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Effects of a high-fibre diet on ammonia and greenhouse gas emissions from gestating sows and fattening pigs

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HIGHLIGHTS

- Dietary fibre has significantly lowered NH_3 emissions from fattening pigs and gestating sows.
- CH_4 emissions were increased in the case of dietary fibre.
- N_2O and CO_2 emissions were not impacted by the dietary fibre content.
- Growth performance of fattening pigs was impaired by high level of fibre inclusion.

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ABSTRACT

This study aims to measure under barn conditions the emissions of NH_3, N_2O, CH_4 and CO_2 associated with gestating sows (trial 1) and fattening pigs (trial 2) fed either a control diet (CTD) based on cereals or a high-fibre diet (HFD) based on sugar beet pulp (SBP). Three successive batches of 10 Belgian Landrace gestating sows were used for trial 1. Two successive batches of 24 Piétrain × Belgian Landrace fattening pigs were used for trial 2. Animals were kept on slatted floor. The gas emissions were measured by infrared photoacoustic detection and expressed per day and per livestock unit, equals to 500 kg body weight. Similar trends were observed for both animal types. With HFD, the NH_3 emissions were reduced (27.2 vs. 36.5 g for the gestating sows, $P < 0.001$; 23.2 vs. 45.0 g for the fattening pigs, $P < 0.001$) but the CH_4 emissions were increased (41.5 vs. 21.0 g for gestating sows, $P < 0.001$; 37.9 vs. 27.2 g for fattening pigs, $P < 0.001$). The fibre content of the diet had not significant impact on N_2O emissions (around 1.4 g for gestating sows and 2.1 g for fattening pigs, $P > 0.05$), and on CO_2 emissions (around 6.0 kg for gestating sows and 9.1 kg for fattening pigs, $P > 0.05$). Most of manure parameters did not statistically differ regarding the treatment. Reproductive performance and body condition of the sows were not affected by the diet. However, growth performance and carcass traits of the HFD-fed fattening pigs were deteriorated compared to CTD.

1. Introduction

The use of dietary fibre in pig production is known as having beneficial effects on animal health and welfare. With gestating sows, energy dilution due to fibrous feedstuffs avoids excessive weight gain that impairs reproductive performance, and reduces the feeding motivation, that may result in stereotyped and aggressive behaviours (Philippe et al., 2008). With weaned piglets and fattening pigs, it has been proved that dietary fibre improves the gut health by reducing gastric ulcerative lesions and strengthening the intestine's protective barrier against the invasion of bacterial pathogens (Bruininx et al., 2009; Hermes et al., 2009; Laitat et al., 2015).

High fibre diets are also known to decrease ammonia (NH_3) emissions. Comparing a fibrous diet based on sugar beet pulp (SBP) with a control diet based on cereals, O'Shea et al. (2009) observed a reduction of NH_3 emissions from slurry samples by 40%. Such a reduction is beneficial for pig health as ammonia is an irritant for

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the respiratory tract and also beneficial for the environment as ammonia contributes to fine particulates formation, eutrophication and acidification of ecosystems (Krupa, 2003).

The use of high fibre diets is however limited by a potential reduction in fattening pig performance (Bruininx et al., 2009) and to an increase of methane (CH_4) emissions (Le Goff et al., 2002; Jarret et al., 2012), one of the three greenhouse gases related to the livestock sector, including nitrous oxide (N_2O) and carbon dioxide (CO_2). In an experiment with sows kept in respiration chambers, Rijnen et al. (2001) observed linear increase of CH_4 emissions from 3.8 to 8.2 g animal^{-1} day^{-1} with SBP content ranging from 0 to 30%.

Most of the studies on the influence of high fibre diets on NH_3 and CH_4 emissions were however carried out under laboratory conditions. So, there is a clear lack of information about the effects of fibrous diet measured under barn conditions. Moreover, the impact of dietary fibre on N_2O and CO_2 emissions is not well known.

Direct emissions of N_2O from pig houses originate from manures but indirect emissions can also result from nitrogen loss from the system in the form of NH_3 and subsequent atmospheric deposition on soils and water surfaces, part of which is converted into N_2O (IPCC, 2006).

The emissions of CO_2 in pig houses consists of two parts, release from manure but mainly exhalation by animals (Ni et al., 1999; Philippe and Nicks, 2015). Indirect CO_2 emissions also occur principally due to feed production and on-farm energy consumption, mainly for heating and ventilation (Ni et al., 1999; Lammers et al., 2012; Hassouna et al., 2013).

Therefore, the aim of this study is to evaluate the impact of high-fibre diet on NH_3, CH_4, N_2O, and CO_2 emissions associated with gestating sows and fattening pigs kept on slatted floor.

