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Production, composition and antioxidants in milk of dairy cows fed diets containing soybean oil and grape residue silage

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ABSTRACT

Four primiparous Holstein cows averaging 504 kg of body weight and 136 days in milk were used in a 4 × 4 Latin square design with four 21 days experimental periods to determine the effects of feeding four concentrations (0, 50, 75 and 100 g/kg of dry matter (DM)) of grape residue silage on DM intake, total tract apparent digestibility (TTAD), milk production, milk composition, milk fatty acid profile and milk concentration of antioxidants when cows were fed a diet containing soybean oil. Intake of DM and nutrients was similar among diets, except for intake of ether extract (EE) which increased with the proportion of grape residue silage in the diet. The TTAD of DM, crude protein (CP), EE, acid detergent fiber and neutral detergent fiber decreased linearly with higher proportions of grape residue silage in the diet. Milk production and concentrations of CP, fat and lactose were similar among treatments, but increased levels of grape residue silage reduced milk urea N content. There was a little effect of diet on milk fatty acid composition, although there was a trend to increased proportion of polyunsaturated fatty acids in milk fat when feeding increased levels of grape residue silage. Concentrations of total polyphenols and flavonoids, and production of conjugated diene hydroperoxides in milk, were not altered by diets. Reducing power in milk was higher with increased dietary levels of grape residue silage. Results suggest that it is possible to improve milk fat quality by feeding cows with grape residue silage as shown by enhanced antioxidant activity, although it was clearly insufficient to overcome the negative effects on milk fat synthesis probably caused by the high levels of fat added to diets as soybean oil.

1. Introduction

After grapes are harvested and crushed to collect the juice for wine, there remains grapes (residue/pomace) which can be incorporated to other products such as grappa, animal feed, or fertilizer. Grape residue is biodegradable, but requires time to mineralize thereby constituting a potential source of pollutants to the environment (Cataneo et al., 2008). Because of its low cost and high fiber concentration (Makris et al., 2007), grape residue can be an alternative feed ingredient to replace partially the

Abbreviations: ADF, acid detergent fiber; BW, body weight; CD, conjugated diene; CP, crude protein; DM, dry matter; EE, ether extract; GAE, gallic acid equivalent; GE, gross energy; MUN, milk urea N; MUFA, monounsaturated fatty acids; NEl, net energy for lactation; aNDF, neutral detergent fiber; OM, organic matter; PTFE, polytetrafluoroethylene; PUFA, polyunsaturated fatty acids; PVPP, polyvinylpolypyrrolidone; QE, quercetin equivalent; SCC, somatic cell count; SFA, saturated fatty acids; TTAD, total tract apparent digestibility.

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Table 1
Chemical composition of the grape residue silage.

	Grape residue silage[a]
Chemical analysis	
Dry matter (g/kg)	337.0 ± 5.07
Organic matter (g/kg DM)	913.7 ± 2.58
Ether extract (g/kg DM)	105.0 ± 7.38
Crude protein (g/kg DM)	205.8 ± 10.58
aNeutral detergent fiber (g/kg DM)	583.5 ± 3.93
Acid detergent fiber (g/kg DM)	431.4 ± 23.66
Cellulose (g/kg DM)	330.0 ± 22.83
Lignin (pm) (g/kg DM)	101.4 ± 3.05
Neutral detergent insoluble N (g/kg total N)	694.3 ± 39.84
Acid detergent insoluble N (g/kg total N)	253.3 ± 1.78
Ash (g/kg DM)	28.1 ± 0.64
Gross energy (KJ/kg DM)	229.5 ± 4.57
pH	4.11 ± 0.01
Fatty acid composition of grape residue silage (g/kg of fatty acids)	
16:0	125.1 ± 4.16
18:0	44.3 ± 1.78
*cis*9-18:1	192.1 ± 4.12
*cis*6-18:2	611.5 ± 9.51
*cis*3-18:3	14.1 ± 0.62
PUFA[b]	634.7 ± 10.11
MUFA[b]	192.1 ± 4.24
SFA[b]	173.2 ± 6.34
n-6[c]	620.1 ± 9.51
n-3[d]	14.6 ± 0.62
n-6:n-3	42.4 ± 1.30
Total polyphenols (mg GAE/g DM)[b]	19.5 ± 0.37
Flavonoids (mg QE/g DM)[b]	2.96 ± 0.01

