

Concentration of volatile sulphur-containing compounds along the gastrointestinal tract of pigs fed a high-sulphur or a low-sulphur diet ☆

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ARTICLE INFO

Keywords:

Dimethyl sulfide
Feed
Hydrogen sulfide
Methanethiol
Pigs

ABSTRACT

Volatile sulphur-containing compounds (VSC) are formed in large quantities in the gastrointestinal tract (GI-tract) of pigs and upon excretion from the animal; these compounds are released from the faeces causing emission of foul odour. However, very little is known about the rate and extent of their production or concentration along the GI-tract of the pig, and to what extent these parameters are influenced by the sulphur content of the diet. In order to address these questions, two diets with different sulphur content were formulated. Growing pigs were fed one of each diet during a minimum of three weeks after which they were killed and gas samples were removed from eight segments of the intact GI-tract and analysed for VSC, hydrogen, carbon dioxide and methane. The concentration of individual VSC in gas samples from the intact GI-tract varied between segments. The total concentration of VSC was high in the cecum and throughout the colon. A significantly higher concentration of methanethiol in the stomach, cecum and proximal colon and of dimethyl sulphide in the cecum and along the colon of pigs fed the high-sulphur diet compared to those fed the low-sulphur diet was measured.

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1. Introduction

Volatile sulphur-containing compounds (VSC) in the gastrointestinal tract (GI-tract) originate from sulphur in the unutilized fodder or sulphur-containing excretions like bile and mucins (Mackie et al., 1998). Thus, raising the dietary supply of sulphur can be hypothesised to increase the production of VSC within the GI-tract of pigs. According to studies on volatile sulphur in digesta from the pig colon, the most likely VSC to be found in the GI-tract of pigs are: hydrogen sulphide, methanethiol and dimethyl sulphide (Ushida et al., 2002). All three compounds have low odour thresholds (Oneill and Phillips, 1992) and can therefore contribute significantly to odour emissions.

In the intestine, hydrogen sulphide is either produced by reduction of oxidized sulphur compounds by sulphur reducing bacteria or by degradation of the sulphur-containing amino acid cysteine (Levine et al., 1998). The most likely source of methanethiol is the amino acid methionine (Kiene and Capone, 1988) and possibly bacterial mediated methylation of hydrogen sulphide. This latter process also produces dimethyl sulphide by methylation of methanethiol (Finster et al., 1990), which can further be degraded to methane and hydrogen sulphide by methanogenic archaea (Kiene and Capone, 1988) (Fig. 1). However, the quantitative significance of the different processes is hitherto unknown.

No studies have yet been carried out investigating the effect of diet composition on the odorous compounds produced within the GI-tract of pigs, whereas a limited number of studies have been conducted on this effect in slurry. Le et al. (2007) found increased odour emissions from manure of pigs fed a diet supplemented with methionine, whereas Cai et al.

☆ This paper is part of the special issue entitled "11th International Symposium on Digestive Physiology of Pigs".

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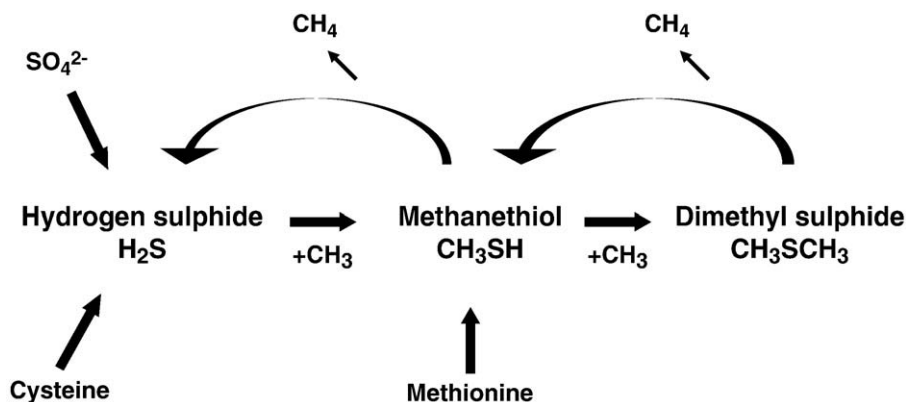


Fig. 1. Proposed cyclic pathway showing the production and degradation of VSC in the gastrointestinal tract.

