academicJournals

Vol. 8(22), pp. 992-995, 11 June, 2013
DOI 10.5897/SRE11.1962
ISSN 1992-2248 © 2013 Academic Journals
http://www.academicjournals.org/SRE

Scientific Research and Essays

Full Length Research Paper

Effects of infrared irradiation on barley grain starch degradation in the rumen of sheep

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Accepted 31 May, 2013

This study was conducted to evaluate effects of infrared irradiation for 60, 90, 120 and 150 s on starch ruminal degradability and chemical composition of barley grain. Three ruminally fistulated rams were used to measure *in sacco* degradation. There was a linear increase on DM chemical compositions irradiated barley grain (P<0.05). Infrared irradiation decreased potentially degradable fraction and constant degradation rate of starch (P<0.001). Effective ruminal degradability of starch for irradiated barley grain decreased linearly (P<0.001) as irradiation time increased until 90. It was concluded that infrared irradiation for 90 s could decrease starch degradability of barley, a benefit characteristic of barley feeding in ruminant nutrition.

Key words: Barley grain, infrared irradiation, ruminal degradation, sheep, starch.

INTRODUCTION

Infrared irradiation (IR) heat processing or micronisation is an efficient food processing technology that employs short time and high temperature to treat cereals or legumes before their final applications in human food or animal feed (BeMiller and Whistler, 2009). Fasina et al. (1999) found out that micronisation increased the content of gelatinized starch in barley; they indicated the importance of moisture content in the barley with respect to gelatinizing starch during micronisation. A similar result was reported by Arntfield et al. (1997) in a lentil study.

In many parts of the world, barley grain (BG) is the primary source of energy in typical ruminant diets, with starch as an excellent nutrient for microbial protein synthesis in the rumen. The whole kernel of untreated barley is not extensively damaged during eating and its fibrous hull limits access to its starchy core by both microbes in the rumen and digestive enzymes in the lower digestive tract. Hence, processing of barley to increase its damage during chewing and rumination is necessary. The effects of different processing methods on ruminal protein and starch degradation of barley have been evaluated (Hungtinton, 1997).

However, there are a few report on effects of micronising by IR sources on ruminal degradation. The purpose of this study was to evaluate the effects of infrared irradiation on ruminal starch degradability of barley grain.

MATERIALS AND METHODS

Samples preparation and treatments

Barley samples (*Hordeum vulgare* L.) were Fajr cultivar from Iran. The barley grains (four samples, each 500 g) were tempered to reach 25% moisture content before micronisation. Samples were micronised for 60, 90, 120 and 150 s in constant distance of infrared source. Processed samples were cooled to room temperature before being packed in Zipper bags (Plastilon Packaging, Pretoria, South Africa) and kept at 22°C.

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Animals and feeding

Three 60±5 kg Chall rams with rumen fistulas were used to determine disappearance extent and rate of starch under confined feeding and housing conditions. Rams were housed in individual 3.4 m long, 2.1 m wide and 1.2 m high pens with concrete floors that were cleaned regularly and offered a diet of alfalfa hay and a barley-based supplement (800 g/kg of ground barley, 60 g/kg of molasses, 100 g/kg of soybean meal, 38 g/kg of trace mineral salt, and 2 g/kg of vitamin A, D, and E premix). The basal diet contained 873 g/kg of alfalfa hay and 127 g/kg of supplement, and was offered at 2% of body weight daily in two equal portions (08:00 and 16:00 h). Rams were adapted to the basal diet for 10 days before initiating the trial. The diet was formulated according to sheep NRC (1985).

Chemical analysis

Corn samples were analysed for DM by oven drying a 1 g sample in duplicate according to the procedure of Association of Official Analytical Chemists (1995) Official Method 930.15 (AOAC, 1995). Nitrogen was determined according to (AOAC) Official Method 984.13(1995) and CP calculated as N × 6.25. Content of ash was determined by burning a 2 g sample in duplicate at 600˚ C, for 2 h in a muffle furnace according to (AOAC) Official Method 942.05(1995). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed according to the method of Van Soest et al. (1991), using an automatic fiber analyser (Fibertec System M, Tecator). NDF was determined without α-amylase and sodium sulfite. A standard method was used to determine ether extract according to (AOAC) Official Method 920.39(1995). The method of McCleary et al. (1994) was used for determination of starch. No correction for sugar was carried out. Thus, the determined content of starch represents starch plus sugar.

Nylon bag experiment

Procedure of ruminal incubation followed the method of Mehrez and Ørskov (1977). Four grams of untreated and treated samples with grounding 2 mm screen were weighed in duplicate into nylon bags (45 µm pore size). Each treatment of 42 samples (two replicates × seven incubation periods × three animals for each treatment) was prepared for individual nylon bags in the assay. The bags were incubated in the ventral sac of rumen for 2, 4, 6, 12, 16, 24 and 48 h. Immediately after removal from the rumen, samples were put in ice to stop the microbial fermentation and then were machine washed and freeze-dried, respectively.

Statistical analysis

Digestion kinetics of starch were determined according to the equation of Ørskov and McDonald (1979):

$$P = a + b\,(1 - e^{-ct})$$

Where P is starch disappearance (g/kg) at time t (h), a, the washout fraction (g/kg), b, the potentially degradable fraction (g/kg) and c, the constant rate of degradation (/h) of the potentially degradable fraction. Effective rumen degradability (ERD) of starch (g/kg) was estimated using the equation of Ørskov and McDonald (1979):

$$ERD = a + [bc/(c + k)]$$

Where ERD is the effective ruminal degradability, k, the fractional ruminal outflow rate, a, b and c are as defined above. Effective ruminal degradability was calculated with an estimated solid outflow rate from the rumen (k) of 0.02, 0.05 and 0.08 /h according to AFRC (1993).