[a] Mean ± standard error of 4 pool samples prepared by compositing 7 daily samples collected from day 15 to 21 of each experimental period.
[b] PUFA = Polyunsaturated fatty acids; MUFA = monounsaturated fatty acids; SFA = saturated fatty acids; GAE = gallic acid equivalent; QE = quercetin equivalent.
[c] cis6-18:2.
[d] cis3-18:3.

forage portion in the diet of ruminants. Ensiling the grape residue is necessary because of its high water content and it is a practice already established on farms. Thus, studying the use of a potentially polluting residue as a feed for ruminants may result in grape residue being a tool for a sustainable production. Recently it has been shown by Greenwood et al. (2012) that grape residue supplementation alters nitrogen metabolism of non-lactating cows by decreasing N urinary excretion due to the high levels of condensed tannins, "which is desirable for an environmental perspective" (Greenwood et al., 2012). Moreover, the seeds and skins of the crushed grapes, which make up about 0.3 of the total volume of the grapes used in wine production (Makris et al., 2007), are very rich in phenolic compounds. There is a growing interest for use of grape products due to the antioxidant activity of their polyphenolic compounds (Llobera and Cañellas, 2007; Negro et al., 2003). However, grape pomace feeding has had negative effects on performance of ruminants. For example, inclusion of 500 g/kg dry matter (DM) of grape residue in the diet of sheep has reduced total tract apparent digestibility (TTAD) of DM and other nutrients (Zalikarenab et al., 2007). The high contents of polyphenols and lignin of grape residue may be responsible, respectively, for decreased digestibility of crude protein (CP; O'Connell and Fox, 2001) and DM (Baumgärtel et al., 2007). However, lower levels of grape residue inclusion in diets of lactating cows could have less negative effects on apparent digestibility while supplying polyphenols that could contribute to prevent oxidation of milk fatty acids.

Supplementation of the dairy cow diets with vegetable oils and oilseeds increases proportions of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) in milk fat and synthesis of conjugated linoleic acid in the rumen (Alzahal et al., 2008), which can increase the occurrence of spontaneous oxidized flavor in milk (Granelli et al., 1998). However, the presence of antioxidants such as α-tocopherol may prevent oxidation of milk enriched in PUFA as well as development of oxidized flavor (Barrefors et al., 1995). Phenolic compounds such as isoflavonoids and lignans can be transferred to the milk as was shown for dairy cows fed clover (King et al., 1998) and flaxseed meal (Petit and Gagnon, 2009), respectively. However, evaluation of grape residue silage as a feed for lactating dairy cows has been little studied, and its potential to transfer antioxidants into milk is unknown. Therefore, the objectives were to determine effects of incorporating grape residue silage to a diet containing soybean oil on feed intake, TTAD, milk production and milk concentration of antioxidants in lactating dairy cows. The aim of the soybean oil supplementation to all diets was to obtain milk with high concentrations of PUFA and MUFA, in order to enhance milk quality. The enriched milk was then used to evaluate the potential of grape residue silage for avoiding (or diminishing) oxidation of this enriched milk. The hypothesis was that increased dietary levels of grape residue silage would increase antioxidant activity, and decrease lipid oxidation, of milk when cows were fed a diet containing soybean oil.

2. Materials and methods

2.1. Cows and diets

Four primiparous Holstein cows averaging 504 ± 26 kg of body weight (BW) and 136 ± 28 days in milk were randomly assigned to a 4 × 4 Williams Latin square design. Each experimental period consisted of 14 days of adaptation to diets and 7 days for daily data collection. The experimental treatments (Table 1) were four dietary concentrations of grape residue silage (0, 50, 75, 100 g/kg DM) in a soybean oil-enriched diet (40 g/kg DM). Grape residue silage (Table 2) contained grape skins and seeds of the purple variety Isabel (Vitis labrusca × Vitis vinifera) obtained from the Cooperativa Agroindustrial de Rolândia (Rolândia, PR, Brazil). After pressing the grapes, the residue material (~280 g/kg DM) was shipped to the Iguatemi Experimental Farm for ensiling. Five silos were made from cylindrical cement tubes which measured 1.10 m of height and 1.2 m of diameter, with a volume of 1.24 m^3. Straw was placed at the bottom of the silos before ensiling to help sealing of the silo. For each silo, about 1300 kg of grape residue were compacted by trampling, resulting in a density of 1048 kg/m^3 of fresh grape residue (353 kg/m^3