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The Application of Microbial Additive in Poultry Production as a Way to Reduce Emission of Harmful Gases into the Environment

Katarzyna Szwedziak[*], *Żaneta Grzywacz*[*], *Kazimierz Wrotkowski*[**]
[*]*University of Technology in Opole*
[**]*University of Life Sciences in Lublin*

1. Introduction

A breakthrough in the structure and demand for poultry meat constantly intensifies poultry production (Kozioł & Krzywoń 2014). Agriculture with industrial animal production, including poultry, is one of the main sources of environmental pollution.

During production of the poultry, volatile substances, such as ammonia (NH_3), hydrogen sulfide (H_2S) and carbon dioxide (CO_2) are emitted to the atmospheric air (Mituniewicz 2013). These gases have the ability to move in the atmosphere, undergoing chemical changes under the influence of sun-radiation, mutual interactions and lightning discharge. The gases released into the atmosphere lead to the cyclic exchange and self-cleaning of the atmospheric air. Unfortunately, the excessive amount of impurities causes that the biosphere loses its ability to regenerate, leading to the contamination of air, soil, water and the loss of biological biodiversity, reducing the quality of life of people and animals (Makles & Domański 2008).

Agricultural environment emits 80-95% of the total ammonia, of which 80% are derivatives of animal production. Ammonia emission is one of the perpetrators of ecosystem eutrophication, acidification of soils and damage to the ozone layer (Kołacz & Dobrzański 2006). The regions with the increased ammonia emission are associated with intensive livestock production. It is in these areas where ammonium forms are recorded in the rainwater (Communication from the Commission to the Council and the European Parliament 2005). In addition, ammonia has a sharp pungent scent, which not only irritates the mucous membranes of the respiratory system, but together with other odour-creative substances becomes the source of many complaints regarding air quality.

Hydrogen sulfide (sulphan), which is created during production of the poultry, is a gas affecting the humans and the environment. This gas is toxic. At low concentrations it gives unpleasant scent resembling the smell of rotten eggs. Released to the environment it is involved in the formation of sulfur anions and acid rain.

The production of animals is also responsible for the emission of greenhouse gases, including CO_2. The share of farm and food sector related to the production of livestock accounts for 9% of carbon-dioxide exudation in anthropogenic emission of the main greenhouse gases (Steinfeld 2006).

The Food and Agriculture Organization of the United Nations (FAO) believes that "the livestock sector" has such profound and varied impacts that should be one of the leading areas of interest in environmental policy (Steinfeld 2006). By 2050, the FAO predicts a doubling of meat consumption. This situation will not have a beneficial effect on food production and the environment. Climate change, which is promoted by gases emitted during the production of animals, can cause more frequent droughts, hurricanes, floods and crop failures (report by Compassion in World Farming 2008).

Previous actions for limiting the effects of climate-related emission of harmful gases at the source focused on maintaining high welfare in the livestock room. Production of the poultry must therefore adapt to the general principles of the Common Agricultural Policy imposed by the European Union by observing the principle of cross-compliance (EMEP/CORINAIR 2007).

Table 1. Acceptable levels and concentrations of gases [ppm] in the livestock room (EMEP/CORINAIR 2007)
Tabela 1. Dopuszczalne stężenia i koncentracja gazów [ppm] w pomieszczeniu inwentarskim (EMEP/CORINAIR 2007)

Category of animals	Carbon dioxide concentration CO_2 [ppm]	Hydrogen sulphide concentration H_2S [ppm]	Ammonia concentration NH_3 [ppm]
Calves	3000	5	20
Pigs	3000	5	20
Broilers	3000	X	20

Ammonia (NH_3) and hydrogen sulphide (H_2S) together with other organic compounds can additionally become offensive odours, causing unpleasant scent spreading over large distances. These substances can be felt even at low concentrations (Kołodziejczyk et al. 2011) They are caused by the process of enzymatic-microbiological mineralization of organic bird droppings. These compounds pollute the atmospheric air with volatile odours that may not only affect the environment, but can also cause various diseases in people subjected to such exposure (Kołacz & Dobrzański 2006).

Table 2. Characteristics of selected odour-creative compounds [ppm]
Tabela 2. Charakterystyka wybranych związków odorotwórczych [ppm] Own elaboration based on: „Lentech" – www.lenntech.com/table.html

The name of the compound	Chemical formula	Scent	Threshold value [ppm]
Ammonia	NH_3	Sharp, acrid	0,037
Hydrogen sulfide	H_2S	Rotten eggs	0,00047

2. Methodology and scope of the study

The research was conducted in the years 2013-2015 on a poultry farm located in the Opole province in Poland in the temperate climate with four seasons. Researchers measured the concentrations of the following harmful gases: ammonia (NH_3), hydrogen sulfide (H_2S) and carbon dioxide (CO_2). The study was performed during eight production cycles of the ROSS 308 broiler and under different temperature conditions.

