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IMPACT ON AMMONIA EMISSIONS UNDER A RESOURCE EFFICIENT FEEDING CONCEPT IN FATTENING PIGS BASED ON PERFORMANCE GROUPS AND CRUDE FIBRE SUPPLEMENTED DIETS

ALEXANDRA LENGLING[1], BERND RECKELS[2], WOLFGANG BÜSCHER[1]

[1] University of Bonn, Institute of Agricultural Engineering, Nußallee 5, Bonn, Germany; lengling@uni-bonn.de; buescher@uni-bonn.de
[2] University of Veterinary Medicine Hanover, Foundation, Institute of Animal Nutrition, Bischofsholer Damm 15, Hanover, Germany; bernd.reckels@tiho-hannover.de

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ABSTRACT: In fattening pig husbandry new feeding concepts offer great potential to reduce nitrogen inputs in the environment. Fattening pigs differ individual in their nutritional needs and feed intake capacity. Classification into performance groups enables to feed the animals efficiently and to avoid luxury consumption. In the study the impact on ammonia emissions under a new feeding concept based on performance groups and crude fibre supplemented diets was investigated. For the study 610 pigs were classified into four performance groups based on body weight and the ratio of backfat and back muscle thickness determined by ultrasound examinations. Using sorting gates and four different feeding areas, each group was fed with a specific diet differing in crude fibre content. Ammonia emissions were measured continuously in the experimental and a control barn. In the experimental barn ammonia emissions were reduced by 40% compared to the control barn. During 50-110 kg mean ammonia emissions were 7.68 g animal^{-1} d^{-1} and 12.67 g animal^{-1} d^{-1} (experimental and control group). Also for the individual fattening period sections (pre-fattening, mid-fattening, finishing) ammonia emissions were significant lower in the experimental barn. The largest difference of 44% was observed during the finishing period. Resource efficient feeding is desirable from an environmental and economic aspect. Furthermore, animal welfare can be improved by crude fibre supplementation. Especially in view of climate change, livestock husbandry has to be adapted to new requirements. The study shows that the tested feeding concept enables the connection of environmental protection, animal welfare and economic efficiency.

Keywords: Feeding technology, feeding groups, ammonia reduction, sustainability, roughage-based diet

INTRODUCTION: In recent years, agricultural livestock husbandry has been characterized by constant change. Animal welfare, as well as climate and environmental protection, are more and more in the focus of social debate regarding modern agriculture. Not least due to the increasingly stringent animal welfare and environmental protection requirements, an adjustment of agricultural animal husbandry is mandatory (BMEL, 2017). As the most important producer in the meat industry, pig farming plays an important role not only in Germany, but also in the European Union (EU) (DBV e.V., 2019). In total, 95% of the annual ammonia (NH_3) emissions are due to agriculture. In Germany, pig farming is the second largest source of NH_3-emissions in the agricultural livestock husbandry (UBA, 2020). By causing acidification and eutrophication, ammonia contributes to lasting damage to the environment (Steinfeld et al., 2006). Furthermore, it is harmful to the health of humans and animals (Drummond *et al.*, 1980; Ryer-Powder, 1991). New feeding concepts for fattening pigs have great potential to reduce NH_3-emissions from fattening pig husbandry. The initial substance for the formation of ammonia is nitrogen, which is primarily absorbed via dietary protein. Excess nitrogen which is not utilised by the animals, is excreted as urea with faeces and urine and thus released to the environment (Aarnink, 1997). An over-supply of protein and thus nitrogen to the animals must therefore be avoided to prevent an excess input of nitrogen into the environment. In phase feeding systems currently used in fattening pigs, the diet is generated according to the average requirement of the whole group (KTBL, 2011). However, fattening pigs differ in their individual nutrient requirements and fattening performance potential (Jeroch *et al.*, 1999). Consequently, individual animals are undersupplied or oversupplied and not fed efficiently (KTBL, 2011). This must be avoided, both in terms of animal welfare and in terms of resource efficiency and economic aspects.

