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Effects of different carbohydrate sources on the performance, ruminal and blood metabolites and nutrients digestibility in fattening male-lambs fed corn steep liquor

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Abstract The current experiment was conducted to evaluate the effects of replacing dietary corn/barley mixture with molasses, a ruminal fermentable carbohydrate source, at 0, 50 and 100 g/kg dietary dry matter (DM) in the diet of fattening lambs containing corn steep liquor (CSL, 130 g/kg DM), a ruminal degradable protein source. Twenty-four male Lori lambs (average body weight of 27.7±3.41 kg; 120.0±7.5 days of age) were randomly assigned into three groups of eight lambs each in a balanced completely randomized design. Results indicated that supplementing dietary CSL with increasing levels of molasses up to 100 g/kg DM linearly increased the digestibility of organic matter and ash-free neutral detergent fiber ($P<0.05$). Increasing the level of molasses in the CSL containing diets had no effect on ruminal pH ($P>0.05$), but linearly decreased rumen concentration of NH_3-N ($P<0.05$). Except for total volatile fatty acids (VFAs) and molar proportion of butyrate which were increased linearly with increasing dietary molasses level, other VFAs were not influenced by the experimental diets. Increasing the level of molasses in the diet up to 100 g/kg DM linearly increased plasma total protein concentration while linearly reduced blood urea nitrogen concentration. Total weight gain and average daily gain were improved but feed conversion ratio decreased linearly with increasing dietary level of molasses. In conclusion, supplementing CSL with molasses at the level of 100 g/kg dietary DM increased the nutrient digestibility and performance of fattening lambs.

Keywords: corn steep liquor, energy source, feed intake, rumen fermentation, sheep

Introduction

Dry climatic conditions and shortage of good quality forage - have considerably increased animal feed costs in developing countries including Iran. As such, incorporating cheap and locally available agricultural by-products or co-products would be an appropriate feeding strategy to enhance animal production and decrease environmental pollutions (Azizi-Shotorkhft et al., 2016). Corn steep liquor (CSL), a main co-product of corn starch processing, is one such a co-product that can be included in the diets of ruminants. The high crude protein (CP) [420 g/kg dry matter (DM)] and metabolizable energy - (ME) [12.6 MJ/kg DM] as well as its good mineral and B-vitamin contents (Filipovic et al., 2002; Nisa et al., 2004; Azizi-Shotorkhoft et al., 2016) has made CSL a valuable co-product for being incorporated in ruminants' diets. Annual production of CSL in Iran is about 4,000 t (Golpour, 2012) with an acidic pH, viscous slurry nature, light to dark brown colour and ensiled odour (Mirza and Mushtaq, 2006). The acidic pH (3.86, Azizi-Shotorkhoft et al., 2006) of CSL is due to its high lactic acid content (200-250 g/kg

DM, Sarwar et al., 2004) which might be a hurdle for its inclusion in the ruminant diets. In some studies, CSL also was used as a pellet binder (Chovatiya et al., 2010).

Corn steep liquor was included in the diets of ruminants, but the results were conflicting. Ribeiro-Filho and Trenkle (2002) reported that feeding steers with diets containing 100 g/kg DM of CSL had no effect on feed intake (FI) and average daily gain (ADG). Incorporation of CSL in lamb diet up to 50 g/kg DM increased ADG and improved feed conversion ratio (FCR), but at the levels higher than 100 g/kg DM the lamb performance decreased (Mirza and Mushtaq, 2006). Azizi-Shotorkhoft et al. (2016) found that activities of rumen fibrolytic microbial enzymes, digestibility of nutrients and consequently animal performance decreased when CSL was fed to fattening lambs at the level of 100 g/kg, but activity of rumen proteases was increased.

Shahzad et al. (2016) found that more than 90% of CP content in CSL was in the form of amino acids and peptides, which can be rapidly degraded in the rumen. Lardy et al. (1997) also reported that CSL proteins were fully degraded in the rumen. The high protein solubility and degradability of CSL in the rumen may lead to asynchrony between protein and energy utilisation. This problem can be alleviated by adding a readily available source of carbohydrate such as cereal grains or molasses, thereby improving microbial protein synthesis (MPS) and consequently the animal performance (Cole and Todd, 2008). Molasses is a cost-effective energy source and has a higher ruminal degradation rate than cereal grains. Therefore, its incorporation in the ruminants' diets when CSL is used, as a protein source, may lead to a better synchrony of protein and energy utilisation in the rumen compared to cereal grains.

