Livestock Science 150 (2012) 240–247

Contents lists available at SciVerse ScienceDirect

Livestock Science

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

Effect of replacement of barley meal with crude glycerol on lactation performance of primiparous dairy cows fed a grass silage-based diet

Marko Kass [a,b,*], Tiia Ariko [a], Tanel Kaart [a,b], Eve Rihma [a,b], Meelis Ots [a,b], David Arney [a], Olav Kärt [a,b]

[a] Institute of Veterinary Medicine and Animal Sciences, Estonian University of Life Sciences, 62 Kreutzwaldi Street, 51014 Tartu, Estonia
[b] Bio-Competence Centre of Healthy Dairy Products LLC, 1 Kreutzwaldi Street, 51014 Tartu, Estonia

ARTICLE INFO

Article history:
Received 29 June 2012
Received in revised form
5 September 2012
Accepted 8 September 2012

Keywords:
Crude glycerol
Barley meal
Grass silage
Rumen environment
Mid-lactation

ABSTRACT

The use of increasingly available glycerol, from the biodiesel industry, in dairy cow diets was assessed. The effects of replacement of barley meal by crude glycerol in a total mixed ration based on the grass silage on dry matter intake, milk yield and composition, rumen pH, silage degradability and metabolic status in mid-lactation Holstein dairy cows were evaluated. Eight, tie-stalled, primiparous cows were assigned to a 4×4 Latin square experimental design with two cows per treatment. Cows were paired according to milk yield and body weight, with one ruminally cannulated cow in each pair. The treatment period lasted 21 days of which 16 days were for adaptation. Cows were given a total mixed ration where barley meal was replaced isoenergetically by 0 kg (control), 1 kg, 2 kg and 3 kg crude glycerol per day per cow. An increased level of crude glycerol in the diet increased total intake ($P<0.001$). Milk yield and composition were not affected by glycerol inclusion to the diet, with the exception of an increase in the milk protein content ($P<0.001$). Cows given the glycerol diet had lower concentrations of blood nonesterified fatty acids ($P=0.038$) and a higher concentration of blood urea ($P<0.001$). Partial replacement of barley meal with crude glycerol in a total mixed ration affected the rumen environment, as the proportions of volatile fatty acids changed. There were no effects of treatment on the effective degradability of silage nutrients. These results indicate that crude glycerol is a suitable replacement for barley meal in a total mixed ration based on grass silage with no detrimental effect on lactation performance or rumen parameters.

1. Introduction

Biodiesel, an alternative fuel for diesel engines, produced from the reaction between a vegetable oil or animal fat with an alcohol, results in the production of crude glycerol as a by-product (Van Gerpen, 2005). The increase in biodiesel production has increased the availability of crude glycerol (European Biodiesel Board Statistics, 2010), making it attractive to farmers as a livestock feed. In early studies, glycerol was used as an aid in the treatment of ketosis (Fisher et al., 1971; Johnson, 1951). More recent studies have evaluated its glucogenic potential for dairy cows, particularly in the transition period (Bodarski et al., 2005; DeFrain et al., 2004; Ogborn, 2006) or in early lactation (Chung et al., 2007; Wang et al., 2009b). Other studies have focused on glycerol as an energy source, replacing starch in the diet of dairy cows (Donkin et al., 2009; Khalili et al., 1997; Schröder and Südekum, 1999).

* Corresponding author at: Institute of Veterinary Medicine and Animal Sciences, Estonian University of Life Sciences, 62 Kreutzwaldi Street, 51014 Tartu, Estonia. Tel.: +372 731478; fax: +372 7313477.
E-mail address:
marko.kass@emu.ee (M. Kass).

1871-1413/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.livsci.2012.09.007

Schröder and Südekum (1999) suggested that glycerol of different purities could replace rapidly fermentable starches in diets for ruminants at up to 10% of the diet DM with no adverse effect on either intakes or the ruminal environment. Donkin et al. (2009) reported that glycerol is a suitable replacement for maize grain in rations up to a level of 15% of dry matter without detrimental effects on milk yield or composition. Similar results were found with lower amounts of glycerol (3.6% of diet DM) replacing a barley-based concentrate (Khalili et al., 1997).

There are conflicting results on the effect of glycerol feeding on glycerol metabolism in the rumen. Early studies concluded that glycerol was entirely fermented to propionate (Garton et al., 1961; Johns, 1953). More recent studies indicated that in addition to propionate there were also increases in the concentrations of acetate (Wright, 1969) and butyrate (Linke et al., 2004; Rémond et al., 1993; Schröder and Südekum, 1999). When replacing starch sources with glycerol, Khalili et al. (1997) noted an increase in the proportions of propionate and butyrate at the expense of acetate, while Mach et al. (2009) found no effect on rumen molar proportions of volatile fatty acids. Such differences in results may be attributable to amounts fed, but also to the other dietary components affecting the complex metabolic pathways within the rumen.

