Small Ruminant Research 147 (2017) 56–62

Contents lists available at ScienceDirect

Small Ruminant Research

journal homepage: www.elsevier.com/locate/smallrumres

Effects of incremental substitution of maize silage with Jerusalem artichoke silage on performance of fat-tailed lambs

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ARTICLE INFO

Article history:
Received 6 July 2016
Received in revised form
11 November 2016
Accepted 23 November 2016
Available online 14 December 2016

Keywords:
Jerusalem artichoke silage
Growing lambs
Growth performance
Ruminal fermentation
Serum metabolites

ABSTRACT

In this study, the effects of substituting maize silage (MS) with Jerusalem artichoke silage (JAS) on feed intake, growth performance, serum metabolites and ruminal fermentation of fattening fat-tailed lambs were evaluated. Fifty Chall male lambs, averaging 119 ± 24.0 (SD) days of age and initial body weight of 26.3 ± 3.98 (SD) kg, were randomly assigned to five isoenergetics and isonitrogenous diets in which MS was replaced by different levels [(0, 50, 100, 150, or 200 g/kg dietary dry matter) (DM)] of JAS. The diets were prepared in pelleted form and offered three times a day (at 08.00, 14.00, and 20.00 h) *ad libitum*. Ruminal parameters were measured before feeding, consecutively for 2 and 4 h post feeding and serum samples were collected from the jugular vein just before feeding on days 0, 42 and 84 of the experimental period. The replacement of MS by JAS did not affect dry matter intake (DMI), average daily gain (ADG) and feed conversion ratio (FCR) (that is, kg DM/kg gain). When the levels of JAS in the diets were increased, serum concentrations of glucose and urea-N, ruminal content of pH, ammonia-N, acetate, propionate, butyrate, valerate, isovalerate and acetate-to-propionate ratios were unaffected ($P > 0.05$). However, with increase in dietary levels of JAS, total protein concentration of serum, total volatile fatty acids (VFA) and isobutyrate concentration of rumen fluid were affected ($P < 0.05$). This study showed that the partial substitution of MS for JAS, up to 200 g/kg DM, in diet of fat-tailed lambs had no adverse effect on growth performance, ruminal fermentation patterns and serum metabolites.

1. Introduction

In arid and semiarid regions of Iran, water scarcity, poor quality soils, and inadequate supply of feed are the major limitations of livestock grazing (Papi, 2015). These areas are described by droughty conditions and erratic rainfall. It has been observed that there is a need for new cultivable crops for the low fertile areas to substitute for crops which are conscious of poor quality soils and weeds. Jerusalem artichoke is a member of the Asteraceae family and is closely associated with sunflower (*Helianthus tubberosus L.*), earning the nickname "wild sunflower" (Kosaric et al., 1984). This persistent species is capable of surviving in different habitats. The plant is erect, often reaching heights more than 2 m, differing from non-branching to branching growth forms (Swanton et al., 1992). Furthermore, preliminary information suggests that the artichoke is relatively a weed, disease and pest-free, showing that it could play a part in lower input systems (Hay and Offer, 1992).

Research with Jerusalem artichoke as an agricultural crop has mainly focused on yield tubers as a crop for food or as a raw material in various industries (Kosaric et al., 1984). Since the yield of green mass and digestible protein per ha for Jerusalem artichoke is higher than that found in typical forage plants, much interest has been directed towards the use of the aerial parts as forage (Kosaric et al., 1985). However, the existence of the major stem axis makes the rapid drying of a large quantity of the forage difficult. There has been noticeable interest in the use of the aerial parts of this plant as silage, with farmers reporting favorable results (Rawate and Hill, 1985). Wyse and Wilfahrt (1982) suggested that maximum silage yields could be collected by harvesting or just before flowering. However, there is a little information about the application of ensiled Jerusalem artichoke forage in ruminant nutrition. Therefore, the present study was conducted to assess the chemical composition of the aerial parts of fresh and ensiled Jerusalem artichoke and to study the effect of feeding substitution rates of maize silage with artichoke silage on feed intake and growth performance in fattening lambs.

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http://dx.doi.org/10.1016/j.smallrumres.2016.11.013
0921-4488/

Table 1
Chemical analyses of maize and Jerusalem artichoke (g/kg DM or as stated).

Chemical analyses	Jerusalem artichoke		Maize
	Fresh	silage	silage
Dry matter (g/kg Fresh)	277	286	259
Organic matter	866	841	894
Crude protein	92.1	105	83.4
Natural detergent fibre	392	388	553
Acid detergent fibre	299	303	346
Acid detergent lignin	72.0	71.0	45.0
ASH	154	160	106
Water soluble carbohydrates	223	67.0	16.0
Calcium	20.6	21.0	6.1
phosphorous	2.1	2.3	1.9
pH	7.1	4.2	4.0
Ammonia-N (g/kg total N)	–	133	63.0
Lactate	–	74.5	53.0
Butyrate	–	0.74	0.13
Acetate	–	13.1	26.0

2. Materials and methods

2.1. Silage preparation

Jerusalem artichoke tubers were planted on the 4th of April and maize grain was planted on the 22nd of June 2013 in the research farm of the Animal Science Research Institute (Karaj, Iran). The field was irrigated every 12 days and weeds were controlled by manual weeding in the first month of planting. The corn forage was harvested at milk-dough stage of seeds and Jerusalem artichoke forage was harvested at the early flowering stage using maize forage harvester (chopper), 10 cm above the ground at the end of summer. The chopped forages (3–5 cm) were ensiled into permanent horizontal silo for 60 days (Daniele et al., 2013). The compaction density of the Jerusalem artichoke was approximately 700 kg fresh matter/m^3. Both silos were opened after 60 days and sampled immediately after opening, then the samples were frozen (−20 °C) for further analyses (Table 1).