The various degradability parameters for nylon bags data were analysed as a randomised complete block design, using animals as blocks. Analysis was carried out using the general linear model procedure of SAS 9.1.3 software (2003) with the statistical model of Yijk =µ+ Ti + Bj + eijk, where Yijk is dependent variable, µ is overall mean, Ti is infrared radiation effect, Bj is animal effect, and eijk is residual error, the data assumed normally and independently distributed. Differences among treatments were separated using polynomial orthogonal contrasts to determine linear and quadratic responses (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

IR irradiation showed no significant effect on chemical composition of barley grain except DM (Table 1). Infrared increased linearly DM with increasing time heating ($P<0.05$). Increased DM of chemical composition irradiated is consistent with results of Thacker (1999) and Zarkadas and Wiseman (2001, 2002). CP of chemical composition irradiated as compared with untreated insightly decreased but was not significant, that is, in agreement with Gonthier et al. (2004) and contrary to Mustafa et al. (2002) and Thacker (1999). Heating with IR caused increasing DM because micronisation is heat treat that can decrease moisture of grains. Percentage of CP in DM decreased with increasing DM. Difference among results of authors on CP connected diversity of DM. Results of Gonthier et al. (2004) and Thacker (1999) revealed insightly increase (non significance) of starch, EE, NDF and ADF. It is possible that micronisation destroyed matrix protein with other component just as mentioned on flaxseed (Kennelly, 1996).

IR irradiation increased washout fraction of starch barley grain in the rumen of sheep but was not significant (Table 2). Infrared decreased the potentially degradable fraction and the constant degradation rate of starch ($P<0.001$). ERD in different outflow rate of starch decreased linearly until 90 s and then increased ($P<0.001$). This finding are similar to the results of Wang et al. (1997, 1999) on DM canola seed, Ramsey et al. (2001) on barley autoclaved, Mustafa et al. (2002) on DM flaxseed, Gonthier et al. (2004) on DM flaxseed, and Sadeghi and Shawrang (2008) on barley microwaved. Potential degradability of starch was decrease by micronised BG. Starch is predominant component of DM in BG (Ramsey et al., 2001) so starch changes are more effecttive on DM. The decrease in starch degradation micronised BG can be attributed to the fact that IR increased the size of slowly degradable fractions as decreased ruminal degradation (Mustafa et al., 2002); also thermal processing has been shown to result in destruction of cell walls and protein structures encapsulating starch which further increases its susceptibility to bacterial attack. Protein matrix

Table 1. Effects of infrared radiation on chemical composition barley grain.

Parameter	Untreated barley grain	IR-irradiated barley grain				SEM	Contrasts	
		60 s	90 s	120 s	150 s		L	Q
Dry matter (g/kg)	906	913	912	923	927	2.186	*	NS
Crude protein (g/kg)	120	119	120	119	118	0.055	NS	NS
Starch (g/kg)	580	587	593	585	579	0.32	NS	NS
Ether extract (g/kg)	27	28	26	27	29	0.082	NS	NS
Neutral detergent fiber (g/kg)	217	219	221	222	224	0.12	NS	NS
Acid detergent fiber (g/kg)	75	76	77	77	78	0.048	NS	NS
Ash (g/kg)	22	22	21	22	22	0.013	NS	NS

L, linear contrast; Q, quadratic contrast; NS, not significant (p>0.05); *, p<0.05; **, p<0.01; ***, p<0.001.

Table 2. Rumen degradation kinetics of starch untreated and infrared irradiated barley grain.

Parameter	Untreated barley grain	IR-irradiated barley grain				SEM	Contrasts	
		60 s	90 s	120 s	150 s		L	Q
Starch								
a(g/kg)	212	223	217	227	228	1.710	NS	NS
b(g/kg)	739	713	705	697	689	1.932	***	***
c(per h)	0.065	0.063	0.059	0.056	0.054	0.011	***	***
Effective rumen degradation (g/kg)								
0.02/h	785	758	706	824	809	0.896	***	NS
0.05/h	726	689	613	713	711	1.113	***	NS
0.08/h	678	635	550	636	642	1.212	***	NS

L, linear contrast; Q, quadratic contrast; NS, not significant (p>0.05); * , p<0.05; **, p<0.01; ***, p<0.001; a, the washout fraction; b, the potentially degradable fraction; c, the rate of rumen degradation.

surrounding the starches granules determines the rate of starch degradability in rumen (McAllister and Cheng, 1996). Discrepancy with results of Wang et al. (1997, 1999) and Mustafa et al. (2002) on degradation may be due to differences in chemical characteristics between barley and oil seeds. Factors that determined the extent and rate of ruminal degradation are pore size of bags, ratio of sample weight: bag surface area, particle size washing technique, and species of animal used in the studies (Ghorbani and Hadj-Hussaini, 2002).

Results suggest that IR of BG was effective in decreasing its ruminal starch until 90 s. Time requirements for micronisation are lower than for other dry and wet heat methods; thus making this process effective for processing BG.

ACKNOWLEDGMENTS

The authors gratefully thank Science and Research Branch, Islamic Azad University for financial support and would also especially like to thank Dr. P. Shawrang for his helpful suggestions. This paper was obtained from the PhD dissertation of the third author in Department of Animal Science, Science and Research Branch, Islamic Azad University, Tehran, Iran.

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