matter	94.21	94.21	94.06	93.40
Total ash	8.46	11.94	8.31	10.39
Organic matter	92.54	88.06	91.69	89.61
Neutral detergent fibre	15.63	48.27	45.72	59.38
Ether extract	11.23	2.12	2.15	1.97
Acid detergent fibre	6.99	12.76	33.32	33.32

Pala, *Ziziphus numularia*; Cowpea, *Vigna sinensis.*

Table 2. Effect of gelatinized and non-gelatinized milk replacer feeding on growth performance, dry matter intake and feed conversion ratio of experimental lambs

Parameter	C-0	MR-G	MR-Ng	SEM	Significance
Initial weight (kg)	5.7	5.7	5.7	0.29	0.452
Weaning weight (kg)	17.1[a]	18.8[b]	18.1[b]	0.49	0.039
Gain in weight (kg)	11.4[a]	13.1[b]	12.4[b]	0.42	0.027
ADG (g/d)	147.5[a]	170.0[b]	160.5[b]	5.50	0.024
Dry matter intake (g/d)					
Concentrate	185.3[b]	158.0[a]	150.5[a]	12.12	0.041
Dry roughage					
Cowpea hay	24.5	18.4	21.9	3.67	0.467
Pala leaves	52.8	53.8	54.3	2.21	0.231
Fresh Ardu leaves	34.6	33.0	32.6	2.37	0.417
Total roughage	111.9	105.2	108.8	6.24	0.321
Milk suckled	77.5[b]	63.9[a]	62.8[a]	2.15	0.121
RM fed	-	34.8	34.8	2.21	
Total dry matter intake	374	362	359	39.2	0.231
Feed conversion ratio	2.28[b]	2.04[a]	2.23[b]	0.12	0.041

[a,b]Values with different superscripts in a row differ significantly (P<0.05).C-0, control; MR-G, gelatinized milk replacer, MR-Ng, milk replacer- non gelatinized; ADG, average daily gain; SEM, standard error of mean.

Table 3. Effect of gelatinized and non-gelatinized milk replacer feeding on plane of nutrition and digestibility coefficients of experimental lambs

Parameter	C-0	MR-G	MR-Ng	SEM	Significance
Plane of nutrition (g/day)					
Dry matter intake	374	362	359	39.23	0.231
Crude protein intake	66.31	66.06	67.30	2.23	0.541
Digestible CPI	46.85	46.47	45.77	1.23	0.543
DOMI (g)	247.9	238.6	237.2	5.42	0.243
MEI (MJ/d)	3.71	3.57	3.55	0.48	0.123
Digestibility (g/100g)					
Dry matter	67.23	66.24	66.16	1.349	0.942
Organic matter	73.25	70.91	71.84	1.110	0.719
Crude protein	70.66	67.16	68.01	1.544	0.661
Neutral detergent fibre	56.37	57.10	52.32	2.223	0.673
Hemicellulose	73.53	74.82	72.92	1.575	0.259

ME (MJ/kg DM) = [(digestible OM, g/kg DM)/1000] × 18.5×0.81. C-0, control; MR-G, milk replacer- gelatinized; MR-Ng, milk replacer- non gelatinized; CPI, crude protein intake; DOMI, digestible organic matter intake; MEI, metabolizable energy intake; SEM, standard error of mean.

(2006), who reported similar improvement in growth and feed efficiency in young ruminant calves on milk replacer feeding. Similarly, Kaankuka *et al*. (1996) reported that cooking improved (P<0.05) apparent digestibility and retention of dietary DM, nitrogen and ether extract, and the process of gelatinization of starch might have resulted in better lamb performance in the current study. Pattanaik *et al.* (2003) observed improved energy utilization due to thermal processing of the grain moiety of calf starter. Improvement in gain was 15.25% in MR-G as compared to control. The growth rate of lambs may be considered moderate to high as defined in earlier reports (Karim *et al*. 2007, Bhatt *et al*. 2009, Bhatt *et al*. 2011, Bhatt *et al*. 2015). In agreement to our results, Hussain *et al*. (2009) reported similar BW gain and higher starter intake in calf fed milk once than twice a day without affecting glucose metabolism (Stanley *et al*. 2002). Higher (P<0.05) concentrate intake in control than MR-G and MR-Ng group correlate well with this statement. No difference in dry as well as fresh roughage intake was observed between the treatments. Dry matter intake through milk suckling was higher (P<0.05) in control group as dams in test groups were milked in the afternoon before the lambs were allowed to suckle. Total daily DM intake in lambs of all the treatments was similar as relatively higher concentrate intake and milk suckled in control group got compensated through DM consumed through MR in the test groups. A lower (P<0.05) value of feed conversion ratio (FCR) in MR-G as compared to MR-Ng and C-0 was indicative of higher efficiency in converting the feed and nutrients for BW gain. The improvement in FCR was 10.5% in MR-G compared to control. High energy feeds are more efficiently used in growth promotion of young animals (Mahgoub and Early 2000). Tesfaye and Pantea (2003) revealed a weight gain of 231 g/d in lambs fed milk replacer up to 35 d of age. Emsen *et al*. (2004) reported that Awassi lambs can be successfully reared on milk replacer with lesser cost.