The farm, where the study was conducted, consisted of two production halls with the same dimensions 450 m^2 and the forced mechanical ventilation system. One of the halls, where production of the poultry was traditional was the control object, while in the other, parallel, the microbial additive was applied.

The application of microbial additive was based on the introduction of the solution containing probiotic bacteria to the litter. Prior to the insertion of chickens, it was 25% aqueous solution, next 10% aqueous solution in a seven-day cycle. It was applied by the E-turbo Mgła sprayer, intended for the use in Polish agricultural farms, with a liquid tank capacity of 10 litres and the droplet size and up to 50 micrometers.

The measurements of the test gases were performed in seven-day cycles using the multi-gas Mulitgas III.4 meter. The concentrations of gases were measured in 9 uniformly tagged measurement points on three different heights.

The applied formulation contained the starting materials, such as lactic acid bacteria, photosynthetic bacteria, fermenting fungi, yeast, organic molasses from sugar cane, revitalized water, salt and mineral complex. The maternal culture included the following bacteria: Bifidobacterium Animals, Bifidobacterium bifidum, Bifidobacterium longum, Lactobacillus acidophilus, Lactobacillus bulgaricus, Lactobacillus casei, Lactobacillus delbrueckii, Lactobacillus plantarum, Lactococcus diacetylactis, Lactococcus lactis, Streptococcus thermophilus, Bacillus subtilis var. natto., Saccharomyces cerevisiae, Rhodopseudomonas palustris.

Fig. 1. View of one of the production halls on the poultry farm where the study was conducted
Rys. 1. Widok jednej z hal produkcyjnych na fermie drobiu, w której prowadzono badania

3. Study results

The study results were used to compare the mean concentration of gases CO_2, NH_3, H_2S obtained during eight production series in the control hall with the results achieved in the hall where the microbial additive was used. Production cycles had different atmospheric conditions; there were slight differences in the amount of broilers inserted and the duration of the cycle associated with the market price of the livestock. The detailed data is presented in Table 3.

Table 3. Particulars of eight test series (C – control hall, EM – hall where the microbial additive was used)
Tabela 3. Dane szczegółowe dotyczące przeprowadzonych ośmiu serii badań
(C – hala kontrolna, EM – hala, w której stosowano dodatek mikrobiologiczny)

Series of tests	Start of test	End of test	Days	Weeks	Halls	Population	The mean outdoor temperature [°C]
I	2013-12-07	2015-01-23	56	8	C	16 160	4,10
					EM		
II	2014-02-17	2014-04-13	56	8	C	15 840	15,13
					EM		
III	2014-05-06	2014-06-30	56	8	C	17 010	21,25
					EM		
IV	2014-07-05	2014-08-29	56	8	C	16 400	25,63
					EM		
V	2014-09-09	2014-11-03	56	8	C	16 560	17,25
					EM		
VI	2014-11-23	2015-01-17	56	8	C	16 500	6,88
					EM		
VII	2015-01-23	2015-03-12	49	7	C	16 380	5,60
					EM		
VIII	2015-03-27	2015-05-14	49	7	C	16 430	14,00
					EM		

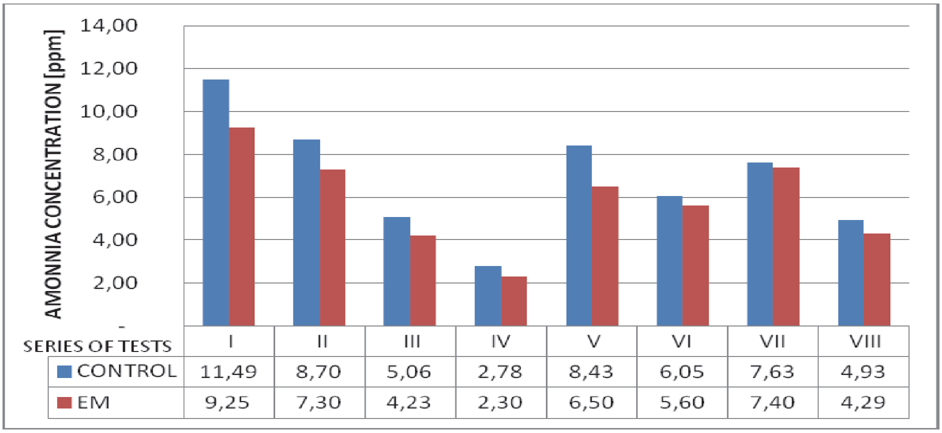

Fig. 2. Mean concentration of ammonia (NH_3) obtained in eight series of tests conducted in the control hall and the hall where the microbial additive was used
Rys. 2. Średnia zawartość amoniaku (NH_3) uzyskana w trakcie ośmiu serii badań w hali kontrolnej oraz w hali, w której stosowano dodatek mikrobiologiczny

