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ORIGINAL PAPER

# EFFECT OF A PHYTOGENIC ADDITIVE IN MIXTURES FOR FATTENERS ON THE REARING RESULTS AND THE CONCENTRATION OF AMMONIA IN A PIGGERY*

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## Abstract

Urine and faeces are main sources of ammonia at pig farms. The maximal concentration of ammonia in buildings should not exceed 10 ppm for piglets, 20 ppm for fatteners and sows. In the present experiment, the effect of a phytogenic supplement on the productive performance of fattening pigs, faeces composition, volatile ammonia concentration in pig houses and on the degree of lung damage in pigs was determined. Animals were housed in two identical piggeries with comparable total volume. Fattening was divided into two phases: from 30 kg to 70 kg and from 70 kg to 110 kg of body weight (BW). The first piggery was used to maintain the control group, which comprised fattening pigs fed complete feed mixtures with no additive. In the second building, the pigs were fed complete feed mixtures with a phytogenic supplement at 0.5 g $kg^{-1}$. The phytogenic supplement had a beneficial effect on pig performance, e.g. BW ($p < 0.05$) and daily weight gain ($p < 0.01$) were significantly higher, while feed conversion ratio per kg weight gain was lower ($p < 0.05$) in animals receiving this additive in the feed. In addition, fattening pigs from the experimental group showed significantly higher meatiness ($p < 0.01$) compared with the control animals. Faeces of the fattening pigs from the experimental group contained a significantly higher nitrogen content ($p < 0.01$) (which can be indicative of reduced urease activity and retention of nitrogen in faeces in the form of urea). This was reflected by a reduced ammonia concentration in the facility housing the animals fed the diet with the phytogenic supplement, both in every measurement period and in the whole experimental period. The lower ammonia concentration reduced the degree of lung damage. In the fattening pigs from the experimental group, lung rejections were reduced by 17% compared to the control group.

**Keywords:** phytogenic supplement, growth performance, ammonia concentration, finishing pigs.

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# INTRODUCTION

Most greenhouse gases are created in the agricultural sector (Podkówka et al. 2012). Among these unwanted gases ammonia plays an important role, by contributing to the acidification of soil and water. Also, its presence in livestock buildings has a negative effect on animals by impairing their welfare. The toxic effect of excess ammonia ($NH_3$) in a pigsty on pigs' health and related performance is commonly known and has been thoroughly studied. The maximum allowable ammonia concentration in buildings for swine is set at 10 ppm for piglets and 20 ppm for fattening pigs and sows (Regulation of the Minister of Agriculture and Rural Development of 15 February 2010, Journal of Laws of the RP 2010 No. 56, item 344). Studies of Kavolelis (2006) indicate that one fattening pig emits between 3.7 to 6.4 kg of ammonia during a 220-day fattening period. Ammonia emission depends on a feeding system, feed type, farming system, frequency of manure removal and indoor temperature.

Volatile ammonia is released mostly from urine and faeces, catalysed by urease (produced by faecal microorganisms). Separation of excrements (urine and faeces) during production is impossible, thus the problem of ammonia emission in animal facilities is unavoidable (Krajewska 2009). Ammonia emission depends on many factors, including the area of exposed manure, animal housing, indoor temperature, faeces pH, content of ammonium nitrogen and type of a ventilation system (Hayes et al. 2006). The largest amounts of ammonia are generated in pigsty in summer at high temperatures (Harper et al. 2004, Philippe et al. 2011). Excess ammonia removal from pigsties is principally based on mechanical or gravitation ventilation systems (which are often inadequate). Therefore, other solutions for reducing ammonia emission in the facilities are looked for, e.g. it has been recommended to use adsorbents (aluminum silicate, peat) and to acidify the feed and litter with phosphoric, sulfuric and hydrochloric acids (Ndegwa 2008). Feeds can also be supplemented with different urease inhibitors, e.g. saponins and volatile oils (Cho et al. 2006). All the aforementioned methods reduce volatile ammonia emission by 20 - 50%. Reports presenting different solutions to this problem are published systematically.