(2007) showed that lowering the sulphur or protein content of the diet resulted in a decrease in emission of several odorous compounds, including hydrogen sulphide, methanethiol and dimethyl sulphide, from headspace of manure from pigs.

The present study was undertaken to gain information on the concentration of VSC and the quantitatively most significant microbiologically produced gases in the gas phase of various regions of the GI-tract of pigs. Furthermore, it was our aim to investigate the impact of the dietary sulphur content on the concentration of the different VSC.

2. Materials and methods

Pigs were fed either a low-sulphur diet or a high-sulphur diet (Table 1) formulated to meet or exceed Danish nutrient requirement estimates (Jørgensen and Tybirk, 2008). The concentrations of cysteine and methionine were 0.26%, in the low-sulphur diet, and 0.37% and 0.34%, respectively, in the high-sulphur diet. The sulphur content was 0.16% and 0.30% in the low- and high-sulphur diets, respectively.

Eight barrows were fed the diets during a minimum of 21 days. At a body weight of $116 \text{ kg} \pm 13.3 \text{ kg}$ the animals were killed with a bolt pistol 3 h after the morning meal, exsanguinated and the GI-tract removed and divided into eight segments: stomach, three equally long segments of the small intestine, cecum, and three equally long segments of the colon including the rectum.

Table 1
Ingredient composition of the experimental diets (g/100 g as fed).

Item	Diet	
	Low-sulphur	High-sulphur
Wheat	66.0	–
Barley	26.0	26.0
Rapeseed double low	–	20.0
Sugar beet pulp	–	34.8
Dehulled toasted soybean meal	4.0	17.6
Calcium carbonate	0.7	0.1
Sodium chloride	0.4	0.4
Dicalcium phosphate	1.2	1.2
Vitamin and mineral premix	0.2	0.2
Chromic oxide	0.2	0.2

Gas pockets were located in the intact intestine by visual inspection. When no gas pockets or insufficient volumes were found, the digesta was manipulated gently to form a gas pocket. Gas samples were rapidly removed from gas pockets in each segment with polypropylene syringes. Two sets of samples were removed: 1) Samples for sulphur gas analysis (2 ml) were removed and immediately injected into 110 ml serum bottles containing N_2 and capped with butyl rubber stoppers. 2) Samples for hydrogen, methane and carbon dioxide analysis were removed and stored in 1 ml syringes until analysis. All samples were analysed within 1 h of sampling.

For VSC analysis, 2 ml of gas was removed from the serum bottles and injected into the sample inlet of a Clarus 5000 gas chromatograph equipped with an amperometric sulphur detector (PerkinElmer-Arnel) and a polydimethylsiloxane column (4 μm ; 30 m by 0.32 mm). Helium was used as carrier gas with a column head pressure of 26 psi. Air and H_2 for combustion were supplied at a flow rate of 0.9 ml/min and 16 ml/min. For calibration, a permeation chamber (Dynacal) containing dimethyl sulphide (73 ng/min, 50 °C) was used.

For hydrogen, methane and carbon dioxide measurements, the samples were analysed in a Microlab gas chromatograph equipped with a thermal conductivity detector and a Hayesep Q column (80/100 mesh; 1.5 m by 1/4 in). Argon was used as carrier gas at a flow rate of 58 ml/min. Standard gas mixtures containing H_2 , CO_2 , N_2 and CH_4 were used for calibration.

The effect of diet on digesta over a range of intestinal segments was statistically analysed according to a normal mixed model, with diet, segment and the interaction between diet and segment as fixed effects. Moreover, a variance component was added to account for the correlation between measurements made on the same animal. The analyses were performed with SAS for Windows version 8.2 (SAS Institute, Cary, NC). When there was an overall effect of diet, at an alpha of $P=0.05$, differences between means were compared pairwise using an *F*-test.

3. Results

The average concentrations of hydrogen sulphide were ~600 ppm throughout the colon of both groups of pigs. Methanethiol and dimethyl sulphide were primarily found in gas from the cecum and colon. The concentration of

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