Original paper

EFFECT OF CARBOHYDRATE SOURCE AND ADDITION CANOLA SEED ON GROWTH PERFORMANCE AND NUTRIENT DIGESTIBILITY OF LAMBS

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Abstract

The objective of this study was to investigate effects of partial replacement of starch with neutral detergent soluble fiber with or without roasted canola seed as a fat source, and possible interactions on apparent digestibility and growth performance of growing lambs. For this purpose, 24 male lambs were used in a completely randomized design with a 2×2 factorial arrangement of treatments. Dietary treatments were 1- starch from barley, 2- starch from barley with roasted canola seed, 3- soluble fiber from beet pulp, and 4- soluble fiber from beet pulp with roasted canola seed. The experimental period was 84 days and forage:concentrate ratio was 10:90 for all diets. Treatments had no significant effect on the dry matter intake, feed conversion ratio, apparent digestibility of protein and organic matter ($p>0.05$). High starch diets compared with high soluble fiber diets caused a significant decrease in the digestibility of dry matter, organic matter, ADF and NDF ($p<0.01$). Canola seed addition to the diets significantly decreased ADF and NDF digestibility ($p<0.01$). The carbohydrate source by canola seed interaction was significant for weight gain and rumen pH ($p<0.01$) indicating that addition of canola seed to high starch diet increased weight gain and rumen pH more dramatically in comparison with soluble fiber diet ($p<0.01$). It is concluded that addition of canola seed to high starch diet had favorable effects on growth performance and rumen pH but because of its negative effect on fiber digestibility and its different response depend on carbohydrate source, more research is needed for conclusion.

Key words: *Dietary energy source, Digestibility, Fattening lamb*

Introduction

Neutral detergent-soluble carbohydrates (NDSC) vary in their fermentation and digestion characteristics, including the profile of metabolizable nutrients that they provide. Ruminal fermentation of starch tend to produce relatively more propionate than acetate, and may produce lactic acid. In contrast, fermentations of neutral detergent-soluble fiber (NDSF) carbohydrates, such as pectic substances, tend to produce more acetate than propionate and do not generate appreciable amounts of lactic acid (Strobel and Russell, 1986). Starch has the potential to be digested in the small intestine, and the resulting monosaccharides are absorbed. The nonstarch polysaccharides of NDSF are digested only by microbial enzymes. It may be possible to influence both the nutrient digestibility and animal growth by modifying the supply of metabolizable nutrients to the fattening lamb through altering the proportions of NDSC types in the diet.

Barley is starch rich and beet sugar pulp is one of the pectin rich feedstuffs commonly fed to fattening lamb. In the most common lamb-finishing system in Iran, feedlot lambs are fed high-concentrate diets. However, this feeding program, is usually associated with digestive disorders, such as ruminal acidosis, causing reduced feed intake, impaired nutrient absorption and depressed animal performance (Bodas et al., 2007). Acidosis also prejudices the reticulo-rumen epithelial tissues producing parakeratosis (Wang et al., 2009). In the study by Strobel and Russell (1986), pectin utilization decreased by 53 % when the pH decreased from 6.7 to 6.0. These researchers concluded that pectin-utilizing bacteria are very sensitive to low pH.

Inclusion of whole oilseeds in the diets of ruminants may provide a high quality protein and increase the energy density of the diet. Whole canola seed contains high levels of lipid (approximately 43%) and large amount of protein (approximately 20.5% CP), with a similar to slightly lower amino acid availability than that of soybean meal (Bell, 1984).

Little information is found in the literature with respect to the effects of partial substitution of cereal grains with pectin-rich feedstuffs, such as sugar beet pulp in the high concentrate diets. Also, few data are available concerning the interaction between NDSC type and fat supplementation. Therefore, the objective of this study was to investigate partial substitution of barley grain with beet pulp with or without roasted canola seed supplementation on growth performance and nutrient digestibility of lambs fed by high concentrate diets.

