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Effects of high concentrations of dietary crude glycerin on dairy cow productivity and milk quality

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ABSTRACT

An increasing worldwide interest in alternative fuel sources and in a more diversified energy matrix has provided incentives for the biodiesel industry, generating large amounts of the by-product crude glycerin, a potential alternative feed for dairy cows. A replicated 3 × 3 Latin square study was conducted to evaluate the effects of high concentrations of crude glycerin on dry matter intake, milk yield and composition, milk fatty acid profile, and blood metabolites of medium-yield cows. Ruminally cannulated Holstein cows (n = 6; 587 ± 39 kg of BW; 114 ± 29 DIM; and 20 ± 1.5 kg/d milk yield) were used in the study. The experimental period included 2 wk for adaptation and 1 wk for data collection. Cows were fed diets containing 0 (control), 15, or 30% crude glycerin (83% glycerol). Cows were milked, milk weights were recorded twice daily, and milk samples were collected for milk quality analyses at d 18 and 19 in each experimental period. Feeding cows with crude glycerin linearly decreased dry-matter intake, the 3.5% fat-corrected milk, and the solid-corrected milk yield. Hepatic enzymes were not affected by dietary treatments, except gamma-glutamyl transferase, which was decreased with the 15% crude glycerin diet. Serum glucose and albumin showed quadratic effect with increasing inclusion of crude glycerin. Plasma cholesterol as well as total protein linearly decreased with increasing inclusion of crude glycerin. Milk fat concentration and yield showed a quadratic effect of treatments. Solid yield decreased linearly with increasing inclusion of crude glycerin. Odd-chain fatty acids and conjugated linoleic acid in milk fat linearly increased with addition of crude glycerin in the diets. Together, these results suggest that crude glycerin has potential to replace corn; however, feeding diets in which corn is replaced with crude glycerin at 30% of dietary DM greatly reduces animal performance.
Key words: blood metabolite, crude glycerin, fatty acid, milk production

INTRODUCTION

An increasing worldwide interest in alternative fuel sources and in a more diversified energy matrix has provided incentives for the biodiesel industry, especially in tropical countries with large productive areas. Crude glycerin, composed of water, glycerol, salts, and methanol, represents the main by-product of biodiesel production. The pharmaceutical, cosmetic, and food industries use purified glycerin (>95% glycerol) in several products (Thompson and He, 2006). However, increasing supply has outweighed these industrial demands and the price of glycerin has fallen, opening the possibility for its use as an alternative to conventional food energy sources, such as corn, in the diets of livestock, including dairy cows.

Once ingested and in the animal rumen, glycerol mostly disappears in the first 24 h (Trabue et al., 2007). It may be directly absorbed through the rumen wall, it may be transformed into propionate by ruminal microorganisms, or it may go through the rumen without transformation (Krehbiel, 2008). Glycerol constitutes an excellent substrate for gluconeogenesis and animal energy generation. Glycerol enters the gluconeogenic pathway at the level of dihydroxyacetone phosphate and 3-phosphoglyceraldehyde and can be converted to glucose in the liver of cattle, providing energy for cellular metabolism (Goff and Horst, 2003).

Researchers have supplemented dairy cow diets with 0.25 to 3.6 kg/d of glycerol for almost 60 yr, initially in the control of ketosis (Johnson, 1954) and more recently as an energy ingredient in the purified (Carvalho et al., 2011) or crude (Boyd et al., 2013) form. Addition of up to 15% purified glycerin in the diets of high-yield dairy cows does not significantly affect DMI,

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milk production, or milk composition (Donkin et al., 2009). In fact, a lower concentration of dietary purified glycerin (3.1%) has been shown to increase milk yield and milk protein concentration (Bodarski et al., 2005). When crude glycerin (82.6% glycerol) was added up to 15.6% in diets for medium-yield cows, no changes were observed in milk production and quality (Harzia et al., 2013), evidencing no difference in results of studies using crude or purified glycerin, as reported by Omazic et al. (2013). Altogether, these experiments indicate that purified or crude glycerin can be fed up to 15% of dietary DM to lactating cows without deleterious effects.

Despite this body of work, and in light of the increasing interest in glycerin as alternative energy source for dairy cows, more studies are warranted for the evaluation of higher concentrations of the compound. Thus, we have assessed the effects of up to 30% dietary crude glycerin on DMI, milk yield and composition, milk FA profile, and blood metabolites of medium-yield cows.