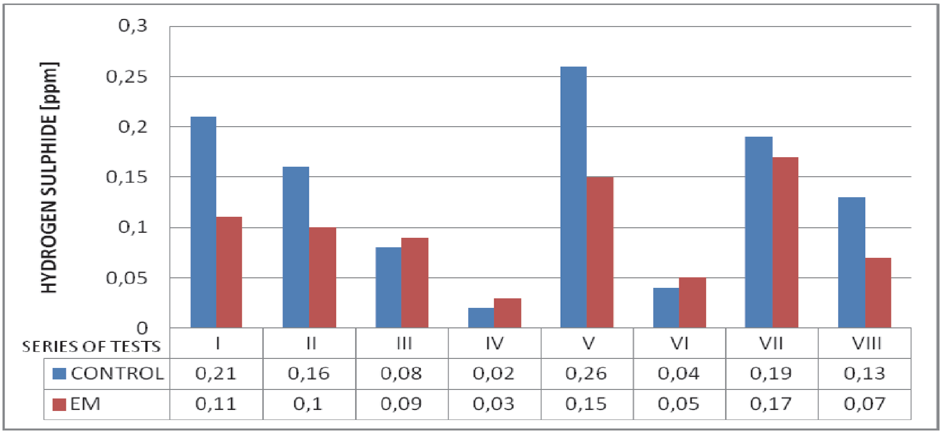

Fig. 3. Mean concentration of hydrogen sulphide (H_2S) obtained in eight series of tests conducted in the control hall and the hall where the microbial additive was used
Rys. 3. Średnia zawartość siarkowodoru (H_2S) uzyskana w trakcie ośmiu serii badań w hali kontrolnej oraz w hali, w której stosowano dodatek mikrobiologiczny

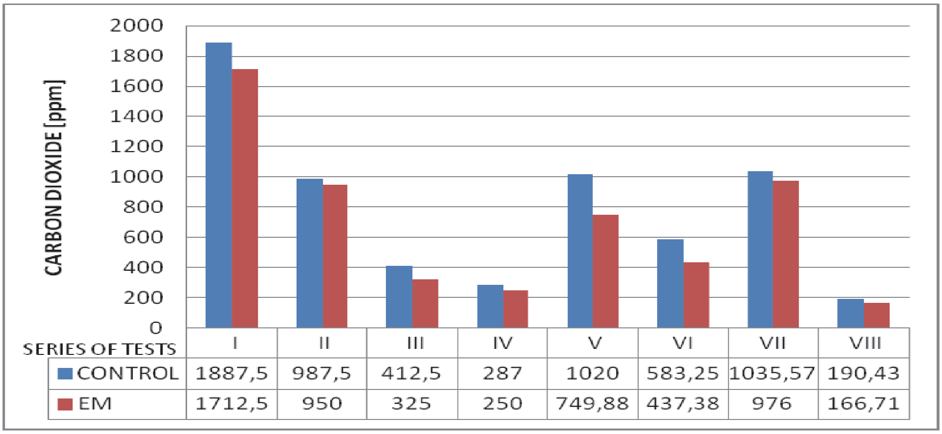

Fig. 4. Mean concentration of carbon dioxide (CO_2) obtained in eight series of tests conducted in the control hall and the hall where the microbial additive was used

Rys. 4. Średnia zawartość dwutlenku węgla (CO_2) uzyskana w trakcie ośmiu serii badań w hali kontrolnej oraz w hali, w której stosowano dodatek mikrobiologiczny

Table 4. A mean decrease in the concentration of CO_2, NH_3 and H_2S [%], in each research series, in the control hall and the hall where the microbial additive with beneficial micro-organisms was used.

Tabela 4. Średni spadek stężenia CO_2, NH_3, H_2S [%], przypadający na poszczególne serie badawcze w hali, w której stosowano preparat zawierający pożyteczne mikroorganizmy w porównaniu z halą kontrolną

Series of test	The concentration difference NH_3 [%]	The concentration difference H_2S [%]	The concentration difference CO_2 [%]
I	19,50	47,62	9,27
II	16,09	37,50	3,80
III	16,40	-12,50	21,21
IV	17,27	-50,00	13,04
V	22,89	42,31	26,54
VI	13,85	-25,00	25,01
VII	3,01	10,53	5,75
VIII	12,98	46,15	12,46