Material and methods

This study was undertaken at the Experimental Farm of Agriculture College, Ramin Agriculture and Natural Resources University of Ahvaz, Iran. Twenty-four male lambs with an average age of 118 ± 10 days and average weighing 23.7± 2.5 kg, were used in a completely randomized design with a 2 * 2 factorial arrangement of treatments. Dietary treatments consisted of 1) barley starch, 2) barley starch with roasted canola seed, 3) beet pulp soluble fiber, 4) beet pulp soluble fiber with roasted canola seed. Ingredients and chemical composition of the experimental diets are reported in Table 1. Before doing the experiment, all lambs were maintained under the same feeding management and environmental condition. The lambs were weighed and randomly allocated to one of four dietary treatments according to live weight. The lambs were individually penned (1*1.5M) and fed for 84 days with two week of adaptation to the diets. Before starting the experiment, the lambs were dewormed by dosing with Dieverm and vaccinated against enterotoxaemia (Razi Institute, Hesarak, Karaj, Iran). The experimental diets were formulated based on NRC (2007) requirements of a finishing lamb. The roughage:concentrate ratio was 10:90. The animals were fed ad libitum a TMR twice daily, morning (0600 h) and afternoon (1800 h). During the experimental period, to calculate the daily gain, the lambs were weighed every 7 days from weaning until the end of the experiment. The weights were taken after about 14 h fasting to minimize error. In order to estimate apparent digestibility of dry matter and nutrients, feed intake and refusals were collected each day, weighed to accurately determine DMI, and discarded also, fecal output was collected thrice (At days 20, 40, and 80 of age), weighed, and recorded. Samples were stored frozen (-20°C) until analysis. Feed, orts and faeces were analysed for DM by drying at 55 ◦C for 48 h. The OM was determined by ashing at 550 ◦C for 6 h (968.08; AOAC, 2006) and CP by a Kjeldahl technique (988.05; AOAC, 2006). Neutral detergent fiber was determined by a procedure of Van Soest et al. (1991) without sodium sulphite or α-amylase and acid detergent fiber was determined according to the method described by Van Soest (1981).

Data analysis was performed using a statistical model based on a completely randomized design with repeated measurements using the model:

$$Y_{ijk} = \mu + T_i + W_l + A_j + D_k + (T*D)_{ik} + \alpha_{iljk}$$

Y_{ijk} = Dependent variable; μ = The overall mean; T_i = Treatments (NDSC source, Addition of roasted canola seed and interaction among these factors); W_l = The effect of initial weight, as covareat; A_j = Random residual effects in the treated lambs; D_k = Effect of Time; $(T*D)_{ik}$ = Interaction of treatment and time, α_{iljk} = The residual error.

Results and discussion

Table 1. *Ingredient and chemical composition (g/kg DM) of the basal experimental diet*

Ingredients (% DM)	Experimental diets®			
	Starch		Beet pulp	
	-RCS	+RCS	-RCS	+RCS
Alfalfa hay	10	10	10	10
Milled barley	64	62	28	28
Dried beet pulp	0	0	36	36
Roasted Canola seed	0	7	0	7
Wheat bran	4	4	0	0
Soybean meal	10	12	14.2	16.2
Canola meal	10	3	10	3
Limestone	1.2	1.2	1.0	1.0
Salt	0.2	0.2	0.2	0.2
Vitamins and minerals supplement*	0.6	0.6	0.6	0.6
Chemical composition(%)				
Dry matter[a]	92.5	93.6	93.7	94.3
Organic matter[a]	90.8	90.2	89.9	90.0
Crude protein[a]	18.3	17.2	18.5	18
Neutral-detergent fiber[a]	24	23	32	32
Acid-detergent fiber[a]	11.6	11.1	17.1	16.6
Non-fiber carbohydrates1[b]	55.3	50.5	46.3	41.0
Ether extract[a]	2.5	5.1	2.0	4.6
Metabolisable energy (MJ/kg DM)[c]	2.83	2.97	2.75	2.82

*–RCS=Without roasted Canola seed; +RCS = With roasted Canola seed

*Vitamin-trace mineral pre-mix provides per kg of mixed ration: 18,750 IU Vitamin A; 3750 IU Vitamin D3; 7.5 IU Vitamin E; 5mg Co; 1.25 mg Cu; 75 mg Fe; 1250 mg Mg; 150 mg Mn; 0.375 mg Se; 100 mg Zn.