Daily DM, protein and metabolisable energy (ME) intakes were not significantly different among lambs in the three treatment groups (Table 3). Digestibility of DM, OM, CP, NDF and hemicellulose was also similar in all the groups. Nutrients fed through milk replacer in test groups were compensated by higher concentrate and higher milk suckled in C-0 group resulting in similar plane of nutrition and nutrient digestibility in all the groups.

Rumen fermentation characteristics and ciliate protozoa population: Rumen fluid pH was significantly (P=0.046) higher in MR-G followed by MR-Ng and control (Table 4). Lower pH in control may be attributed to higher concentrate intake (Tripathi *et al*. 2007). Rumen metabolites, viz. total-N and ammonia- N was higher (P<0.05) in MR-Ng followed by control and lowest in MR-G. Gelatinization resulted in better synchronization of protein and carbohydrates degradation yielding increased microbial protein synthesis (Andrade-Montemayor 2004). This could support better growth in MR-G compared to other groups. An increase in ruminal fluid pH in MR-G and MR-Ng could be due to added protein supply through milk replacer feeding as evidenced with increased ammonia

Table 4. Effect of gelatinized and non-gelatinized milk replacer feeding on rumen metabolites, volatile fatty acid (VFA) production and spirotrich population of experimental lambs

Parameter	C-0	MR-G	MR-Ng	SEM	Significance
Metabolites					
SRL pH	6.83[a]	7.12[b]	7.00[ab]	0.054	0.046
Total N (mg/dl)	208.7[a]	230.1[ab]	247.7[b]	15.016	0.025
TCA-ppt-N (mg/dl)	53.45	46.21	57.62	3.121	0.340
Ammonia (mg/dl)	27.88[a]	34.81[a]	41.64[b]	3.046	0.045
Spirotrichs ($\times 10^4$ cells/ml)	281.04[b]	216.15[a]	217.40[a]	22.018	0.019
VFA production (mmole/l)					
Acetic acid	21.3	17.0	17.25	2.425	0.745
Propionic acid	8.58[b]	4.67[a]	5.65[a]	1.032	0.029
Butyric acid	5.08	3.29	3.92	0.840	0.711
TVFA	36.44[b]	25.94[a]	27.84[a]	3.84	0.029
Proportion (%)					
Acetic acid	60.18	63.72	60.95	1.53	0.647
Propionic acid	22.11	21.86	22.91	2.44	0.986
Butyric acid	13.61	10.84	12.36	1.29	0.714

[a,b]Values with different superscripts in a row differ significantly (P<0.05). C-0, control; MR-G, milk replacer- gelatinized; MR-Ng, milk replacer- non gelatinized; SEM, standard error of mean; TVFA, total volatile fatty acids.

N concentration. The ruminal TVFA concentration increased (P=0.029) in control compared to test groups and the lambs also showed higher concentration of propionic acid in this group. No differences in proportions of individual VFA was observed among the different groups. Rumen ciliate protozoa count ($\times 10^4$) were lower (P=0.019) in MR-Ng compared to control and MR-G. The added fat in MR might have a direct inhibiting effect on ciliate protozoa population (Jet-kins 1993). Fat or oils rich in saturated medium-chain and unsaturated long-chain fatty acids inhibited ruminal protozoa *in vitro* and *in vivo* (Machmuller and Kreu-zer 1999, Ivan *et al*. 2001). In addition, better synchronization of energy and protein in the diet often reported to influence entodiniomorphs population. Chen and Hsu (1998) reported lower population in continuous culture system with better protein and energy synchronized diet.

Higher intake of concentrate in control group added to input cost, which was higher in control (₹ 291.0) as compared to MR-G (₹ 248.0) and MR-Ng (₹ 237.0) group. The additional input cost accrued in MR-G and MR-Ng group due to MR feeding was ₹ 300.2. Thus, the total nutritional input cost accounted to ₹ 776.7 in control and ₹ 1027.7 in MR-G and ₹ 1018.2 in MR-Ng group. An increase in BW gain of 1.7 kg in MR-G and 1.0 kg in MR-Ng yielded additional return of ₹ 425 and ₹ 250 (considering the market price of ₹ 250 per kg live weight), which compensated the input cost of MR fully in MR-G and partially in MR-Ng. Further, the return from sale of 9.0 kg

Table 5. Economic analysis of lambs fed gelatinized and non-gelatinized milk replacer along with control

