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Vegetable oil soapstocks reduce methane production and modify ruminal fermentation☆

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A B S T R A C T

Four soapstocks from the refinery vegetable oil industry (SSpalm, SSoliv, SSsoyb and SSsunf (RIOSA, Baeza-Linares, Spain), from processing of palm, olive, sunflower, and soybean oils, respectively) and a mixture of lauric and miristic acids (4:1, LMA) added to diets with different forage proportions (50, 150 and 250 g barley straw/kg diet; F5, F15 and F25 diets, respectively) were examined to assess their potential to modify ruminal fermentation *in vitro*, in particular CH_4 production. Serum bottles containing 400 mg of substrate (F5, F15, F25 diets) including 30 or 60 g/kg of the materials and 50 ml of buffered rumen fluid were incubated at 39 °C for 24 h. After incubation, gas and CH_4 production, pH and volatile fatty acid (VFA) concentrations in the incubation medium were measured. All materials linearly decreased gas production ($P<0.05$), and SSoliv, SSsoyb and SSsunf reduced CH_4 production ($P<0.05$) and methane produced per mol of total VFA formed ($P<0.05$), and LMA also reduced CH_4 proportion in the gas ($P<0.05$), whereas SSpalm tended to decrease it. LMA linearly ($P<0.05$) decreased acetate production and the acetate to propionate ratio, and raised the propionate molar proportion and pH ($P<0.05$). SSoliv and SSsoyb caused a linear ($P<0.05$) decline in acetate, and rise in propionate, molar proportions, thus decreasing the acetate to propionate ratio ($P<0.05$), whereas SSsunf tended to have the same effects ($P<0.10$). As the forage proportion increased, CH_4 and acetate proportion, acetate to propionate ratio and final pH increased, while gas, VFA (individual and total) and CH_4 production, and propionate and butyrate molar proportions, decreased. Soapstocks, especially SSsoyb and SSsunf, are promising dietary alternatives to depress ruminal methanogenesis.

1. Introduction

Ruminants lose 2–12% of their gross energy intake as CH_4, depending on the quality and quantity of the diet consumed (Johnson and Johnson, 1995). Methane produced by ruminants not only affects the efficiency of energy utilization but also contributes to environmental degradation. It has been estimated that ruminant livestock are responsible for about 15–20% of the total anthropogenic emissions of CH_4 (Moss et al., 2000). A possible mitigation strategy of the CH_4 produced within

Abbreviations: DM, dry matter; FA, fatty acids; MUFA, monounsaturated FA; aNDF, neutral detergent fiber assayed with a heat stable amylase and expressed inclusive of residual ash; PUFA, polyunsaturated fatty acids; SFA, saturated FA; SSoliv, soapstock from olive oil refinery; SSpalm, soapstock from palm oil refinery; SSsoyb, soapstock from soybean oil refinery; SSsunf, soapstock from sunflower oil refinery.

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the rumen is use of dietary fats. It has been recognized for many years that long chain fatty acids (FA) can depress CH_4 production in the rumen (Czerkawski et al., 1966), whereas other recent studies have found that medium chain FA, such as lauric acid, can also reduce rumen CH_4 production (Soliva et al., 2003). In a later study, a mixture of 4:1 lauric:miristic acids, which had a synergistic effect in suppressing methanogenesis, was proposed for practical use in ruminant nutrition, since lauric acid is less palatable than miristic acid (Dohme et al., 2001; Soliva et al., 2004a). However, effects of FA on CH_4 production can be counteracted by other components of the diet, such as calcium, or affected by the forage to concentrate ratio (Machmüller et al., 2003).

Use of different types of vegetable oilseeds and oils (Fievez et al., 2003; Machmüller et al., 1998, 2000; Martin et al., 2008) or of FA mixtures (Soliva et al., 2004b) to reduce ruminal methanogenesis has been widely studied. However, to our knowledge, less expensive alternatives, such as byproducts from the vegetable oil industry, have not been examined. A byproduct is a product that has value as an animal feed and is obtained during processing of a commodity in which a human food or fuel is derived (Fadel, 1999). Soapstocks constitute a substantial portion of the oil which is obtained from alkali refining of vegetable oil (Bender, 2009). Consequently, these products usually consist of soaps, neutral oils, gums and other materials such as meal fines which can be found in the crude oil. The chemical composition of soapstocks depends on the type of oil and refining conditions (Woerfel, 1983). Information on use of soapstocks in ruminant feeding is scarce, even though it has been regarded as a promising and economical source of partially protected lipid for use in the diets for dairy and beef cattle (Shain et al., 1993; Abel Caines et al., 1998). Additionally, Perry and Weatherly (1976) proposed inclusion of soapstocks in the diet as an approach to reduce rumen CH_4 production, but no further studies were completed in this area.

The aim of this study was to examine effects of diets with different forage to concentrate ratios, and the potential of different soapstocks added at two doses to these diets, to modify ruminal fermentation *in vitro*, in particular CH_4 production.

2. Material and methods

2.1. In vitro fermentation

Four soapstocks from processing of palm, olive, soybean and sunflower oils (SSpalm, SSoliv, SSsoyb and SSsunf, respectively) and a 4:1 mixture of lauric and miristic acids were used. Soapstocks were obtained from a refinery industry (RIOSA, Baeza-Linares, Spain). The mixture of 4:1 lauric:miristic acid (Sigma–Aldrich, St. Louis, MO, USA) was used as a positive control due to their known antimethanogenic properties (Soliva et al., 2004a). The four soapstocks and the mixture of lauric and miristic acids (LMA) were individually added at doses of 30 and 60 g/kg DM to diets with different forage proportions (50, 150 and 250 g barley straw/kg diet – as fed basis – to create the F5, F15 and F25 diets) to examine their effects on ruminal fermentation. The 30 and 60 g/kg doses are the range at which these type of ingredients are usually used in animal feeding (Mao et al., 2010; Martin et al., 2008; McGinn et al., 2004). The ingredients and chemical composition of the diets, as well as the chemical composition of the soapstocks (main FA) are in Table 1.

In vitro gas production measurements were conducted using a pressure transducer as described by Theodorou et al. (1994). Samples of 400 mg of substrate (F5, F15 or F25 diets including 30 or 60 g/kg DM of the materials, and controls without

Table 1
Ingredients and chemical composition of diets and soapstocks.

	Diets		
	F5	F15	F25
Ingredients (g/kg)			
Barley grain	490	433	388
Maize grain	210	150	80
Soybean meal (440 g CP/kg)	220	237	252
Barley straw	50	150	250
Vitamin mineral supplement	30	30	30
Chemical composition (g/kg DM)			
DM (g/kg)	893	896	900
aNDF	196	259	323
Crude protein	181	181	181
Ash	60	73	83

	Soapstocks			
	SSpalm	SSoliv	SSsoyb	SSsunf
Fatty acids (g/kg)				
C16:0	240	120	110	90
C18:0	225	45	60	45
C18:1	330	655	350	360
C18:2	175	150	450	475
MUFA	365	665	350	365
PUFA	190	160	470	490
SFA	445	175	180	145