[a]Obtained from measurements in the laboratory

[b]Non-fiber carbohydrates (NFC) were calculated using the formula: %NFC = 100 - (%CP + %EE + %NDF + %ASH). [c] Metabolisable energy was calculated according to NRC (2007).

Table 2. *Growth performance of fattening lambs fed by experimental diets (kg)*

Parameters	Experimental diets*				S.E	P values of effects**					
	Starch		Beet pulp								
	-RCS	+RCS	-RCS	+RCS		NDSC	RCS	NDSC * RCS	TRT	Time	TRT×Time
Initial body weight,	23.4	23.8	24.1	23.6	0.5	0.89	0.88	0.78	---	---	---
Final body weight	44.9	47.8	46.7	47.9	1.33	0.87	0.92	0.30	0.11	<0.01	<0.01
Average daily intake	1.41	1.51	1.48	1.48	0.05	0.52	0.75	0.66	0.50	<0.01	0.07
week 4	1.24	1.28	1.29	1.30	0.05	0.70	0.74	0.67	---	----	----
week 8	1.47	1.58	1.52	1.50	0.07	0.76	0.74	0.65	---	----	----
week 12	1.53	1.68	1.63	1.65	0.05	0.74	0.76	0.64	---	----	----
Feed conversion	5.5	5.3	5.4	5.2	0.72	0.46	0.28	0.51	0.57	<0.01	0.004
week 4	4.1	4.4	4.3	4.1	0. 64	0.43	0.29	0.51	---	----	----
week 8	5.4	5.3	5.7	4.6	0.68	0.49	0.25	0.46	---	----	----
week 12	7.1	6.6	6.5	7.1	0.85	0.46	0.33	0.52	---	----	----
Average daily gain	0.256	0.286	0.269	0.289	0.04	0.04	0.35	0.03	0.31	<0.01	<0.01
week 4	0.306	0.299	0.301	0.311	0.05	0.51	0.59	0.71	---	----	----
week 8	0.248	0.305	0.269	0.325	0.03	0.007	0.03	0.006	---	----	----
week 12	0.215	0.255	0.239	0.232	0.03	0.56	0.44	0.51	---	----	----

** -RCS= Without roasted Canola seed; +RCS = With roasted Canola seed

**NDSC =Starch vs. Neutral detergent-soluble; RCS= Diets with Roasted canola seed vs. Diets without roasted canola seed and diets interaction

Table 3. *Growth performance of fattening lambs fed by experimental diets (%)*

Nutrient	Experimental diets*				S.E	P values of effects					
	Starch		Beet pulp								
	-RCS	+RCS	-RCS	+RCS		NDSC	RCS	NDSC * RCS	TRT	Time	TRT×Time
DM	77.6	81.5	83.3	85.6	2.97	0.007	0.65	0.65	0.001	0.006	0.39
week 4	77.7	77.6	80.5	83.0	2.75	0.012	0.62	0.68	---	----	----
week 8	79.4	82.1	86.3	86.2	3.01	0.008	0.65	0.63	---	----	----
week 12	79.6	84.2	87.2	87.4	3.27	0.001	0.66	0.67	---	----	----
OM	58.8	68.8	71.7	69.8	3.62	0.002	0.67	0.63	0.71	0.80	0.65
week 4	59.4	67.5	70.3	70.1	3.76	0.003	0.65	0.64	---	----	----
week 8	58.6	69.7	72.7	69.3	3.43	0.002	0.68	0.66	---	----	----
week 12	58.4	69.2	72.1	69.9	3.62	0.002	0.66	0.61	---	----	----
CP	72.6	70.4	70.1	68.7	1.72	0.65	0.61	0.77	0.63	0.44	0.45
week 4	73.2	70.2	69.8	68.6	1.33	0.67	0.67	0.79	---	----	----
week 8	71.2	69.2	69.8	67.6	1.56	0.67	0.63	0.77	---	----	----
week 12	73.2	71.7	70.7	69.7	1.93	0.66	0.65	0.79	---	----	----
NDF	30.1	27.7	50.8	46.1	2.21	0.01	0.003	0.48	<0.001	0.53	0.36
week 4	30.5	26.7	48.9	43.1	1.77	0.003	0.004	0.51	---	----	----
week 8	30.1	27.2	49.9	43.9	1.68	0.031	0.003	0.44	---	----	----
week 12	31.7	29.5	53.6	51.3	2.02	0.011	0.005	0.47	---	----	----
ADF	22.5	21.4	45.9	38.1	1.68	0.021	0.003	0.48	<0.001	0.72	0.02
week 4	19.6	18.8	39.5	35.9	1.62	0.003	0.038	0.5	---	----	----
week 8	21.6	20.7	46.0	39.3	1.52	0.013	0.063	0.46	---	----	----
week 12	26.4	24.7	52.3	39.4	1.73	0.042	0.043	0.49	---	----	----