Ammonia emission depends largely on a nutrition system and feed composition, especially in terms of energy and protein balance (Canh et al. 1998, Otto et al. 2003, Philippe et al. 2011). It was found that the use of highly digestible proteins and crystalline amino acids reduced ammonia emission. Studies by Leek et al. (2007) indicate that cereal type and feed supplementation with enzymes can contribute to a reduction in ammonia emission. These authors revealed that feed rations based on wheat and corn increased ammonia emission by 30 % compared to barley. Similar results were obtained in studies of O'Shea et al. (2010), where the application of barley and oat grain in a feed mixture decreased the ammonia concentration in the piggery. The lower ammonia emission with barley-based feeds is explained by a higher content of non-starch polysaccharides (NSP) in this cereal compared with wheat and corn. The addition of the enzyme *β*-glucanase to barley-containing rations increased ammonia emission.

Other directions in the studies on the reduction of ammonia emission are related to the use of steroidal and non-steroidal saponins. For this purpose, extracts from the plants *Yucca Schidigera* and soapbark (*Quaillaja saponaria*) have been used (Mroczek 2008). This author documented that saponin preparations reduced ammonia emission by ca. 30% due to urease blockade. Colina et al. (2001) recorded up to a 50% reduction of the ammonia concentration with the use of preparations of this type. These authors also highlighted the antibacterial, antifungal and immunostimulating actions of saponins. However, they pointed out that steroidal saponins, by influencing different metabolic pathways, can also affect the hormonal system of animals because an elevated testosterone production was discovered. The researchers stated that this process resulted in much better protein accumulation and higher growth rate. However, there are concerns as to whether the meat of such animals (for consumption) can contain higher amounts of this hormone. Therefore, it is safer to use non-steroidal (triterpenoid) saponins that have a similar action (i.e. suppress ammonia release) but do not produce the steroidal effect.

Another group of phytogenic substances that reduce ammonia emission includes volatile oils extracted from different plants. The studies by several authors (Cho et al. 2006, Franz et al. 2010) indicated that the application of these compounds could reduce ammonia emission by 20 - 25% due to elevated nitrogen accumulation in the muscle tissue. Available studies also showed that phytogenic feed supplements increased efficiency of the gut-associated lymphoid tissue (GALT), which contributed to a higher retention of dietary nitrogen and better utilisation of ration nutrients. This resulted in improved production performance of fattening pigs (Windisch et al. 2008, Zeng et al. 2015).

The problem with an excessive nitrogen concentration in pigsties and its negative effect on pig performance in unavoidable. For this reason, solutions for reducing ammonia emission and improving pig production efficiency are constantly searched for. The aim of the present study was to assess a phytogenic supplement added to a feed for inhibiting ammonia emission in pig houses and improving productive performance of pigs.

## MATERIAL AND METHODS

The experiment was conducted in two identical piggeries with identical total volumes. The ventilation systems and dimensions of the windows and doors were also the same. The usable area of each building was 750 $m^2$, production area – 198 $m^2$ and volume 2400 $m^3$. Each building was equipped with a ventilation system consisting of 6 Multifan ventilators, each with the capacity of 8600 $m^3$ $h^{-1}$.

Each piggery housed one experimental group. In both buildings, fattening· pigs were maintained in a litter-free system. The animals were allocated (in each building) to 20 pens, 11 animals in each replication (trying to keep the sex ratio at 1 : 1). The pen area for a single head was about 0.8 $m^2$. Pens were equipped with feeders for dry feed and nipple drinkers. The feed was served to animals by hand.

The BW of the animals assigned for fattening was 30 kg. The fattening period was divided into two phases: from 30 kg to 70 kg of BW (48-days of fattening) and from 71 kg to 110 kg (42-days of fattening). In the first (grower) and the second (finisher) phase, the animals were fed standard loose feed mixtures of grower and finisher (according with Nutrient Requirement of Pigs 1993). The animals from group I (the control group) were fed a diet with no additives, while the pigs from group II (the experimental group) received a feed supplemented with a phytogenic additive in amount of 0.5 g $kg^{-1}$ of feed.

In the experiment, the animals were weighed at assignment to pens, during the change (grower to finisher) and at the sale for slaughter. The intake of both type feed mixtures was calculated per head. The feed mixtures for group I (control) and group II (experimental) had an identical basic composition, but a phytogenic additive in the amount of 0.5 g $kg^{-1}$ of feed was added to the experimental diet (Table 1).

Analysis of the basic experimental feed mixtures was carried out by standard methods of the Association of Official Analytical Chemists (AOAC 2012). The aroma of the supplement in the feed mixture could be ensed by the personnel handling animals on the pig farm. The levels of energy, protein and other nutrients were in conformity with feeding standards for fattening pigs in specific rearing phases (Nutrient Requirement of Pigs 1993).