In the presented study, a new resource-efficient feeding system for fattening pigs was investigated. As described by Lengling et al. (2020) and Reckels et al. (2020) fattening pigs can be classified into performance groups based on differences in their backfat and backmuscle thickness. By using sorting gates and spatially separated feeding areas, the animals should be fed to the exact nutritional requirements of individual performance groups. Based on daily measurements by the sorting gate, a constant adaption of the diets should be made possible. Lengling et al. (2020) were able to show that animals with different fattening performance potential differ in their feed intake capacity and that this correlates negatively with the crude fibre content in the diet. Based on those results, in this study it was investigated whether animals with a high feed intake capacity can be controlled in their feed intake via an increased crude fibre content in the diet and if this affects NH_3- emissions positively by reducing them. The results presented in this paper are limited exclusively to the investigations of NH_3-emissions. The investigations should contribute to a comprehensive evaluation of the new feeding system and thus enable a more resource-efficient feeding in fattening pig husbandry.

MATERIAL AND METHODS:

Animals and Housing: The study was carried out from May to August 2020 on a pig fattening farm in Germany. Two barns, which were designed for large group housing, were available for the study. Barn I was used to measure NH_3-emissions under experimental conditions, while barn II was used as control.

Barn I was subdivided into two compartments (I.1 and I.2) by half-height partition walls, and had a total surface area of 556 m² and a capacity of up to 656 animals, so 278 m² and

328 animals per compartment. For the experimental group, 610 fattening pigs (cross-breed products of the Genesus F1 sow (Yorkshire x Landrace) and Canadian Duroc boar) with an average body weight of 25.8 kg were housed in. There was a usable surface area of approx. 0.9 m² per animal. On day three after housing, each pig was equipped with a Radio-Frequency-Identification (RFID) ear tag for individual identification. Barn II had a total surface area of 585 m² and a capacity of up to 700 animals. For the control group, 670 fattening pigs, with the same genetic and average body weight as for barn I, were housed in. The usable surface area was approx. 0.9 m² per animal, respectively. Each barn was equipped with two sorting gates (one per compartment in barn I) of the company Hölscher + Leuschner (Hölscher + Leuschner GmbH and Co. KG, Emsbüren, Germany) which connected the activity areas from two spatially separated feeding areas (feeding area "A" and "B"). Both barns were force ventilated with fresh air supply along the eaves and decentralized over floor extraction by means of exhaust fans. An outline of barn I and II is given in Fig. 1.

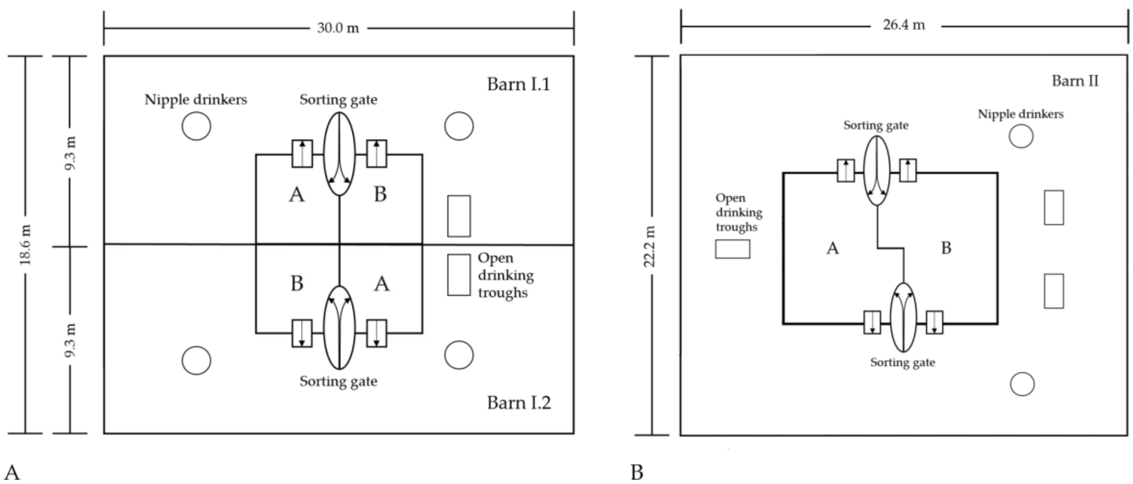

Fig. 1. Outline of the experimental and control barn. Figure A: Barn I with its two compartments I.1. and I.2. Each compartment was equipped with two feeding areas (A and B, respectively), which could be reached by the animals of each compartment via a sorting gate and left via an exit door. Figure B: Barn II with one compartment. Barn II was equipped with two feeding areas (A and B, respectively), which could be reached by the animals via two sorting gates and left via two exit doors.