** -RCS= Without roasted Canola seed; +RCS = With roasted Canola seed

**NDSC =Starch vs. Neutral detergent-soluble; RCS= Diets with Roasted canola seed vs. Diets without roasted canola seed and diets interaction

Mean values of the growth performance trial containing initial body weight, final body weight, average feed intake, feed conversion and average daily gain are report in Table 2. Initial body weight showed no significant difference due to stratification within dietary treatments (P > 0.05). High starch diets compared with high soluble fiber diets had no significant effect on final body weight, average daily DM intake and feed conversion ratio. Roasted canola seed addition to the diets also had no significant on these parameters (P > 0.05). A similar trend was observed by a comparison diets interaction for traits (P > 0.05). In an experiment by Mandebu and Galraith (1999) examined the effects of diets containing different proportions of barley and beet pulp on growth performance of male lambs and no significant differences observed for feed intake and feed conversion ratio. Similar results have been reported by Bodas et al. (2007). In contrast, Rouzebhan et al. (1999) reported the decrease in dry matter intake with increasing level of beet pulp in the diet. Different factors could affect the dry matter intake including stretch of gastrointestinal tract. Amount of stretch that could limit DMI is different in the animals with different levels of production and among diets with various concentrations of energy, nutrients, dry matter and physical properties (Allen, 1996). Effectiveness of stretch of rumen wall in reduction of DMI is likely attributable, in part, to the weight and bulk of consumed feed. Beet pulp could increase filling effect of consumed feed with its higher water holding capacity and therefore reduce feed intake (Robinson et al., 1990). It look like that the level of beet pulp in the rations used in current study was not high enough that could limit feed intake.

In agreement with the current study, Several researchers found no adverse effects of supplemental fat on DM intake and feed conversion of sheep (Goulas et al., 2003; Zhang et al., 2007). Similar findings have also been reported for dairy cows fed canola seed (Khorasani et al., 1991), sunflower seed (Markus et al., 1996) or flaxseed (Mustafa et al., 2003). Feeding supplemental fat in the form of oilseeds is expected to have less detrimental effects on DM intake than if a similar amount was added as free oil (Kennely, 1996).

An interaction between NDSC and RCS was observed for daily gain (P < 0.05) because the level of increase in weight gain with addition of RCS was different among carbohydrate sources. Limited research has been conducted investigating the interaction between carbohydrate source and fat supplementation.

Bhattacharya *et al*. (1975) reported that growing fattening sheep fed on a diet contained 45% beet pulp + 45% corn gained faster and required less feed per unit of gain than those fed on either 90% corn or 90% beet pulp. Similar conclusions were also reported by Bouaque *et al*. (1976) on young bulls and Mandebvu and Galbraith (1999) on lamb. The significant difference in average daily gain observed in lambs fed with high soluble fiber could be the result of high water holding capacity of dry beet pulp due to the existence of pectic substances, methyl and carboxyl groups in its molecular structure that might be the reason of its better digestion. Inclusion of beet pulp in feeding of ruminants delays rate of passage outside the rumen (Vollker and Allen, 2003) and increased methanogenic bacterial count, Lactobacilli and Streptcocci and enzymatic yield of polygalacturonase and pectinesterase (Vollker and Allen, 2003).