In the course of the experiment, the ammonia concentration in the pigsties was measured in the period from 10$^{th}$ of May to 11$^{th}$ of July (63 days). An apparatus used for measurements of ammonia levels (Gas Badge, Industrial Scientific Corp., USA) was placed on a stand in the middle part of the piggery at a height of 50 cm from the floor level. Faeces samples were collected three times and subjected to chemical analysis of basic components according to a standard method (AOAC 2012).

At the end of the fattening period, when the animals reached 110 kg of BW, they were transferred to a slaughter house. After slaughter, the meatiness of each carcass was evaluated using a Piglog 105 ultrasound scanner (Frontmatec). A veterinary practitioner present during slaughter evaluated the condition of the lungs and decided which organs were damaged and had to be rejected.

Table 1

Composition and nutritive value of mixture

| Item (%) | Mixtures | |
|---|---|---|
| | grower | finisher |
| Wheat (12% crude protein) | 38.55 | 14.00 |
| Barley (11% crude protein) | 38.00 | 45.00 |
| Triticale (11% crude protein) | - | 20.00 |
| Soyabean meal (46% crude protein) | 13.00 | 9.00 |
| Rapeseed cake (10% crude fat) | 3.50 | 5.00 |
| Farmers' premix[x] | 2.50 | - |
| Farmers' premix[xx] | - | 2.50 |
| Horsebean | 2.50 | 4.00 |
| Soya oil | 1.65 | 0.50 |
| Feed additive for swine[xxx] | 0.30 | - |
| Nutritive value per 1 kg of mixture | | |
| Metabolisable energy (MJ) | 13.30 | 13.02 |
| Crude protein (g) | 170.1 | 159.0 |
| Crude fat (g) | 36.2 | 25.9 |
| Crude fiber (g) | 40.8 | 43.7 |
| P (g) | 4.82 | 5.37 |
| Ca (g) | 6.92 | 7.09 |
| Na (g) | 1.48 | 1.61 |
| Lysine (g) | 10.93 | 9.36 |
| Methionine+Cystine (g) | 7.03 | 6.12 |
| Methionine (g) | 3.68 | 3.05 |
| Threonine (g) | 7.13 | 6.51 |
| Tryptophan (g) | 2.01 | 1.92 |

[x] Farmers' premix (2.5%) – content in 1 kg: lysine 120 g, methionine 32 g, threonine 35 g, Ca 220 g, $P_{total}$ 68 g, Na 60 g, Mg 10 g, Mn 2,0 mg, Zn 4,0 mg, Fe 4,0 mg, Cu 800 mg, I 40 mg, Se 12 mg, betaine 3,35 mg. Vitamins: A 450,0 IU, $D_3$ 75,0 IU, E 2,0 mg, K 100 mg, $B_1$ 60 mg, $B_2$ 200 mg, $B_6$ 100 mg, $B_{12}$ 1,200 µg, biotin 8,0 µg, niacin 800 mg, folic acid 24 mg, calcium pantothenate 800 mg, choline 5,0 mg. Feed additives: antioxidant, feed enzymes, phytase, aroma, active complex.

[xx] Farmers' premix (2.5%) – content in 1 kg; Vitamins: A 400,0 IU, D3 90,0 IU, E 3,5 mg, choline 3,0 mg, betain 20,0 mg, Ca 147.357 g, P 55 g, Na 60 g, Cl 93.323 g, lysine 94 g, methionine 20 g, tryptophan 40 g.

[xxx] Feed additive for swine – Contain medium chain fatty acids (MCFA) from 6 to 12 atoms of carbon ($C_6$ - $C_{12}$). Produced from coconut and palm oil. Decrease incidence of diarrhoea, stabilize the microbial status of the small intestine, dcrease the count of *E. coli*, *Streptococcus* sp. and *Clostridium* sp, and stimulate an increase in the count of lactic acid bacteria.

A phytogenic additive was added to the experimental diet in the amount of 0.5 g $kg^{-1}$ of feed. The phytogenic additive is produced by Delacon Biotechnik GmbH (Steyregg, Austria). It contains encapsulated volatile oils suspended in aluminum silicate that increase secretion of digestive juices and exhibit antioxidant properties. It is also rich in non-steroidal saponin extracts (a mixture of extracts from *Quaillaja saponaria*), which reduce urease activity and, consequently, ammonia emission in pig houses. The product has a characteristic intense herbal aroma.