Parameter	C-0	MR-G	MR-Ng
Input cost (₹)			
Concentrate	291.8	248.9	237.0
Cowpea hay	18.4	13.8	16.4
Dry pala leaves	39.6	40.4	40.7
Green Ardu leaves	51.9	49.5	48.9
Reconstituted milk replacer	0.0	300.2	300.2
Total feeding cost	401.7	652.7	643.2
Management cost	325.0	325.0	325.0
Medicine cost	50.0	50.0	50.0
Total cost (₹)	776.7	1027.7	1018.2
Output cost (₹)			
Milk collected/ewe (kg)	-	9.0	9.0
Price @ (₹) 40/kg	0.0	360.0	360.0
Net input	776.7	667.7	658.2
Gain in weight (kg)	11.4	13.1	12.4
Cost/kg weight gain (₹)	68.1	51.0	53.1

C-0, control; MR-G, milk replacer- gelatinized; MR-Ng, milk replacer -non gelatinized.

milk from dam that were milked once a day in the afternoon accounted to ₹ 360 with an average market price of ₹ 40 per kg milk, which was over and above the profit ascertained from increase in live weight due to MR feeding. When the net input was calculated by considering the return from dam milk the cost per kg live weight gain become ₹ 51 in MR-G and ₹ 53.1 in MR-Ng compared to ₹ 68.1 in control group.

Gelatinization of starch moiety of milk replacer resulted in higher live weight gain with an improved feed conversion efficiency and better return from the sale of lambs. Further, restricted suckling of lambs by allowing one time milking of ewes and compensatory feeding of milk replacer to lambs showed no adverse effect on growth performance. On the contrary, milk replacer feeding supported additional live weight gain with a lower cost of production due to sale of dam milk.

ACKNOWLEDGEMENT

Authors thank Director of the institute for providing necessary facilities and guidance for conducting this research.

REFERENCES

AAC. 1990. *Feeding standards for Australian Livestock*. Ruminant Subcommittee, Australian Agriculture Council. (CSIRO Publishing Melbourne).

Andrade M H, Hernández F, Madrid J and Megías M D. 2004. Comparison of different models to estimate purine bases absorbed in goats. *South African Journal of Animal Science* **34**: 28–30

AOAC. 1995. *Official Methods of Analysis*. 16th edn. Association of Official Analytical Chemists, Gaithersburg, MD, USA.

Baldwin R L, McLeod K R, Klotz J L and Heitmann R N. 2004. Rumen development, intestinal growth and hepatic metabolism in the pre- and post-weaning ruminant. *Journal of Dairy Science* **87**: E55–E65.

Bartlett K S, McKeith F K, VandeHaar M J, Dahl G E and Drackley J K. 2006. Growth and body composition of dairy calves fed milk replacers containing different amounts of protein at two feeding rates. *Journal of Animal Science* **84**: 1454–67.

Bhatt R S, Soren N M, Tripathi M K and Karim S A. 2011. Effect of different levels of coconut oil supplementation on performance, digestibility, rumen fermentation and carcass traits of Malpura lambs. *Animal Feed Science and Technology* **164**: 29–37.

Bhatt R S, Tripathi M K, Verma D L and Karim S A. 2009. Effect of different feeding regimes on pre weaning growth, rumen fermentation and its influence on post weaning performance of lambs. *Journal of Animal Physiology and Animal Nutrition* **93**: 568–76.

Bhatt R S, Sahoo A, Shinde A K and Karim S A. 2015. Effect of calcium salt of fatty acids supplementation on performance of Malpura lambs. *Animal Production Science* **55**: 1123–30.

Brown E G, Vandehaar M J, Daniels K M, Liesman J S, Chapin L, Heisler T D H and Weber Nielsen M S. 2005. Effects of increasing energy and protein intake on body growth and carcass composition of heifer calves. *Journal of Dairy Science* **88**: 585–94.

Ching Y C and Jih T H. 1998. The effects of starch and protein degradation rates, hay sources, and feeding frequency on rumen microbial fermentation in a continuous culture system. *Proceedings of National Science Council* **22**(4): 159–65.

Diaz M C, Van Amburgh M E, Smith J M, Kelsey J M and Hutten E L. 2001. Composition of growth of Holstein calves fed milk replacer from birth to 105-kilogram body weight. *Journal of Dairy Science* **84**: 830–42.

Emsen E, Yaprak M, Yaprak O C, Emsen B and Ockerman H W. 2004. Growth performance of Awassi lambs fed calf milk replacer. *Small Ruminant Research* **53**: 99–102.

Hussain J, Shaheen M, Bhat A S, Ganai N A, and Medhi D. 2009. Effect of milk feeding intervals on growth performance of crossbred jersey calves. *Indian Veterinary Journal* **86**: 1057–59.