Therefore, the present study aimed to evaluate the effects of replacing barley and corn grains with molasses on the production performance, some ruminal and some blood metabolites and nutrient digestibility of fattening male-lambs fed CSL containing diets.

Materials and methods

Animals and experimental diets

The chemical composition of CSL, purchased from a commercial supplier (Glucozan Company, Qazvin, Iran) is shown in Table 1. Animal care and use were approved by the Ethical Committee of Lorestan University and conducted according to the guidelines outlined in the Guide for the Care and Use of Agriculture Animals in Agriculture Research and Teaching (FASS, 2010). Twenty-four fat-tailed male Lori lambs) 120.0±7.5 days of age and initial body weight (IBW) of 27.7±3.41 kg (were randomly allocated to three experimental diets in a completely randomized design (CRD). Lambs were housed in individual pens (1.3×1.2 m). The feeding trial lasted for 89 days with two weeks for adaptation to the pens and diets, and 75 days for fattening period. During the adaptation period, lambs were vaccinated against enterotoxaemia (3 mL per lamb; Razi Vaccine and Serum Research Institute, Iran), and treated with anthelmintics for external (1 mL of Azantole 10% per 7 L of water, as spraying method; Bayer, Germany) and internal (Triclabendazole+levamisole, 12 mL per lamb; Darou-Pakhsh Co., Iran) parasites.

Table 1. Chemical composition of corn steep liquor (CSL, % of dry matter or as stated)

Item	CSL
Dry matter	52.5
Organic matter	92.5
Crude protein	42.5
Soluble protein	36.5
Neutral detergent fiber	0
Acid detergent fiber	0
Ether extract	1.25
Lactic acid	15.5
Metabolizable energy (MJ/kg DM)	12.6

Each value is the mean of 4 replicates.

The experimental diets were iso-energetic and iso-nitrogenous (Table 2; NRC, 2007). The diet ingredients were similar, except that corn/barley was replaced by molasses at the levels of 0 (control), 50 (M5) or 100 (M10) g/kg DM. The diets were provided ad libitum as a total mixed ration in tree equal meals daily at 08:00, 14:00 and 20:00 h for 75 days with a 5% of daily refusal. The feed offered and orts of each lamb were collected and weighed daily. All animals had free access to drinking water. Lambs were individually weighed on days 0, 30, 45, 60 and 75 at 8:00 h after 16 h of feed deprivation. In each period, individual ADG was calculated using total gain (TG) divided by number of days, and the FCR was calculated by dividing daily DM intake (DMI) to ADG.

On day 50 of the experiment, fecal samples (50 g) were collected for 5 consecutive days for all lambs, and pooled (5 samples) to determine total-tract apparent digestibility of nutrients using acid-insoluble ash as an internal marker (Van-Keulen and Young, 1977).

Rumen fluid (RF) samples (40-50 mL) were collected on day 55 of trial 3 h after the morning feeding using a stomach tube. To avoid saliva contamination, the first 20 mL of RF form each animal was discarded (Jasmin et al., 2011). The RF was strained through 4 layers of cheese cloth and pH was immediately determined using a pH meter (Sentron, model A102-003). For ammonia (NH_3-N) determination, 5 mL of strained RF (SRF) were acidified with1 mL of 0.2 N HCl to stop fermentation and frozen (−20oC). For volatile fatty acid (VFAs) analysis, 1 mL of SRF was mixed with 0.25 mL of an acid solution containing 200 mL/L of orthophosphoric acid and 20 mM 2-ethyl-butyric acid and frozen at -20oC.

On day 57, blood samples were collected from all lambs via jugular venipuncture into tubes containing lithium heparinate 3 h after the morning feeding. Plasma was harvested by centrifuging at 3000×g for 15 min and kept at −20oC pending further analyses.