All the collected data were subjected to statistical analysis. Comparison between the two groups was performed with Student's t-test for independent variables (Statistica 2014). Results were considered as significant if $P$ value was lower than 0.05.

## RESULTS AND DISCUSSION

The productive performance indices are presented in Table 2. The initial BW of the animals did not differ significantly. Significant differences in BW ($p < 0.05$) were noted after 48 days of fattening when the pigs from the con-

Table 2

Performance and meatiness of pigs

| Item | | Treatments | | *p*-value |
|---|---|---|---|---|
| | | control | phytogenic preparation | |
| Number of animals in a piggery | heads | 224 | 224 | |
| Mortality | | | | |
| - during grower period (1st to 42nd day of fattening) | heads | 6.00 | 5.00 | |
| - during finisher period (43rd to 90th day of fattening) | heads | 0 | 0 | |
| Initial body weight - grower period (1st day of fattening) | (kg) | 31.03 ± 2.91 | 30.11 ± 2.87 | 0.271 |
| - finisher period (43rd day of fattening) | | 67.24*a* ± 3.07 | 71.96*b* ± 2.73 | 0.012 |
| Final body weight (90th day of fattening) | (kg) | 105.15*a* ± 4.35 | 111.23*b* ± 6.54 | 0.021 |
| Daily body weight gains - grower period (1st to 42nd day of fattening) | (g) | 759.78*A* ± 54.21 | 885.17*B* ± 61.94 | 0.000 |
| - finisher period (43rd to 90th day of fattening) | | 896.34 ± 59.41 | 924.94 ± 97.53 | 0.283 |
| - average - during whole fattening (1st to 90th day of fattening) | | 824.37*A* ± 49.00 | 903.83*B* ± 74.42 | 0.002 |
| Feed intake per head | (kg) | | | |
| - grower period (1st to 42nd day of fattening) | | 102.34*a* ± 8.50 | 114.86*b* ± 6.90 | 0.015 |
| - finisher period (43rd to 90th day of fattening) | | 118.44 ± 21.83 | 116.25 ± 17.64 | 0.317 |
| Feed conversion ratio - grower period (1st to 42nd day of fattening) | (kg kg$^{-1}$) | 2.85*a* ± 0.06 | 2.75*b* ± 0.13 | 0.017 |
| - finisher period (43rd to 90th day of fattening) | | 3.10*a* ± 0.14 | 2.97*b* ± 0.19 | 0.015 |
| - average - during whole fattening (1st to 90th day of fattening) | | 2.92*a* ± 0.11 | 2.85*b* ± 0.16 | 0.020 |
| Meatiness | (%) | 56.12*A* ± 1.63 | 58.45*B* ± 0.79 | 0.001 |

Differences in rows signed with *a*, *b* significant at $p \leq 0.05$; *A*, *B* significant at $p \leq 0.01$

trol group showed significantly lower BW compared with animals from the experimental group. Differences in BW were reflected by daily gains. The experimental animals in the grower phase were characterized by significantly ($p < 0.01$) higher daily gains. The results were associated with a better feed intake in the pig house where the phytogenic additive was used. The difference in feed intake was very large and amounted to 13 kg when calculated per pig, which indicates a strong response of the young animals to this feed supplement. The pattern of changes in the feed conversion ratio (grower) per 1 kg of weight gain was similar. The feed conversion ratio in the experimental group was significantly lower ($p < 0.05$). Similar results with the use of saponin supplements were obtained by Bartoš et al. (2016), who observed an increase in feed intake by 4.5%, and in growth rate by 6%. The higher feed intake probably also resulted from the presence of encapsulated volatile oils contained in the preparation. This was evidenced in studies carried out by Zeng et al. (2015) and Bartoš et al. (2016), who noted an increased feed intake and conversion after feed supplementation with volatile oils resulting in an elevated growth rate of the animals.

Mortality of animals during grower period reached about 3%. In the finisher period, no losses of animals were noted in the experimental groups, what testifies to good rearing conditions.

The final BW of the animals allotted for slaughter after 42 days of fattening using the finisher diet showed significant differences ($p < 0.05$). Pigs from the control group still had a lower BW compared to the experimental group (difference in mean weights between the groups amounted to 6 kg, thus it was the same as at the end of the grower phase). Feed conversion was again better in the experimental group ($p < 0.05$). Such a response indicates that a higher feed intake during the grower phase was decisive for the growth rate (because the feed intakes in the finisher phase were similar). Therefore, it can be supposed that the control pigs during the finisher phase exhibited so-called growth compensation. The results obtained under typical production conditions evaluated in the whole fattening period (from 30 kg to 110 kg) can be regarded as positive. The animals receiving the phytogenic feed supplement presented daily gains higher by 80 g on average, and the feed conversion was better by 0.07 kg $kg^{-1}$.