Barley meal as a primary starch source and grass silage-based diets are common feedstuffs in Europe (Todorov, 1988). Most glycerol-feeding studies have focused on the replacement of maize-based concentrate with glycerol in the diet, and there has been a focus on the feeding of glycerol in early lactation. There is a lack of data on barley meal- and grass silage-based rations, and effects in mid-lactation. The objective of this study was to determine the optimum replacement level of barley meal with crude glycerol in grass silage diets fed to dairy cows. The experiment was designed to analyse effects in mid-lactation in order to provide guidance for the practical application of glycerol feeding to dairy farmers throughout lactation, and in the context of northern Europe.

2. Material and methods

2.1. Animals and diets

Eight primiparous Holstein cows were used in a 4×4 Latin square trial with two replicates. The cows were housed individually, tethered in stalls, in which they were fed and milked. Cows with mean days in milk (DIM) of 134 ± 15 were divided into pairs according to milk yield (24.7 ± 1.0 kg/d) and body weight (535 ± 13.5 kg). Within each pair, one cow was fitted with a rumen fistula. Each experimental period lasted 21 days; an adaption period of 16 days and five days of data collection.

Cows were fed a total mixed ration (TMR) twice a day at 06.00 and 16.00 on an ad libitum intake basis, the amounts offered adjusted to ensure a 5–10% feed refusal. Feed residuals were removed and weighed before fresh feed was offered. TMR was hand-mixed for each individual cow before feeding. The basal diet (control, C) contained grass silage, barley meal, soybean meal, limestone, sodium chloride and a mineral mix (Table 1). Treatment diets consisted of the basal diet in which 1 kg (low glycerol, LG), 2 kg (medium glycerol, MG) or 3 kg (high glycerol, HG) of crude glycerol replaced an isoenergetic amount of barley meal in the daily ration. The experimental diets were isonitrogenously balanced by the addition of a commercially available protected urea (Optigen II; Alltech, USA).

Table 1
Ingredients and chemical composition of experimental diets in g/kg dry matter.

Item	Treatments			
	C	LG	MG	HG
Ingredients				
Grass silage	469	470	471	472
Soybean meal	111	112	112	112
Barley meal	394	339	283	227
Crude glycerol[a]	–	52	104	156
Optigen® II[b]	–	3	6	8
Mineral mix[c]	11	11	11	11
Calcium carbonate	8	8	8	8
Sodium chloride	6	6	6	6
Chemical composition				
Organic matter	919	865	812	758
Crude protein	155	156	157	158
Ether extract	24	23	23	22
Neutral detergent fibre	363	351	339	327
Acid detergent fibre	221	217	213	209
Metabolizable energy (MJ)	11.1	11.2	11.2	11.2

[a] Crude glycerol = BioOil Ltd., Estonia, 82.6% glycerol, 9.3% salts, 7.1% water, 0.6 crude fat and 0.4% methanol.
[b] Optigen II (Alltech, USA) = nitrogen—410 g/kg, crude fat–114 g/kg.
[c] Mineral mix (Veskimeister Ltd., Estonia; contained $CaCo_3$ 30%, NaCl 20%, Ca $(H_2PO_4)_2$ 20%, $Mg_3(PO_4)_2$ 19.5%).

The study was carried out at the Eerika Experimental Farm of the Estonian University of Life Sciences. The study was run in accordance with the Animal Protection Act of the Republic of Estonia.

2.2. Sample collection and analysis

The cows were weighed in a crush at the beginning of the trial and on two consecutive days at the end of each experimental period. The cows were milked twice a day, in their stalls. Milk yield was recorded in the last five days of each experimental period at every milking, and samples were taken for analyses on the last two days (days 20 and 21). Milk samples were stabilized with bronopol (Broad Spectrum Microtabs, D & F Control Systems Inc., Norwood, USA). Milk fat, protein, lactose and urea concentrations and somatic cell counts were measured using an automated infrared milk analyzer (System 4000, Foss Electric, Hillerød, Denmark).

Soyabean meal, barley meal and silage samples were taken in the last five days of each experimental period and were analysed for chemical contents using established methods (AOAC, 2005). Dry matter content was determined by heating a feed sample for 2 h at 130 °C to constant weight. Analysis for crude fat content was performed by petroleum ether extraction in a Soxtec System 2043