Ivan M, Mir P S, Koenig K M, Rode L M, Neill L, Entz T and Mi, Z. 2001. Effect of dietary sunflower seed oil on rumen protozoa population and tissue concentration of conjugated linoleic acids in sheep. *Small Ruminant Research* **41**: 215–27.

Jetkins T C. 1993. Lipid metabolism in the rumen. *Journal of Dairy Science* **76**: 3851–63.

Kaankuka F G, Balogun T F and Tegbe T S B. 1996. Effects of duration of cooking of full-fat soya beans on proximate analysis, levels of antinutritional factors and digestibility by weanling pigs. *Animal Feed Science and Technology* **62**: 229–37.

Karim S A, Tripathi M K and Singh V K. 2007. Effect of varying levels of concentrate supplementation on growth performance and carcass traits of finisher. *Livestock Research and Rural Development* **19**(11). www.cipav.org.co /lrrd /lrrd19/11/ kari19173. htm.

Karim S A, Tripathi M K and Soren N M. 2008. Nutrition of lambs in pre- and post-weaning phase of growth. *Small Ruminant Production in India: Strategies for Enhancing*. (Eds) Karim S A, Tripathi M K, Chaturvedi O H and Shinde A K. Satish Serial Publication House, Delhi, India. pp 51–68.

Krishnamoorthy U and Moran J. 2011. *Rearing Young Ruminants on Milk Replacers and Starter Feeds.* (Ed.) Harinder P S Makkar. FAO Animal Production and Health Manual No. 13, Rome

Machmuller A and Kreuzer M. 1999. Methane suppression by coconut oil and associated effects on nutrient and energy balance in sheep. *Canadian Journal of Animal Science* **79**: 65–72.

Mahgoub O, Lu C D and Early R J. 2000. Effects of dietary energy density on feed intake, body weight gain and carcass chemical composition of Omani growing lambs. *Small Ruminant Research* **37**: 35–42.

Pattanaik A K, Sastry V R B, Katiyar R C and Lal Murari. 2003. Influence of grain processing and dietary protein degradability on nitrogen metabolism, energy balance and methane production in young calves. *Asian Australasian Journal of Animal Science* **16**: 1443–50.

Robertson J B and Van Soest P J. 1981. *Detergent System of Analysis and its Application to Human Foods*. Cornell University, Ithaca, New York.

Ryan S M, Unriuch J A, Corrigan M E, Drouillard J S and Seyfert M. 2007. Effect of concentrate level on carcass traits of Boer crossbred goats. *Small Ruminant Research* **73**: 67–76.

Sahoo A, Agarwal N, Kamra D N, Chaudhary L C and Pathak N N. 1999. Influence of the level of molasses in de-oiled rice bran based concentrate mixture on rumen fermentation pattern in crossbred calves. *Animal Feed Science and Technology* **80**: 83–90.

Sahoo A, Kamra D N and Pathak N N. 2005. Pre- and postweaning attributes in faunated and ciliate-free calves fed calf starter with or without fish meal. *Journal of Dairy Science* **88**: 2027–36.

Shinde A K, Bhatta R and Sankhyan S K. 2000. *Research Techniques in Grazing Studies*. ICAR- Central Sheep and Wool Research Institute, Avikanagar, India.

Stanley C C, Williams C C, Jenny B F, Fernandez J M, Bateman II H G, Nipper W A, Lovejoy J C, Gantt G T and Goodier G E. 2002. Effects of feeding milk replacer once versus twice daily on glucose metabolism in Holstein and Jersey calves. *Journal of Dairy Science* **5**: 2335–43.

Tesfaye A and Pentea M. 2003. The principles of milk replacer feeding and morpho-physiological changes in milk replacer fed lambs. *Seria Medicina Veterinaria* **60**: 151–56.

Tripathi M K, Chaturvedi O H, Karim S A, Singh V K and Sisodiya S L. 2007. Effect of different levels of concentrate allowances on rumen fluid pH, nutrient digestion, nitrogen retention and growth performance of weaner lambs. *Small Ruminant Research* **72**(2): 178–86.

Van Soest P J, Robertson J B and Lewis B A. 1991. Methods of dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. Symposium: carbohydrate methodology, metabolism and nutritional implications in dairy cattle. *Journal of Dairy Science* **74**: 3583–97.

Vicenti1 A, Maria A C, Marco R and Francesco T. 2004. Effect of type of suckling and polyunsaturated fatty acid use on lamb production, chemical and fatty acid composition of raw and cooked meat. *Italian Journal of Animal Science* **3**: 81–91.

Williams A G and Withers E S. 1991. Effect of ciliate protozoa on the activity of polysaccharide- degrading enzymes and fiber breakdown in the rumen ecosystem. *Journal of Applied Bacteriology* **70**: 144–55.