Sorting gate: The sorting gate connects the lying and activity area with the two separated feeding areas in each barn. When the animals want to reach the feeding area they have to pass through the sorting gate (Jungbluth *et al.*, 2017). For this the pig has to enter the sorting gate via an electronically controlled entrance door. Using a scale at the bottom of the sorting gate the body weight of the animal is determined. Additionally, by means of 3D-camera technology the body weight can be measured optically. The data are stored and processed on a connected computer system. Due to the individual RFID ear tags and an ear tag recognition inside the sorting gate, the data can be assigned individual to each animal. According the group affiliation and the measured body condition data, the animal is guided in one of the two feeding areas via one of two exit doors. After feed intake the animals can leave the feeding area via an one-way exit door. Due to the fact that the pigs pass the sorting gate several times a day, the body condition data are recorded continuously during the whole fattening period. Thus the diets can be adapted to the nutritional requirements based on the daily measurements (KTBL, 2011).

Feeding:

Feeding Groups: In barn I animals were divided into two groups according their body weight which was determined via the sorting gate. Group 1 consisted of the 50% heaviest animals, while group 2 consisted of the 50% lightest animals. Each group was further divided into two feeding groups according the ratio of backfat thickness and diameter of back muscle (*Musculus longissimus dorsi*) in "fat" and "lean". The ratio was determined using ultrasound examinations as described by Reckels et al. (2020) and Lengling et al. (2020). So, for group 1 there have been the feeding groups "heavy lean" (HL) and "heavy fat" (HF) and for group 2 the feeding groups "light lean" (LL) and "light fat" (LF). In barn II the control group was only differentiated into heavy and light animals, without spatially separation of the animals.

Feeding technology: All animals in all groups were fed *ad libitum* with a liquid feeding system (Hölscher + Leuschner GmbH & Co. KG., Emsbüren, Germany) throughout the fattening period. The four performance groups in barn I were fed a constant amount of crude fibre in the diet over the entire fattening period. The crude fibre content of the four diets were 2.5, 5.0, 7.5 and 10.0% in dry matter (DM). The HF and LF groups received the diets with the highest crude fibre content (HF 10.0%; LF 7.5%), while the lean groups received the lower crude fibre content (HL 5.0%; LL 2.5%). A triticale whole plant silage (WPS) was used as source of crude fibre. The diets differed only in their crude fibre content, while protein and energy content were almost the same in all diets (protein content approx. 155 g per kg DM; energy content approx. 12.5 MJ metabolizable energy (ME) per kg DM). The control group in barn II received a conventional fattening diet, consisting of Corn-Cob-Mix (CCM) and two different supplementary feeds, without any additional crude fibre.

Emission Measurement: For the investigation of NH_3-emissions, concentrations of ammonia were measured continuously inside and outside barn I and II using Photoacoustic-Infrared-Spectroscopy (PAS). The measurements were carried out as described by Lengling *et al.* (2020) and Schmithausen *et al.* (2016). Fresh air from outside and exhaust air from inside the barns were sampled and analysed using a Multi-Gas-Monitor and a Multipoint-Sampler (LumaSense Technologies A/S, Ballerup, Denmark) in each barn, respectively. For calculation of the NH_3-emissions the ventilation rates were determined using calibrated measuring fans (Reventa GmbH, Horstmar, Germany) inside the exhaust chimneys inside the barns as described by Lengling *et al.* (2020) respectively. Based on ammonia concentrations inside and outside the barns and the measured ventilation rates emissions were calculated using following equation:

$$E_{Gas} = V * (C_{in} – C_{out}) \quad (1)$$

with V the ventilation rate ($m^3\ h^{-1}$) and C_{in} and C_{out} the ammonia concentrations ($g\ m^3$) inside and outside the barns. Temperature and relative humidity inside and outside the barns were measured respectively using Testo data loggers (Testo SE and Co. KGaA, Lenzkirch, Germany) (Lengling *et al.*, 2020).

RESULTS: For data analysis and comparison of experimental and control group results are presented as mean values for different weight sections of pre-fattening (50-60 kg), mid-fattening (60-90 kg) and finishing period (90-110 kg) as well as weight section 50-110 kg representing the total fattening period. A weight section of 10 kg body mass gain corresponds to n = 7 measurement days. As presented in Fig. 2, NH_3-emissions were significant lower in the experimental group compared to the control group during all weight sections. On average NH_3-emissions were 7.68 g animal^{-1} d^{-1} in experimental group and 12.67 g animal^{-1} d^{-1} in control group. This corresponds to a reduction of 39.4%. Highest difference could be found during finishing period with 9.61 g animal^{-1} d^{-1} and 17.19 g animal^{-1} d^{-1} in experimental and control group respectively. This corresponds to a reduction of 44.1%. Ammonia emissions increased in course of fattening period in both barns about approx. two and a half times.