In addition, significant ($p < 0.01$) differences in the meatiness of the carcasses were noted. Group I pigs were characterised by meatiness of 56%, while the experimental animals achieved 58%. This result can be explained by better protein accumulation in the carcass of the latter animals, which was related to their higher growth rate and the age at slaughter. The difference in meatiness equal 2 percent points is quite appreciable. Similar results were reported by Mroczek (2008), who used a preparation based on an extract from *Yucca schidigera* as a supplement to a feed for fattening pigs. Tofant et al. (1999) applied a similar preparation belonging to biostimulators that inhibited urease production, enhanced utilisation of nutrients and stimulated regulatory functions of bacterial flora of the small and large intestine.

The study of WINDISCH et al. (2008) also demonstrated a strong regulatory function of volatile oils for bacterial flora of the digestive tract.

The collected results indicated that the ammonia level in all measurement periods was significantly reduced in the pig house where fatteners were offered a feed with the phytogenic supplement (Table 3, Figure 1). The ammonia concentration in different months showed high variability. In May, when the pisties were closed at night (due to chills), the ammonia concentration exceeded the upper limit, i.e. 20 ppm. In the piggeries where the animals were fed a feed without additives, the ammonia level in the air was higher. The difference in ammonia concentrations in the air amounted to ca. 14%. Measurements conducted in June, when the windows and doors were partially closed at night, demonstrated that the ammonia concentration was much lower compared with the result obtained a month earlier. In the house where the feed contained the phytogenic supplement, the ammonia concentration in the air was within the permissible range (> 20 ppm). In July, the windows and doors were open all the time due to the hot weather, and the ammonia concentration in the air was 21.47 and 9.87 ppm, respectively, clearly confirming the efficiency of the phytogenic supplement also in summer.

A comparison of average values (recorded for 63 days) demonstrated that the difference in ammonia concentration between the pig house where the phytogenic supplement was used and the control pig house reached

Table 3

Concentration of ammonia in piggeries; chemical composition of faeces and lung damage

| Item | Treatments | | *p*-value |
|---|---|---|---|
| | control | phytogenic preparation | |
| Ammonia measurements | | | |
| I – 24 days of May (ppm) | 32.33*A* ± 2.81 | 28.04*B* ± 3.04 | 0.000 |
| II – 24 days of June (ppm) | 26.91*A* ± 7.68 | 19.84*B* ± 4.72 | 0.000 |
| III – 15 days of July (ppm) | 21.47*A* ± 4.13 | 12.76*B* ± 6.48 | 0.000 |
| Average concentration of ammonia (ppm) | 27.68*A* ± 6.77 | 21.20*B* ± 7.01 | 0.000 |
| Chemical composition of faeces | | | |
| Dry matter (%) | 20.95 ± 1.52 | 21.45 ± 1.87 | 0.621 |
| Nitrogen (%) | 0.60*A* ± 0.03 | 0.74*B* ± 0.06 | 0.001 |
| Crude fat (%) | 1.40 ± 0.16 | 1.42 ± 0.22 | 0.835 |
| Crude fibre (%) | 4.31 ± 0.58 | 4.33 ± 0.43 | 0.952 |
| Crude ash (%) | 2.38 ± 0.26 | 2.74 ± 0.18 | 0.019 |
| Ca (g $kg^{-1}$) | 2.34 ± 0.22 | 2.45 ± 0.33 | 0.900 |
| P (g $kg^{-1}$) | 3.78 ± 0.94 | 4.03 ± 0.66 | 0.600 |
| pH | 6.54 ± 0.16 | 6.49 ± 0.18 | 0.625 |
| Lung damage | | | |
| Lung damage (%) | 45.33*A* ± 8.60 | 28.25*B* ± 4.87 | 0.001 |