MATERIALS AND METHODS

Cows, Dietary Treatments, and Experimental Design

The São Paulo State University Institutional Animal Care and Use Committee approved all experimental protocols of the present study (approval number: 1892108). The experiment was conducted in the Animal Unit of Digestive and Metabolic Studies and Laboratory of Ingredients and Pollutant Gases, at the Animal Science Department of São Paulo State University, Campus of Jaboticabal, Brazil.

Six ruminally cannulated, multiparous Holstein cows (587 ± 39 kg, 114 ± 29 DIM, and 20 ± 1.5 kg/d milk production) were distributed in a replicated 3 × 3 Latin square design. Cows were paired according to initial weight, parity, and milk production. After lactation peak, each pair of matched cows was assigned randomly across squares to 1 of 3 dietary treatments with cows being housed in individual tie stalls.

The animals were fed diets with similar amount of protein and energy, meeting NRC (2001) guidelines for 550-kg Holstein dairy cows producing 25 kg of milk/d with 3.5% of milk fat. All diets were formulated with 14.1% CP and with roughage:concentrate ratio of 45:55 (DM basis). The base ration contained corn silage, cracked corn grain, sunflower meal, corn gluten meal, urea, vitamins, and minerals (Table 1). Cows were fed twice daily (0800 and 1800 h) for ad libitum intake (10 to 15% weighbacks) for 21 d in each experimental period (2 wk for adaptation and 1 wk for data collection). The dietary treatments were **G0** (control treatment, containing no crude glycerin), **G15** (containing 15% crude glycerin as a percentage of ration DM), and **G30** (containing 30% crude glycerin as a percentage of ration DM). The crude glycerin used in this trial was in liquid form, soybean-based, and composed of 83% glycerol, 89% DM, 6% NaCl, and less than 0.01% methanol. Corn silage was top-dressed with crude glycerin and then mixed with concentrate at the time of feeding.

Table 1. Ingredient, chemical, and FA composition of experimental diets

Item	Treatment[1]		
	G0	G15	G30
Ingredient, % DM			
Corn silage	45.0	45.0	45.0
Cracked corn grain	36.5	19.3	2.8
Sunflower meal	10.7	11.4	11.3
Corn gluten meal	5.1	6.6	8.1
Urea	0.5	0.5	0.6
Crude glycerin[2]	0.0	15.0	30.0
Mineral–vitamin premix[3]	1.7	1.7	1.7
Limestone	0.6	0.6	0.6
Chemical composition, %			
CP	14.4	14.3	14.1
RDP[4]	9.8	9.7	9.5
RUP[4]	4.6	4.6	4.6
NDF	34.8	33.3	31.5
ADF	19.0	18.9	18.6
NFC[5]	42.0	43.3	45.0
Ether extract	3.2	2.6	2.1
Ash	5.6	6.5	7.3
Na	0.12	0.66	1.21
Cl	0.32	0.66	1.01
ME,[4] Mcal/kg	2.8	2.8	2.8
NE_L,[4] Mcal/kg	1.6	1.6	1.6
FA profile, % FAME			
C12:0	0.02	0.02	0.04
C14:0	0.08	0.11	0.15
C15:0	0.03	0.04	0.05
C16:0	12.76	13.37	13.78
C16:1	0.16	0.17	0.21
C17:0	0.10	0.11	0.14
C 17:1	0.04	0.05	0.06
C18:0	2.52	2.62	2.75
C18:1n-9	33.58	32.58	31.47
C18:1n-7	1.41	1.48	1.22
C18:2n-6	46.62	46.33	46.55
C18:3n-6	0.08	0.12	0.17
C18:3n-3	1.25	1.51	2.04
C 20:0	0.56	0.56	0.51
C20:1n-9	0.23	0.25	0.23
C22:0	0.25	0.32	0.30
C23:0	0.05	0.05	0.04
C24:0	0.26	0.31	0.29

[1]G0 = control, no crude glycerin added; G15 = 15% crude glycerin; G30 = 30% crude glycerin.

[2]Crude glycerin: 83% glycerol, 89% DM, 6% NaCl, <0.01% methanol.

[3]Composition of mineral–vitamin premix (g/1,000 g) = vitamin A, 200 kIU; vitamin D, 60 kIU; vitamin E, 60 IU; Ca, 190 g; P, 73 g; Na, 62 g; Mg, 44 g; Cl, 90 g; S, 30 g; Zn, 1,350 mg; Mn, 940 mg; Co, 3 mg; Cu, 340 mg; I, 16 mg; Se, 16 mg; Fe, 1,064 mg; F, 730 mg.

[4]Estimated based on NRC (2001).

[5]NFC = 100 − (% CP + % NDF + % ash + % ether extract).