2. Material and methods

The protocol was approved by the ethics committee for animal use and care of the University of Liège, Belgium, in compliance with Directive 2010/63/EU of the European parliament and of the Council of the European Union. Two trials were successively carried out in experimental rooms located at the Faculty of Veterinary Medicine of Liège University (Belgium) with gestating sows (trial 1, 3 replicates) and fattening pigs (trial 2, 2 replicates).

2.1. Experimental rooms

Two identical experimental rooms (volume: 103 m^3; surface: 30 m^2), were arranged and equipped for this experiment. The rooms were divided in a service area and a pen designed to house a group of five gestating sows (trial 1) or 12 fattening pigs (trial 2). For trial 1, the pens had a surface area of 15 m^2 (3.0 m^2 sow^{-1}) and comprised a resting area (1.8 m^2 sow^{-1}) and a feeding area (1.2 m^2 sow^{-1}). The floor of the resting area consisted of a concrete slatted floor with 15% void. The feeding area was made up of five individual feeding stalls that were equipped with front feeding troughs, rear gates and concrete solid floor. The sows had permanent access to the feeding stalls but were blocked in the stall during one hour per day (at 8:00 AM) for the daily meal. A water trough was installed in the resting area. For trial 2, the pens had a total surface area of 9 m^2 (0.75 m^2 pig^{-1}), corresponding to the resting area of the pens of trial 1. The floor consisted of a concrete slatted floor with 15% void. Two single-spaced feeders with an integrated watering nipple were installed per pen. For both trials, the slurry pit was under the slatted floor. Just before each replicate, water was poured into the pit in order to avoid crust formation and to ensure good homogenisation of the slurry in the pit from the beginning (300 and 400 L for gestating sows and fattening pigs, respectively). After each replicate, the slurry was removed and the pens were cleaned. The slurry was weighed and sampled after homogenisation (two samples per room and per replicate). The samples were analysed to determine the contents of dry matter (DM), organic matter (OM), total nitrogen (N, Kjeldahl method) and ammonium ions (NH_4^+), using Dutch standard methods for manure and derivatives (Schulten, 1998a, 1998b, 1998c, 1998d).

2.2. Animals

For trial 1, three successive batches of 10 Belgian Landrace gestating sows were used. They were divided into 2 groups of 5 animals similar according to the parity, the body weight (BW) and the backfat thickness. Each group was randomly allocated to a treatment: control diet (CTD) or high fibre diet (HFD). The gestating sows arrived in the experimental rooms about 7 weeks after service. The stay duration was 64 days for each replicate. At the beginning and at the end of the trial period, the sows were individually weighed and the backfat thickness was measured on P2-site by ultrasonography (Dourmad et al., 2001). The numbers of piglets born alive and stillborn were recorded at farrowing.

For trial 2, two successive batches of 24 Piétrain × Belgian Landrace fattening pigs were used. They were divided into 2 groups of 12 animals similar according to the age, the sex and the BW. Each group was randomly allocated to a treatment: CTD or HFD. The fattening pigs arrived in the experimental rooms at the age of 3 months. The stay duration was 91 days for each replicate. At the beginning and at the end of the trial period, the pigs were individually weighed. At slaughterhouse, carcass weight, muscle thickness, backfat thickness and lean yield percentages (CGM optical method, Sydel, France) was individually determined.

2.3. Experimental diets and feeding management

For both trial, the CTD were based on cereals and the HFD on SBP (Table 1). For gestating sows, the amount of daily feed was restricted and determined per sow as a function of parity and backfat thickness. The feed was supplied once a day at 08:00 AM and all the sows were blocked in the individual feeding stalls during the feeding time (1 h). For fattening pigs, the feed was supplied ad libitum. The feed and water intakes were recorded per group. Meters (Wateau®, EEC approval no. B02 314.29) were used to determine the water consumption (including potential spillage but not cleaning water).

2.4. Gas measurements

2.4.1. Flow rate and air temperature

Each room was ventilated with an exhaust fan (Fancom, Panningen, The Netherlands) and the ventilation rate was adapted automatically to maintain a constant ambient temperature by means of FCTA regulator (Fancom, Panningen, The Netherlands). Fresh air entered through a 0.34 m^2 opening which was connected to the service corridor of the building; the outside air was thereby preheated before entering the experimental rooms. The air temperatures of the experimental rooms, the corridor and the outside were measured automatically every hour. The ventilation rates were measured continuously with an Exavent apparatus (Fancom, Panningen, The Netherlands) with accuracy of 35 m^3 h^{-1} and a maximal ventilation capacity of 3000 m^3 h^{-1} as specified by the manufacturer. The hourly means were recorded.

2.4.2. Gas concentrations

The concentrations of gases in the experimental rooms and in the corridor supplying fresh air were measured by infrared