Table 2. Feed ingredients, chemical composition (% of DM) and metabolizable energy of the experimental diets

	Energy sources		
	Control	M5	M10
Ingredients			
Wheat straw	10.0	10.0	10.0
Alfalfa hay (dried)	20.0	20.0	20.0
Wheat bran	10	9.0	9.0
Soybean meal	3.0	4.0	4.0
Corn steep liquor (CSL)	13.0	13.0	13.0
Barley grain, ground	19.75	17.25	14.75
Corn grain, ground	19.75	17.25	14.75
Molasses	0	5.0	10
Vitamin-mineral premix[1]	2.0	2.0	2.0
Salt	0.5	0.5	0.5
Sodium bicarbonate	2.0	2.0	2.0
Chemical composition			
Dry matter (% of fresh weight)	86.8	85.7	85.5
Organic matter	89.5	89.1	88.6
Crude protein	15.8	15.7	15.6
Neutral detergent fiber	28.9	27.8	26.6
Acid detergent fiber	15.8	15.4	15.1
Ether extract	2.76	2.65	2.50
Non-fiber carbohydrates	42.1	42.9	43.9
Metabolizable energy (Mcal/kg DM)	2.55	2.54	2.52

M5, diet containing 5% molasses; M10, diet containing 10% molasses. [1]Contained (per kg): 99.2 mg Mn, 50 mg Fe, 84.7 mg Zn, 1 mg Cu, 1 mg I, 0.2 mg Se, 9000 IU vitamin A, 2000 IU vitamin D and 18 IU vitamin E (Roshd-Daneh, Karaj, Iran).

Analytical procedures

Experimental diets, CSL and orts were analyzed for DM (# 930.15; AOAC, 2000), ash (# 924.05; AOAC, 2000), and CP (# 984.13; AOAC, 2000), ash-free neutral detergent fiber (NDFom) and ash-free acid detergent fiber (ADFom; without sodium sulphite and with amylase treatment; Van Soest et al., 1991) and lignin (sa) (Robertson and Van Soest, 1981). Soluble protein (SP) content in CSL was determined as described by Licitra et al. (1996), and ME content of CSL was estimated by gas production technique (Marten and Barnes, 1980). The non-fiber carbohydrate (NFC) content of the experimental diets was calculated as (Hall, 2000):

NFC (g/kg DM) = 1000 – [NDF (g/kg DM) + CP (g/kg DM) + EE (g/kg DM) + ash (g/kg DM)].

Rumen concentration of NH_3-N was determined according to the procedure described by Broderick and Kang (1980). The VFAs were determined by Shimadzu GC-14 B gas chromatography (GC) machine (Shimadzu, Tokyo, Japan) equipped with a Carboxen TM 1000, 45/60, 2 m × 1/8 column (Supelco, St. Louis, MO, USA) and a flame ionization detector. The VFAs were measured using 1 mL of the RF collected in a microfuge tube containing 0.20 mL metaphosphoric acid (25 mL/100 mL). An internal standard (2-ethyl-n-butyric acid) was used to help quantify VFA concentrations. The mixture was allowed to stand for 3 h at room temperature and centrifuged at 15,000 × g at 4°C for 15 min and supernatants were transferred to chromatography vials for VFA analysis and stored at -20°C until analysis. For this purpose, 0.2 µL supernatant was injected into a gas chromatograph (Nucon-5765) equipped with a double flame ionization detector (FID) and chromosorb glass column (4 ft length and 1.8 mm diameter) as described by Cottyn and Boucque (1968). The gas flows for nitrogen, hydrogen and air were 30, 30 and 320 mL/min, respectively. The temperature of the injector oven, column oven and detector was 270, 172 and 270 °C, respectively. Plasma samples were analyzed by colorimetric methods for total protein (TP), albumin, blood urea-N (BUN), creatinine, triglycerides and glucose using Pars Azmun Diagnostic kits (Tehran, Iran).

Statistical analysis

Data on the digestibility of nutrients, ruminal and blood parameters were analyzed using MIXED procedure of SAS 8.2 (2001). The model used was:

$Y_{ij} = \mu + T_i + e_{ij}$

where Y_{ij} is the dependent variable, μ is the population mean for the variable, T_i is the treatment effect on the assessed parameters (i.e. nutrient digestibility, blood and ruminal parameters) and e_{ij} is the random error associated with the observation ij.

Data on growth performance were analyzed using the following model:

$Y_{ij} = T_i + ß_i(X_{ij}- \bar{X})+e_{ij}$

where Y_{ij} is the observation parameters, T_i is the fixed effect of treatment on the assessed parameters, $ß_i$ is the regression coefficient, X_{ij} is the IBW with mean $\bar{X}$ (covariate) and e_{ij} is the standard error of the term. The IBW was used as covariate for analysis of body weight gain data.

For all statistical analyses, significance was declared at $P<0.05$. Differences among means were tested using the Duncan's test (Steel and Torrie, 1980). Orthogonal contrasts were used to test linear (L) or quadratic (Q) effects of molasses levels on the assessed parameters. None of the Q effects were significant.