2.2. Experimental diets

Five isonitrogenous and isoenergetic diets were formulated according to NRC (2007), where maize silage was replaced by Jerusalem artichoke silage (Table 2). Alfalfa hay was chopped into short lengths (2–3 cm), mixed with silages and concentrates, and then prepared in pelleted complete rations. The pellets were made in cylindrical shape with diameter of 1.5 cm and length of 2.5 cm.

2.3. Animals and management

Fifty weaned male lambs of fat-tailed Chall breed with 119 ± 24.0 (SD) days of age and initial body weight of 26.3 ± 3.98 (SD) kg were used. Lambs were randomly assigned to five dietary treatments (10 replicates per treatment). Animals were housed in individual boxes (1.2 m × 1.3 m) in a closed building and had free access to feed and water through the trial. During the first two weeks of trial, lambs were allowed to adapt to their diets, treated for external (Azantol, Bayer, Germany) and internal (Ivermectin, Razak Co., Iran) parasites and vaccinated against enterotoxaemia as well as foot and mouth disease. Lambs were fed three times a day at 08.00, 14.00, and 20.00 h for 84 days. All lambs were individually weighed on days 0, 21, 42, 63, and 84 at 08.00 h after 16 h of feed deprivation. Average daily gain (ADG) for individual lambs was calculated using the sum of average daily gains of every 3 weeks record divided by 4 (times of BW recording). Individual feed intake was recorded every day and feed conversion ratio (FCR) for each lamb was calculated as the ratio of daily dry mater intake (DMI) to ADG.

Table 2
Ingredients and chemical composition of the experimental diets (g/kg DM).

Item	Level of JAS in diet (g/ kg DM)				
	0	50	100	150	200
Ingredients					
Alfalfa, 14.57% CP	100	100	100	100	100
Maize silage	200	150	100	50.0	0.00
Jerusalem artichoke silage	0.00	50.0	100	150	200
Wheat bran	65	70	64	55	50
Barley grain	280	268	270	251	265
Maize grain	180	190	200	230	230
Soybean meal, 42.3% CP	142	140	135	134	125
Vitamin-mineral premix[a]	10	10	10	10	10
Limestone	8	7	6	5	5
Salt	5	5	5	5	5
Sodium bicarbonate	10	10	10	10	10
Chemical composition (g/kg DM)					
Crude protein	150	150	150	150	150
Calcium	9.9	9.7	9.5	9.3	9.5
Phosphorous	3.6	3.6	3.5	3.4	3.3
Metabolizable energy (MJ/kg DM)	10.84	10.79	10.79	10.80	10.80

JAS, Jerusalem artichoke silage.
[a] premix contained (per kg): vitamin A, 750,000 IU; vitamin D_3, 200,000 IU; vitamin E, 4000 IU; Mn, 20 g; Na, 60 g; Mg, 12 g; Fe, 6 g; Cu, 3.5 g; Ca, 180 g; Zn, 17 g; Co 50 mg; I, 150 mg; Se, 100 mg; Antioxidant (Ethoxyquin), 3 g.

2.4. Laboratory analyses

Samples of fresh forage, silages and diets were oven-dried (for 48 h at 70 °C), ground using 2 mm sieve, and analyzed for dry matter (DM, method 930.15), ADF (method 983.18), ash (method 924.05), calcium (method 927.02), and phosphorus (method 965.17) by AOAC (1990). Nitrogen (N) was measured using the Kjeldahl procedure with a Kjeltec-UDK 126A and then, the amount of N was multiplied by 6.25 to calculate CP (984.13) (AOAC, 1990). The aNDF was measured using heat-resistant $\acute{\alpha}$-amylase without sodium sulfite (Van Soest et al., 1991). The aNDF and ADF fractions include residual ash. Lignin (sa) was measured using the sulfuric acid method (Robertson and Van Soest, 1981). The pH values of the silage were determined using MAFF (1986). WSC were measured in samples which were freeze-dried using the anthrone method MAFF (1982). Ammonia-N in silage was measured using phenol-hypochlorite (Broderick and Kang, 1980). VFA (that is, acetic and butyric acids) and lactic acid were determined using high performance liquid chromatography (Faithfull, 2002). Metabolizable energy values of the diets were calculated from feed composition tables of the National Research Council (2007).

2.5. Serum metabolites and ruminal parameters

Serum samples were collected from the jugular vein just before feeding on days 0, 42, and 84 of the experimental period from the four same animals assigned to each treatment. The samples were centrifuged (Sigma-16-P- Germany) at 3000 × *g* for 10 min and the serum samples were stored at −20 °C until further analyses. Serum concentrations of total protein, glucose, and blood urea nitrogen (BUN) were measured using an auto analyzer system with commercial kits (Far assamed, Co., Iran) according to Kerscher and Ziegn Born (2001).

The rumen liqueur samples were collected by stomach tube at 0 (before morning feeding), 2, and 4 h after morning feeding on days 82, 83, and 84 of the experimental period from 4 animals assigned to each treatment. The pH was determined immediately after sampling using a digital pH meter (Rocky Mount NC 27804, U.S.A) and then samples were strained using two layers of cheesecloth.