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Effects of rutin and buckwheat seeds on energy metabolism and methane production in dairy cows

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ABSTRACT

Flavonoids are secondary plant metabolites with several health promoting effects. As dairy cows often suffer from metabolic imbalance and health problems, interest is growing in health improvements by plant substances such as flavonoids. Our group has recently shown that the flavonoids quercetin and rutin (a glucorhamnoside of quercetin) are bioavailable in cows when given via a duodenal fistula or orally, respectively, affect glucose metabolism, and have beneficial effects on liver health. Furthermore, flavonoids may reduce rumen methane production in vitro through their antibacterial properties. To test the hypothesis that rutin has effects on energy metabolism, methane production, and production performance in dairy cows, we fed rutin trihydrate at a dose of 100 mg/kg of body weight to a group of 7 lactating dairy cows for 2 wk in a crossover design. In a second experiment, 2 cows were fed the same ration but were supplemented with buckwheat seeds (*Fagopyrum tartaricum*), providing rutin at a dose comparable to the first experiment. Two other cows receiving barley supplements were used as controls in a change-over mode. Blood samples were taken weekly and respiration measurements were performed at the end of each treatment. Supplementation of pure rutin, but not of rutin contained in buckwheat seeds, increased the plasma quercetin content. Methane production and milk yield and composition were not affected by rutin treatment in either form. Plasma glucose, β-hydroxybutyrate, and albumin were increased by pure rutin treatment, indicating a possible metabolic effect of rutin on energy metabolism of dairy cows. In addition, we did not show that in vivo ruminal methane production was reduced by rutin. In conclusion, we could not confirm earlier reports on in vitro methane reduction by rutin supplementation in dairy cows in established lactation.

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INTRODUCTION

Flavonoids belong to the large group of secondary plant metabolites with phenolic structures (Formica and Regelson, 1995; Nijveldt et al., 2001). Flavonoids have been reported to have various health-promoting effects due to their antiviral, antibacterial, anti-inflammatory, and antihepatotoxic properties. Quercetin, as one of the best described flavonoids in plants, is mainly bound to sugars forming glycosides, such as rutin, whereas quercetin aglycone is bound to rutinose (Nijveldt et al., 2001). Rutin is one of the most consumed flavonoids in human nutrition and is found, for example, in tea and buckwheat (Formica and Regelson, 1995; Materska, 2008). Interest is growing in the use of plant-derived substances as a potential natural alternative to using synthetic agents and pharmaceuticals to improve animal health and productivity (Materska, 2008; Rochfort et al., 2008).

In view of the beneficial effects flavonoids have in humans and rodents (Panchal et al., 2011; Galleano et al., 2012), increasing interest has been noted in possible health benefits among dairy cows by plant bioactive compounds and, in particular, flavonoids. Associated with the onset of high milk production, dairy cows experience negative energy balance often followed by metabolic imbalances and health problems. Our group has recently shown that quercetin contained in rutin is much more bioavailable in cows compared with quercetin aglycone when administered intraruminally (Berger et al., 2012), whereas quercetin aglycone requires administration via a duodenal fistula to be systemically available (Gohlke et al., 2013a). Some beneficial effects on performance (Guo et al., 2010), glucose metabolism, as well as milk composition (Gohlke et al., 2013b) and liver health (Stoldt et al., 2015) were reported in dairy cows. Furthermore, it is known from other species that flavonoids affect energy, in particular glucose and lipid metabolism (Hoek-van den Hil et al., 2013; Wein and Wolffram, 2014).

Some in vitro studies using pure flavonoids (Oskoueian et al., 2013; Seradj et al., 2014) or plants rich in flavonoids (Wang et al., 2013; Niderkorn and Macheboeuf, 2014) revealed the potential to reduce methane production without negative effects on fermentation processes (Oskoueian et al., 2013; Berger et al., 2015). Flavonoids have been shown to alter the rumen microbiome and to reduce the population of protozoa and methanogenic bacteria (Santra et al., 2012; Oskoueian et al., 2013), which is presumably the underlying mechanism of reduced methane production. Methane is a potent greenhouse gas with enormous climate-warming potential (Etim et al., 2013), and ruminant livestock is an important contributor to anthropogenic methane emission (Pitesky et al., 2009). Furthermore, methane production by rumen microbes implies loss of gross energy for the cow. Thus, a potential reduction in methane production by flavonoids would be environmentally favorable.