Results

Nutrient digestibility

Supplementing dietary CSL with increasing levels of molasses linearly increased organic matter (OM) ($P=0.05$) and NDFom ($P<0.05$) digestibility, with no significant effect on DM, CP and ADFom digestibility ($P>0.05$; Table 3).

Ruminal parameters and blood metabolites

The effects of experimental diets on rumen fermentation parameters and blood metabolites are presented in Table 4. Increasing the level of molasses in the CSL containing diets had no effect on ruminal pH ($P>0.05$), but linearly decreased rumen concentration of NH_3-N ($P<0.05$). Except for rumen concentrations of total VFA -

and molar proportion of butyrate which were increased linearly (L, P<0.05) with increasing dietary molasses level, rumen concentrations of other individual VFAs including acetate (C2), propionate (C3), iso-butyrate, valerate, isovalerate and C2:C3 were not affected by the experimental diets.

Increasing the level of molasses in the diet up to 10% linearly increased plasma TP concentration, while linearly reduced BUN concentration (P<0.05; Table 4). Concentrations of other plasma metabolites including albumin, creatinine, triglycerides and glucose remained unchanged with the increasing level of molasses in the diets.

Feed intake and growth performance

During the first 30 days of the experiment, ADG increased linearly (P<0.05; Table 5) by increasing dietary molasses level. During the whole fattening period (i.e. 1-75 days), total weight gain (TWG) and ADG were increased (P<0.05) but FCR decreased linearly (P<0.05; Table 5) with increasing molasses level in the diet. However, final body weight (FBW), DM, OM, CP, NDFom and ADFom intakes remained unchanged by feeding the experimental diets.

Table 3. *In vivo* nutrient digestibility coefficients of Lori-male lambs fed experimental diets containing corn steep liquor (CSL)

Item	Experimental diets (energy sources)			SEM	P-value
	Control	M5	M10		L
Dry matter	0.777	0.790	0.797	0.013	0.35
Organic matter	0.790^{b}	0.802^{ab}	0.828^{a}	0.011	0.05
Crude protein	0.782	0.792	0.795	0.021	0.68
Neutral detergent fiber	0.579^{b}	0.602^{ab}	0.610^{a}	0.008	0.02
Acid detergent fiber	0.522	0.513	0.538	0.014	0.47

M5, diet containing 5% molasses; M10, diet containing 10% molasses; SEM, standard error of the mean; L, linear.
$^{a-b}$ Within rows, means with common superscript(s) do not differ (P>0.05).

Table 4. Ruminal parameters and plasma metabolites of Lori-male lambs fed experimental diets containing corn steep liquor (CSL)

Item	Experimental diets (energy sources)			SEM	P-value
	Control	M5	M10		L
Ruminal Parameters					
pH	6.26	6.20	6.18	0.036	0.11
Ammonia (mg/dL)	21.8^{a}	18.2^{bc}	17.6^{c}	0.589	<0.01
Total VFA (mmol/L)	101^{b}	106^{ab}	113^{a}	3.22	0.05
Acetate (C2)	57.6	60.3	61.7	3.03	0.24
Propionate (C3)	20.4	19.8	20.1	0.634	0.53
Butyrate	17.7^{b}	19.1^{ab}	19.9^{a}	0.571	0.02
Iso-butyrate	2.27	2.24	2.29	0.375	0.73
Valerate	2.66	2.57	2.72	0.165	0.44
Iso-valerate	1.89	1.93	1.96	0.136	0.76
C2:C3	2.85	3.08	3.07	0.149	0.41
Plasma metabolites					
Total protein (g/dL)	7.52^{b}	7.61^{ab}	8.15^{a}	0.201	0.05
Albumin (g/dL)	3.60	3.65	3.90	0.122	0.15
Blood urea-N (mgdL)	3.88^{a}	3.48^{bc}	3.37^{c}	0.073	<0.01
Creatinine (mg/dL)	0.543	0.415	0.531	0.125	0.94
Triglycerides (mg/dL)	28.8	30.2	29.5	2.72	0.84
Glucose (mg/dL)	77.8	77.5	76.8	2.69	0.79

M5, diet containing 5% molasses; M10, diet containing 10% molasses; SEM, standard error of the mean; L, linear.
$^{a-b}$ Within rows, means with common superscript(s) do not differ (P>0.05).

