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Short communication

Effect of abomasal or ruminal supplementation of citrus pulp and soybean oil on nutrient digestibility and ruminal fermentation of dairy cows

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ABSTRACT

The aim of this research was to investigate the effects of supplementing two products, soybean oil (SBO; 0.2 kg/d) or SBO + citrus pulp (CPP; 1.0 kg/d), at two different sites, rumen or abomasum, on intake, total tract apparent digestibility (TTAD) and ruminal fermentation. Four ruminally fistulated lactating Holstein cows were assigned to a 4 × 4 Latin square design with a 2 × 2 factorial arrangement of treatments: 1) SBO administered in the rumen; 2) SBO infused in the abomasum; 3) SBO + CPP administered in the rumen; and 4) SBO + CPP infused in the abomasum. Basal DM intake was lower for cows fed SBO + CPP than for those fed SBO only (16.5 *versus* 17.3 kg/d) and infusion in the abomasum tended (P = 0.07) to decrease it compared to administration in the rumen (16.6 *versus* 17.1 kg/d). Ruminal pH and ammonia *N* concentration were similar among treatments. There was an interaction between product and site of supplementation for total volatile fatty acids concentration as administration of SBO + CPP in the rumen increased it compared to that of SBO and infusion of the products in the abomasum had no effect. There was a trend (P = 0.09) for lower TTAD of crude protein with administration of products in the rumen compared to infusion in the abomasum and supplementation with SBO + CPP compared to SBO led to higher TTAD of ether extract. Treatments had no effect on TTAD of dry matter and neutral detergent fiber. Ruminal or post-ruminal supplementation of soybean oil with citrus pulp compared with that of soybean oil had little effects on TTAD of nutrients and ruminal fermentation characteristics. There was no advantage for a source of antioxidants such as citrus pulp to bypass the rumen when cows were supplemented with polyunsaturated fatty acids as SBO.

1. Introduction

Feeding dairy cows with polyunsaturated fatty acids (FA) contributes to enhance milk fat quality. Although the presence of polyunsaturated FA in the rumen is known to inhibit ruminal microbial activity and fermentation (Yang et al., 2009) and

Abbreviations: FA, fatty acids; SBO, soybean oil; CPP, citrus pulp; DM, dry matter; DMI, dry matter intake; EE, ether extract; TTAD, total tract apparent digestibility; VFA, volatile fatty acids.

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Table 1
Ingredient, chemical composition, and fatty acid profile of the total mixed diet, citrus pulp, and soybean oil.

Item	Total mixed diet	Citrus pulp	Soybean oil
Ingredient (g/kg dry matter)			
Corn silage	600.2		
Ground corn	183.1		
Soybean meal	197.0		
Mineral supplement[a]	15.0		
Dicalcium phosphate	0.1		
Limestone	0.9		
Ca bicarbonate	3.7		
Chemical analysis[b]			
Dry matter (g/kg)	525.1	887.5	
Cryde protein (g/kg dry matter)	163.7	58.4	
Ether extracE (g/kg dry matter)	25.2	17.7	
aNeutral detergent fiber (g/kg dry matter)	389.5	189.3	
Acid detergent fiber (g/kg dry matter)	220.2	160.2	
Net energy for lactation (MJ/kg dry matter)[c]	7.11	8.28	
Fatty acid[2] (g/kg of total fatty acids)			
14:0 (Myristic acid)	2.4	8.4	13.5
16:0 (Palmitic acid)	165.5	295.5	117.9
18:0 (Stearic acid)	37.0	50.3	20.0
*cis*9-18:1 (Oleic acid)	301.1	202.2	257.6
*cis*9,*cis*12-18:2 (Linoleic acid)	432.0	341.9	545.0
*cis*6,*cis*9,*cis*12-18:3 (Linolenic acid)	62.0	79.0	46.1
Other acids	ND[d]	22.8	ND

[a] Contained (per kg, as-is basis): Ca 240 g, P 60 g, Mg 15.0 g, S 18.0 g, Na 78.0, Fe 2,200 mg, Zn 3.800 mg, Cu 680 mg, Mn 1.105 mg, I 40 mg, Co 10 mg, Se 25 mg, vitamin A 100,000 IU, vitamin D3 66,700 IU, and vitamin E 1000 IU.
[b] One sample obtained from four pool samples prepared by compositing seven daily samples.
[c] Calculated using described published values of feed ingredients (NRC, 2001).
[d] ND = not detected.

decrease fiber digestion (Coppock and Wilks, 1991), rumen bypass FA has no negative effects on ruminal fermentation and nutrient digestibility while still improving milk FA profile (Litherland et al., 2005; Kazama et al., 2010; Côrtes et al., 2011). Another strategy to overcome the negative effect of unsaturated FA supplementation on microbial activity in the rumen is by supplementing antioxidants. Indeed, feeding 200 mg/kg dry matter (DM) of a synthetic antioxidant (blend of ethoxyquin and tertiary-butyl-hydroquinone) to dairy cows has improved the utilization of diets containing both oxidized and fresh fat by increasing fiber and carbohydrate digestibilities (Vázquez-Añón and Jenkins, 2007).

Agricultural and industrial byproducts are attractive sources of natural antioxidants (Moure et al., 2001). Citrus pulp (CPP) is a byproduct from the food processing industry that has been widely used as a high energy feed in diets of lactating dairy cows (Bampidis and Robinson, 2006). Furthermore, CPP also is a source of the flavonoids hesperidin and naringin (Williams et al., 2004; Bampidis and Robinson, 2006), which are potent antioxidants (Tsai et al., 2007; Al-Ashaal and El-Sheltawy, 2011). However, there is a paucity of information on the antioxidant properties of CPP on rumen fermentation and nutrient digestibility of dairy cows fed polyunsaturated FA. Therefore, we hypothesized that ruminal and post-ruminal supplementation of vegetable oil (rich in polyunsaturated FA) with a source of antioxidants induces different effects on nutrient digestibility and ruminal fermentation. The overall aim of this research was to investigate the effects of ruminal or abomasal supplementation of soybean oil (SBO) or SBO + CPP on total tract apparent digestibility (TTAD) and ruminal fermentation characteristics in lactating dairy cows.

2. Material and methods

2.1. Cows, diets, and experimental procedures

Four multiparous lactating Holstein cows (92 ± 13 d in milk, 29.0 ± 2.2 kg of milk/d, and 559 ± 67 kg of body weight at the beginning of the experiment) fitted with ruminal *cannulas* (10 cm, Bar Diamond Inc., Parma, ID, USA) were assigned to a 4 × 4 Latin square design with a 2 × 2 factorial arrangement of dietary treatments. Each experimental period included 14 d for dietary adaptation followed by 7 d for sampling. Cows were housed in individual stalls with free access to water. Cows were milked at 06:30 and 16:00 h and milk yield was recorded at each milking. All cows were fed with the same total mixed ration (Table 1) twice a day (07:00 and 14:00 h) for *ad libitum* intake (100 g/kg of refusals on as fed basis). Feed consumption was recorded daily. The diet was formulated to meet requirements of the NRC (2001). The Animal Care and Use Committee of the Universidade Estadual de Maringá approved all animal procedures.

The experimental treatments consisted of 0.2 kg/d SBO administered in the rumen and 15.0 kg/d tap water infused in the abomasum; 2) 0.2 kg/d SBO and 15.0 kg/d tap water infused in the abomasum; 3) 0.2 kg/d SBO and 1.0 kg/d CPP administered in the rumen and 14.0 kg/d tap water infused in the abomasum; 4) 0.2 kg/d SBO, 1.0 kg/d CPP and 14.0 kg/d tap water infused