To investigate whether selected flavonoids affect health, energy metabolism, and methane emission in dairy cows, we conducted a feeding trial with rutin including indirect calorimetry gas exchange measurements (Derno et al., 2009). Because quercetin is largely degraded by rumen microbes when given orally (Berger et al., 2012), we chose rutin as a likely rumen-protected source of quercetin (Berger et al., 2012) for supplementation. Given that buckwheat has a high rutin content (Fabjan et al., 2003) and is suitable as feed for ruminants (Amelchanka et al., 2010; Kälber et al., 2012), we also tested whether supplementation of tartary buckwheat (*Fagopyrum tartaricum*) seeds have properties comparable to pure rutin isolate. We hypothesized that oral supplementation of rutin as a pure substance or via buckwheat seeds would have beneficial effects on energy metabolism, methane production, and milk yield and composition in dairy cows in established lactation.

MATERIALS AND METHODS

Animals and Diet

The study was conducted in compliance with the German animal protection regulations with approval of the authorities of the land Mecklenburg-Vorpommern, Germany (Landesamt für Landwirtschaft, Lebensmittelsicherheit und Fischereiwesen Mecklenburg-Vorpommern, Germany; LALLF M-V/TSD/7221.3–2.1–019/12).

In the study, 7 German Holstein cows with >7,000 kg of milk in their first lactation and an average BW of 608 ± 14 kg (mean ± SE) were monitored over a period of 4 wk starting on d 100 of the second lactation. The cows were kept in tiestalls, had free access to water, and were offered a TMR for ad libitum intake. The diet composition was calculated in accordance to recommendations of the German Society of Nutritional Physiology (GfE, 2004). Chemical composition of the TMR was determined according to Weender standard procedure (Naumann and Bassler, 1993) and is shown together with the feed components in Table 1. The DMI and milk yield were recorded daily, milking time was daily at 0630 and 1630 h.

Cows were fed a TMR only (control) or with daily supplementation of 100 mg of rutin trihydrate (Carl Roth GmbH, Karlsruhe, Germany) per kilogram of BW for a period of 2 wk in a crossover design, resulting in a 4-wk experimental period. The rutin dose used was based on the results of a previous study of our group (Berger et al., 2012). Subsequently, in a second experiment, 2 of the cows received the same TMR plus 6.5 g/kg of BW tartary buckwheat seeds (*Fagopyrum*

Table 1. Ingredients and chemical composition (g/kg of DM, unless otherwise noted) of TMR diet (means)

Item	Measurement
Ingredient	
Grass silage	173
Corn silage	332
Straw	34.9
Grass hay	38.9
Corn (ground)	79.5
Soybean meal	19.9
Rapeseed meal	20.1
Sugar beet pulp[1]	37.7
Concentrate[2]	256
Minerals[3]	8.9
Feed lime	4.5
Chemical composition	
DM (g/kg of FM[4])	508
Crude ash	67
CP	161
NDF	343
Crude fat	30
ME[5] (MJ/kg of DM)	11.2
NE_L[5] (MJ/kg of DM)	7

[1]Arp, (Thordsen, Rautenberg GmbH & Co. KG, Sollerupmühle, Germany): 7.3 MJ of NE_L/kg of DM and, 153 g of utilizable protein/kg of DM.

[2]Concentrate MF 2000 (Vollkraft Mischfutterwerke GmbH, Güstrow, Germany): 33% extracted soy meal, 20% corn, 17% wheat gluten, 8% extracted rapeseed meal, 5% sugar beet pulp, 2% sodium hydrogen carbonate, 1.3% calcium carbonate, 0.2% sodium chloride, 8.0 MJ of NE_L/kg of DM, and 204 g of utilizable protein/kg of DM.

[3]Rinderstolz 9522 lactation (Salvana Tiernahrung GmbH, Sparrieshoop, Germany): 92% crude ash, 20% calcium, 5% phosphorus, 6% magnesium, 8% sodium, and 0.03% retinol, 0.06% β-carotene, 0.0005% 25-OH-vitamin D_3, and 0.40% DL-α-tocopherolacetate.

[4]FM = fresh matter.

[5]Calculated as recommended by the German Society of Nutrition Physiology (GfE, 2004).