Discussion

Digestibility of nutrients

Replacing corn and barley with molasses in the CSL containing diets improved the apparent total tract digestibly of OM and NDFom, which might be attributed to the lower fiber contents (i.e. NDFom and ADFom) of molasses containing diets compared to the control diet (Table 2). Increasing the NFC content of diet through increased molasses level (Table 2) is another possible reason. The water soluble carbohydrates (WSC) in molasses are fermented in the rumen more rapidly compared to the starch of cereal grains (Chamberlain et al., 1993). Therefore, WSC supplied by molasses, as an energy source, may provide a better synchrony of protein and energy utilization by the rumen micro-organisms when CSL, as a source of rumen degradable protein (RDP), is included in the diet. Indeed, it has been shown that activity of rumen fibrolytic enzymes and fiber digestibility were improved when sheep fed diets synchronized for fermentable energy and RDP sources (Azizi-Shotorkhoft et al., 2018). The findings of the present study agreed with those of Azizi-Shotorkhoft et al. (2013) who reported that adding 10% molasses to diet of sheep fed processed broiler litter, as a non-protein nitrogen (NPN) source, increased the apparent total tract digestibility of DM, CP and NDF. Additionally, in the study

of Huhtanen (1988), the OM digestibility in cattle increased when barley was substituted with molasses in a silage based diet. Broderick and Radloff (2004) also reported that adding molasses at 0, 40, 80 or 120 g/kg of DM instead of corn linearly increased the apparent total tract digestibility of DM, OM, NDF and ADF in dairy cows.

Table 5. Effect of energy sources on feed intake and growth performance of Lori-male lambs fed experimental diets containing corn steep liquor (CSL)

Item	Experimental diets (energy sources)			SEM	P-value
	Control	M5	M10		L
Day 1-75					
Initial body weight (kg)	27.5	27.4	28.4	0.865	0.41
Final body weight (kg)	43.2	44.4	45.6	0.881	0.11
Total weight gain (kg)	15.8[b]	17.0[ab]	17.3[a]	0.406	0.04
Average daily gain (g)	212[b]	229[a]	230[a]	3.65	0.02
Feed conversion ratio	6.32[a]	6.10[b]	6.13[b]	0.042	0.04
Dry matter intake (g)	1385	1380	1400	45.4	0.56
Organic matter intake (g)	1235	1223	1244	7.90	0.33
Crude protein intake (g)	220	218	219	5.29	0.84
NDF intake (g)	402	366	389	9.41	0.13
ADF intake (g)	218	209	214	4.34	0.23
Day 1-30					
Total weight gain (kg)	5.30	5.88	6.02	0.247	0.15
Average daily gain (g)	174[b]	197[ab]	202[a]	9.41	0.04
Feed conversion ratio	6.27	5.90	6.06	0.249	0.29
Dry matter intake (g)	1090	1144	1205	35.2	0.10
Day 31-45					
Total weight gain (kg)	3.47	3.47	3.73	0.199	0.26
Average daily gain (g)	226	229	247	9.85	0.15
Feed conversion ratio	5.97	5.90	5.54	0.274	0.84
Dry matter intake (g)	1426	1355	1418	57.2	0.31
Day 46-60					
Total weight gain (kg)	3.61	3.68	3.82	0.319	0.34
Average daily gain (g)	238	244	254	6.48	0.13
Feed conversion ratio	6.07	6.11	5.89	0.143	0.32
Dry matter intake (g)	1450	1498	1465	52.9	0.53
Day 60-75					
Total weight gain (kg)	3.31	3.42	3.67	0.256	0.23
Average daily gain (g)	221	228	245	17.1	0.24
Feed conversion ratio	6.54	6.55	6.22	0.206	0.85
Dry matter intake (g)	1470	1500	1507	52.2	0.45

M5, diet containing 5% molasses; M10, diet containing 10% molasses; SEM, standard error of the mean; L, linear; NDF, neutral detergent fiber; ADF, acid detergent fiber.
[a-b] Within rows, means with common superscript(s) do not differ (P>0.05).

Ruminal parameters and blood metabolites

In the present study, the rumen pH values did not differ between the diets and were within the normal physiological ranges (Van Soest et al., 1994); these were consistent with the results of Hatch and Beeson (1972) who found that replacing corn with molasses at the levels of 10 or 15% in the diet of steers had no effect on the rumen pH. In the literature, the effects of adding molasses on rumen pH are inconsistence. In several studies, dietary supplementation of molasses decreased rumen pH (Benavides and Rodriguez, 1971; Sahoo et al., 2002; Azizi-Shotorkhoft et al., 2012, 2013), while in the others rumen pH was increased by adding molasses to the diet (Preston et al., 1971; Marty and Henderickx, 1973; Araba et al., 2002).