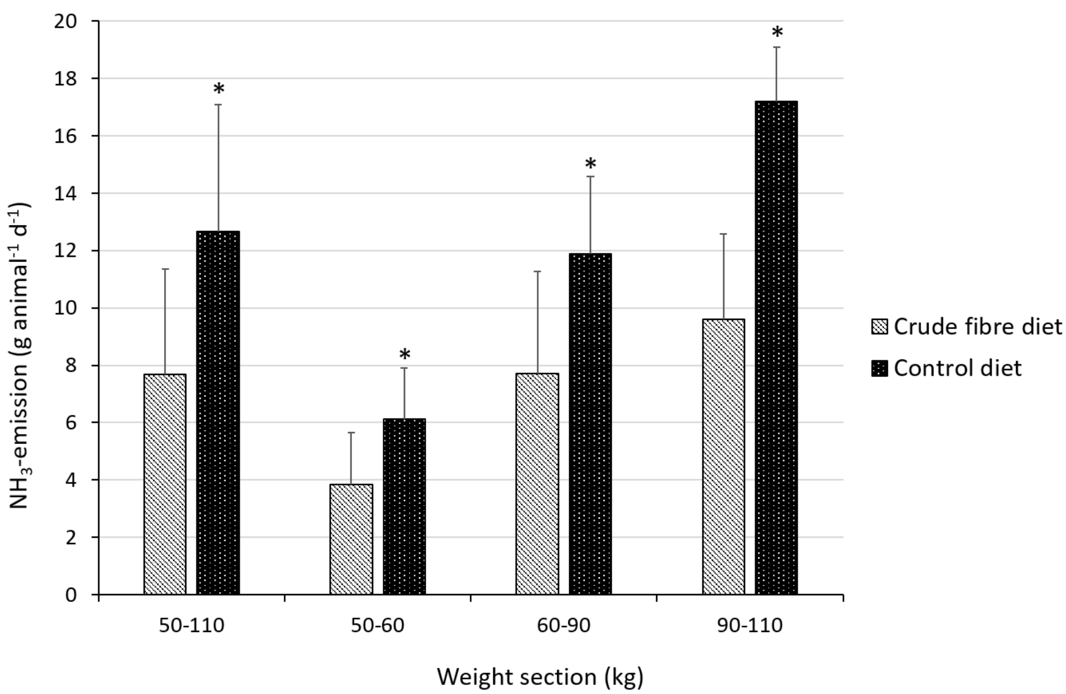

Fig. 2. Mean NH_3-emissions (g animal^{-1} d^{-1}) and standard deviation during different weight sections (pre-fattening 50-60 kg, mid-fattening 60-90 kg, and finishing period 90-110 kg) for the experimental group with crude fibre supplemented diet and control group with control diet. * indicate significant differences between experimental and control group within the same weight section ($p < 0.05$).

Figure 3 shows the mean NH_3-concentrations (ppm) measured inside barn I and II during the different weight sections. On average concentrations were 20.1 % lower inside barn

I (experimental group) compared to barn II (control group). Again the highest difference could be found during finishing period with on average 8.53 ppm and 13.25 ppm in barn I and barn II respectively.