Differences in rows signed with *A*, *B* significant at $p \leq 0.01$

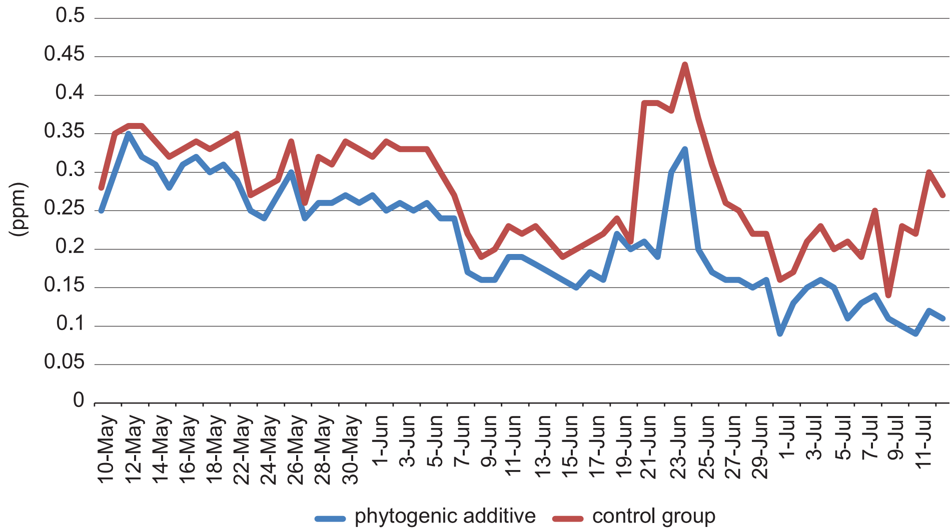


Fig. 1. Average concentration of ammonia in piggeries

36.1%. It should be noted that regarding the ammonia level in the building where feeds with the phytogenic supplement were used, the ammonia concentration was close to the reference value (20 ppm). The study results of other authors addressing similar issues agree very well (NDEGWA et al. 2008, FRANZ et al. 2010, BARTOŠ et al. 2016). These authors achieved a reduction of indoor ammonia concentration by ca. 30% with the use of preparations containing saponins and volatile oils. Moreover study of PANETTA et al. (2006) shows that application of *Yucca schidigera* extract directly to manure is effective to reduce ammonia emission.

Nitrogen content in faeces was regularly higher in the animals fed the phytogenic supplement. Independently of the date of sample collection, the difference was ca. 25% on average. It can be explained by a lower activity of urease when the feed contained non-steroidal saponins and volatile oils. The presence of ammonia in the pig house where the phytogenic supplement was used indicates that this gas was released in spite of the inhibition of urease activity. However, its concentration was lower compared with the control building. In general, the nitrogen level was higher by 25% in the faeces of animals given feed with the phytogenic supplement, corresponding with its reduced concentration by 30% in the air of the pig house. Retention of nitrogen in form of protein in faeces is beneficial process because break down of protein in manure is slow. During 70 days in temp. 18°C only 43% of protein has been broken down (AARNINK, VERSTEGEN 2007). While break down of urea to ammonia and carbon dioxide last one hour.

Ammonia irritates the mucosa and impairs the immunity of animals; it is also responsible for breathing problems which are connected with hemorrhages to trachea and bronchi and pulmonary edema (SEEDORF, HARTUNG

1999). In the house where the phytogenic supplement was used, the fattening pigs showed less intense coughing. Post-slaughter examination of the lungs seems to be the best way to evaluate respiratory system efficiency in the animals. Lung rejections (due to different causes) in the control group were significantly higher ($p < 0.01$) than in the group receiving the phytogenic supplement. The difference between both study groups amounted to ca. 17 percentage points. This confirms the better health status of the pigs given the phytogenic supplement. The obtained result clearly corresponds with the data on growth rate and feed conversion and ammonia concentration in the piggery and faecal nitrogen concentration.

## CONCLUSIONS

The addition of the phytogenic supplement to grower and finisher feed mixtures offered a number of benefits to fattening pigs. The animals receiving this supplement in a feed showed a higher growth rate, better feed conversion and health status compared with the control group. This for example resulted from the reduced indoor ammonia concentration in the pigsty by 30% - 40%. Undigested and metabolic nitrogen was retained in the faeces and was not released into the environment, which could have been attributed to the reduced urease activity. Young animals in particular responded strongly to the excessive concentration of ammonia in a piggery. In the finisher phase, a less strong response of the animals was also evoked by the reduced ammonia level in the pig house. The higher growth rate and meatiness of animals and fewer lung rejections in the group fed the phytogenic supplement, containing non-steroidal saponins and encapsulated volatile oils, is indicative of a better health status of the animals and more efficient conversion of nutrients to muscle and fat tissue.

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