Reduction of ruminal NH_3-N with increasing dietary molasses level in the present study was likely due to a better synchrony between supply of rumen fermentable organic matter (mostly provided by WSC of molasses) and rumen degradable protein (supplied by SP content of CSL) which may have improved utilization of the produced ammonia for MPS. However, in the present study MPS was not measured or estimated. In agreement with our findings, Chamberlain et al. (1993) stated that sugars, particularly sucrose, reduced ruminal NH_3-N concentration compared to wheat starch in sheep fed a grass silage-based diet. They also reported that intestinal supply of microbial protein (MP) in sheep fed sucrose supplemented diet was 2.8 g/d more than those fed starch rich diets. In line with our results, Obara and Dellow (1993) found that intraruminal infusion of urea and sucrose reduced rumen concentration of NH_3-N in sheep fed chopped alfalfa hay. However, in the study of Sahoo et al. (1999) ruminal ammonia was increased by increasing the level of molasses in the diet, which was due to a sudden drop in rumen pH and reduced NH_3-N absorption across the rumen wall.

The VFAs represent the main supply of ME for the ruminants, and a decrease in VFA production would be nutritionally unfavourable (Van Soest, 1994). In the present study, total VFA and molar proportion of butyrate increased with increasing molasses level in the diets, which was probably attributed to the improved OM and NDF digestibility. Enhanced molar proportion of butyrate by supplementing the diet with molasses was due to the

fact that molasses shifts rumen fermentation towards production of more butyrate at the expense of propionate (Hatch and Beeson, 1972, Pate, 1983). Consistent with our results, Azizi-Shotorkhoft et al. (2012) reported that dietary replacement of corn and barley with molasses at inclusion level of 24% in sheep diet increased rumen concentrations of total VFA and butyrate. In another study, adding different levels of molasses up to 10% in the diet of sheep fed 24% processed broiler litter, as a NPN source, increased rumen butyrate concentration, but had no effect on the concentrations of other VFAs.

Increased blood TP concentration by increasing the level of molasses in the diet might be due to increased intestinal supply of MP (Abarghuei et al., 2014; Jolazadeh et al., 2015), which would enhance the availability of amino acids for absorption in the intestine. Decreased BUN in lambs fed increasing levels of molasses was due to lower rumen NH_3-N synthesis (Table 4). It has been demonstrated that there is a positive correlation between rumen concentration of NH_3-N and BUN concentration (Sannes et al., 2002). Blood glucose concentration was similar among the dietary treatments which was probably due to the same ruminal propionate production because propionate is the main glucose precursor in ruminants accounting for for greater than 75% of total blood glucose concentration (Brockman, 1993).

Feed intake and performance

Increased TWG, ADG and improved FCR in lambs fed CSL containing diets supplemented with increasing molasses levels were not accompanied with increased feed intake thus confirming the claim that synchronous supply of ruminal fermentable energy and protein improves the growth performance in ruminants by increasing MPS as previously reported by several researchers (Sinclair et al., 1991, 1993; Khezri et al., 2009). Based on Cornel Net Carbohydrate and Protein System (CNCPS) model, microorganisms that ferment soluble sugars (i.e. in molasses) could produce approximately 18% more MPS compared with starch fermentation (i.e. in high moisture corn). Increased OM and NDFom digestibility (Table 3) and total VFA production (Table 4) in lambs fed M5 and M10 diets could also have contributed to improved TWG, overall ADG and FCR. Similarly, Richardson et al., (2003) found that synchronized supply of rumen fermentable energy and protein in growing lambs did not affect their feed intake which is supported by our findings. Also, Chanjula et al. (2004) demonstrated that synchronized supply of starch sources and NPN in the rumen of lactating dairy cows did not affect the feed intake, but improved milk production. In another study, Sahoo et al. (1999) found that feeding different levels of molasses (up to 30% dietary DM) to the male crossbred calves at the expense of de-oiled rice bran had no effect on DMI, wheat straw and concentrate intakes.

Conclusion

Results of the present study showed that dietary replacement of a corn/barley mixture with molasses up to 100 g/kg DM increased the OM and NDFom digestibility, rumen concentration of total VFA and production performance of fattening lambs fed a diet containing CSL, while feed intake was unchanged. However, more experiments are needed to improve the utilization efficiency of CSL as a cheap protein source for ruminants.

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