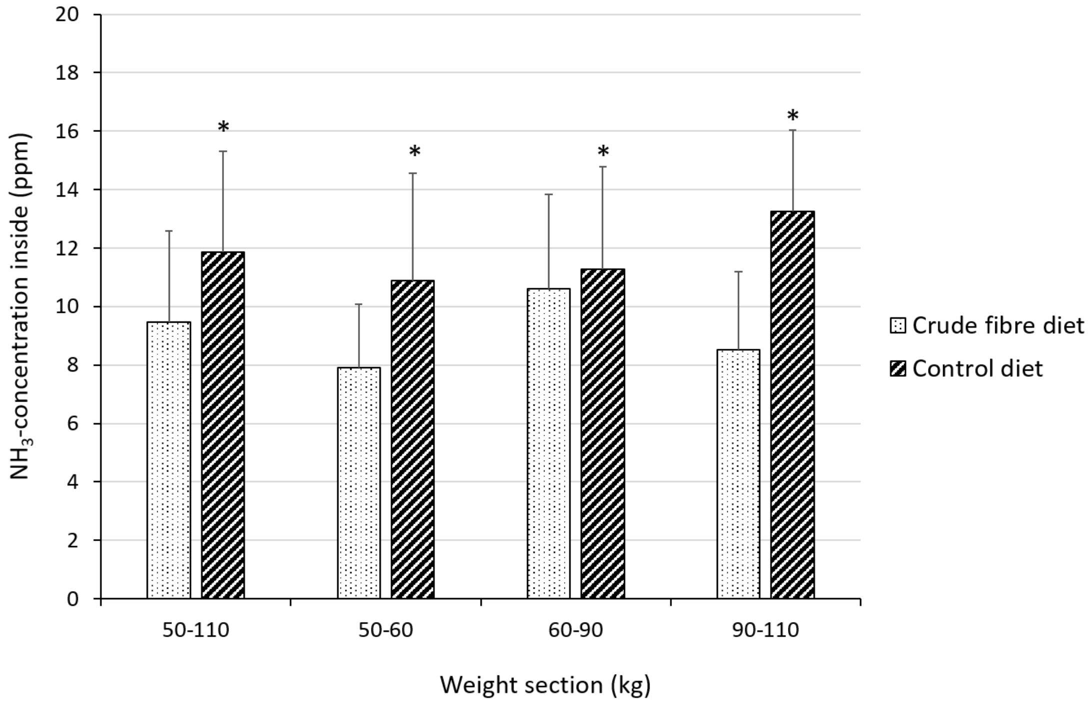

Fig. 3. Mean NH_3-concentrations (ppm) and standard deviation measured inside the barns during different weight sections (pre-fattening 50-60 kg, mid-fattening 60-90 kg, and finishing period 90-110 kg) for the experimental group with crude fibre supplemented diet and control group with control diet. * indicate significant differences between experimental and control group within the same weight section ($p < 0.05$).

DISCUSSION: In the presented study it was investigated whether NH_3-emissions can be reduced by dividing fattening pigs into performance groups according their body composition and by using crude fibre supplemented diets to control the animals feed intake. Results showed that there were significant lower ammonia emissions for the experimental group compared to the control group. Other studies received comparable reductions in ammonia emissions by using crude fibre supplemented diets (Jarret *et al.*, 2012; Philippe *et al.*, 2015). In the study, fast-growing animals received the highest crude fibre concentration in the diet. This was intended to control the feed intake of animals with a particularly high feed intake capacity in order to avoid luxury consumption and to prevent excessive nitrogen intake. The results support the hypothesis that the investigated feeding system results in less nitrogen and consequently ammonia being released into the environment. In the course of the fattening period, the physiological feed intake capacity of the animals increases. At the same time, the animals' protein requirement decreases (Jeroch *et al.*, 1999). This suggests that control of feed intake and the associated ammonia reduction is therefore most effective in the finishing period of fattening. The presented results confirm this. The maximum concentration for ammonia in pig houses permitted in Germany is 20 ppm (TierSchNutztV, 2001). Concentrations exceeding this value can lead to damage of e.g. the respiratory tract of the animals (Drummond *et al.*, 1980). With regard to animal welfare and a good air quality inside the barns necessary for this, recommendations of 10 ppm ammonia in a pig barn are made (Boehringer Ingelheim, 2016). In experimental groups as well as in the control group the limit of 20 ppm could be kept. However, ammonia concentrations were significant lower in the experimental group. Furthermore, on average the recommendation value of 10 ppm could be kept in every fattening section, while higher values were determined in the control group. This suggests that the feeding system investigated leads to less ammonia in the air inside the barn and thus made a positive contribution to animal welfare.

CONCLUSION: In summary animals with high feed intake capacity can be controlled in their feed intake by using crude fibre supplemented diets and thus avoid luxury consumption. Based on the results presented in this study it can be conclude that NH_3-emissions can be reduced significantly by using the investigated new feeding concept. Beside the positive effect on the environment, a reduction of ammonia concentrations inside the barns can contribute to animal welfare. New feeding systems like the one investigated in this study are necessary to meet the increasing demands for environmental protection and animal husbandry. The study shows that the investigated feeding system offers a possibility to combine environmental protection and animal welfare in modern agriculture. However, further studies are necessary to provide a comprehensive evaluation of the system with all relevant aspects and to be able to apply the system in practice.

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