Addition of canola seed to the high starch diet caused dramatic increase in weight gain in comparison with high soluble fiber diet. Data is lacking using full fat oilseeds in high starch diets. This difference in response might be attribute, in part, to the correlated change in rumen pH (results are not reported). An increase in rumen pH observed when RCS included in the high starch diet. Wallace and Cotta (1989) indicated that at low pH, bacteria spend part of the available energy in maintaining the proton-motive force across the cell membrane, increasing maintenance requirements at the expenses of growth (Nagaraja and Titgemeyer., 2007). The result is the reduction of microbial nitrogen flow to the small intestine. Hoover and Miller (1992) summarized several studies in which pH was modified in in vitro conditions and observed that the efficiency of microbial protein synthesis was affected when pH decreased below 5.5 (high starch diet without RCS supplementation).

Effects of experimental diets on digestibility of dry matter, organic matter, crude protein, NDF and ADF are shown in Table 2. Neutral detergent-soluble carbohydrates significantly affect dry matter and organic matter digestibility ($p<0.05$). High-starch diets compared with diets containing soluble fiber reduced the digestibility of dry matter and organic matter. Addition of roasted canola seed had no significant effect on the digestibility of these two parameters ($p<0.05$).

NDSC source had a significant effect on NDF and ADF digestibility and replacement of starch with soluble fiber resulted in increase in NDF and ADF digestibility ($P<0.001$). Increase in dietary fat with RCS incorporation in the ration significantly decreased NDF and ADF digestion. No significant interaction observed between NDSC source and RCS.

In agreement with the current study, Voelker and Allen (2003) reported greater ruminal and total tract NDF digestion when dried, pelleted beet pulp replaced corn in lactating dairy cow diets. Also, Mojtahedi and Danesh Mesgaran (2011) have reported increased digestibility of dry matter, organic matter by partial substituting of barley with beet pulp in the diet of steers. Beet pulp NDF has a shorter lag time and more rapid digestion rate than most other sources of fiber (Bhatti and Firkins, 1995) partly because it has been previously soaked in hot water (Bichsel,1988). Therefore, increasing the contribution of beet pulp NDF to total NDF can increase the overall rate of NDF digestion, independent of any associative effects of beet pulp NDF on the digestion of NDF from other sources. Substituting the readily degraded pectin and NDF of beet pulp for barely may also increase the rate of digestion of other dietary fiber through associative effects of both fiber and starch. Adding beet pulp might have increased the population of fibrolytic bacteria and fibrolytic enzyme activity by providing excess available substrate for fiber degraders. Dilution of the concentration of dietary starch would also reduce the negative effects of starch fermentation on cellulolytic bacteria (Voelker and Allen, 2003). It has been suggested that the decrease in pH caused by rapid fermentation of starch and lactate production can also affect the reduction in fiber digestion (Voelker and Allen, 2003). However, even if the pH is kept constant, the lower NDF digestibility can occur with the addition of starch (Mandebu and Galraith, 1999).

Stanford et al (2000) reported the decrease in digestibility of NDF and ADF with increase in dietary fat from canola seed source. These researchers conclude that the result is due to the toxic effects of fat on cellulose-degrading bacteria and protozoa. In vitro studies (Henderson, 1973; Maczulak et al., 1981) demonstrated that the unsaturated fatty acids, particularly C18:1, inhibit ruminal cellulolytic microbes. MacLeod and Buchanan-Smith (1972) postulated that the depressing effects of fat on fiber digestion might also be partially due to a physical coating of fiber particles, forming a lipid barrier that impedes enzyme penetration.

Conclusions

Partial replacement of starch with neutral detergent soluble fiber in high concentrate diets had positive effects on weight gain and nutrient digestibility. Also, incorporation of canola seed in high concentrate diets, specially high starch diets, improved growth performance but because of its adverse effect on the digestibility of fiber fraction more reseach is needed for conclusion.

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