4. Discussion

The analysis of the mean concentration of ammonia (NH_3) and carbon dioxide (CO_2) conducted for both halls showed the reduced mean concentration of these gases in all tested production cycles (Fig. 2), (Fig. 4). The greatest difference in the concentration (NH_3) and (CO_2) was reported in series V, where the mean outdoor temperature in this cycle was 17,25°C. The mean concentration of hydrogen sulphide (H_2S) during eight series of tests varied. In series III, IV and VI, the concentrations recorded in the hall, where the microbial additive was used, were higher. In these cases, the difference was between 0.01 and 0.02 ppm was within the normal range (EMEP/CORINAIR 2007). Hydrogen sulphide emission is not primarily associated with avian fauna. Its higher concentration is recorded and controlled in particular in calf and pig husbandry (EMEP/CORINAIR 2007). The differences obtained in the measurement results are related to atmospheric conditions prevailing outside the building affecting the intensification of mechanical ventilation work. Maintaining an appropriate temperature adapted to the age of birds guarantees safe and effective production. During summer heat, it is recommended to increase ventilation velocity up to (1 m/s) (Jankowski 2012). Therefore, during the tests performed, the air temperature and humidity in both halls were in accordance with zoo hygienic requirements (Kołacz & Dobrzański 2006). However, changes in the intensification of work of mechanical ventilation contributed to the effectiveness of the microbiological additive. When analysing results, the changes can be observed in the concentrations of the tested gases, depending on the season in which the tests were performed and the temperatures characteristic for it. The highest results were obtained in the autumn period, in the series V, where the average temperature for the particular weeks of breeding was within the range of 11-24°C. During this period, the hall using the microbiological additive reduced the ammonia (NH_3) content by 22.89% compared to the control hall. However, the highest average percentage difference in the content of carbon dioxide (CO_2) was 26.54% and hydrogen sulphide (H_2S) 42.31%.

5. Summary

The use of a microbiological additive can reduce the concentration of harmful gases at source during broiler production and their reduced emission to the environment.

The effectiveness of the additive depends on the temperature prevailing outside the production building and the related intensification of the mechanical ventilation work. The best results of using the selected microbiological additive are obtained during moderate temperatures of 11-24°C.

Summing up the all results of mean concentrations of gases tested in eight cycles, in the two 2 halls, under the same conditions, we can conclude that in the hall where the microbial additive was used, 73.53 ppm less ammonia, about 6604.9 ppm less carbon dioxide and 0.26 ppm less hydrogen sulfide penetrated to the natural environment than in the control hall.

Referring to odour nuisance and air pollution with offensive odours and taking into account the thresholds at which test compounds, such as ammonia (NH_3) and hydrogen sulphide (H_2S) can cause unpleasant scents (ammonia 0.037 [ppm], hydrogen sulphide 0.00047 [ppm]), it can be stated that the reduction of these gases could limit odour nuisance in the environment.

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Stosowanie dodatku mikrobiologicznego w produkcji drobiarskiej jako metody ograniczenia emisji szkodliwych gazów do środowiska

Streszczenie

Emisja szkodliwych gazów z produkcji zwierzęcej, w tym drobiarskiej, wzrasta ze względu na zwielokrotnienie spożycia mięsa drobiowego na świecie. Proces ten wiąże się nieodłącznie z niekorzystnym oddziaływaniem gazów na środowisko. Usuwanie mikrozanieczyszczeń staje się więc wiodącym zadaniem dla inżynierii środowiska.

Biorąc pod uwagę emisję szkodliwych gazów, w artykule tym przeprowadzono analizę stężeń gazów w trakcie produkcji drobiu. Przedstawiono stężenia amoniaku (NH_3), siarkowodoru (H_2S) i dwutlenku węgla (CO_2) oraz pokazano ich wpływ na środowisko oraz jakość życia człowieka. Zwrócono uwagę na narastający problem i poszukiwanie nowych rozwiązań, których wdrożenie mogłoby zapobiec procesom degradacji środowiska naturalnego, do którego przyczyniają się przede wszystkim gazy wytwarzane przez środowisko rolnicze i produkcję zwierzęcą (80%).

Aktualne działania redukcji gazów powstałych u źródła w trakcie produkcji zwierzęcej amoniaku (NH_3),siarkowodoru (H_2S), dwutlenku węgla (CO_2) skupiają się na utrzymaniu dobrostanu w pomieszczeniu inwentarskim. W związku z tym w artykule tym przedstawiono metodę, w której użyto dodatek mikrobiologiczny w celu minimalizacji stężeń szkodliwych gazów i ich emisji do środowiska naturalnego.

Badania, w których zastosowano nową metodę, przeprowadzono podczas ośmiu serii produkcyjnych na fermie drobiu znajdującej się na terenie województwa Opolskiego. Ferma ta składała się z dwóch hal o takiej samej powierzchni i takim samym systemie wentylacji mechanicznej wymuszonej.

W artykule szczegółowo przedstawiono charakterystykę badanych cykli produkcyjnych, w których panowały różne warunki atmosferyczne (uwzględniono średnią dobową temperaturę zewnętrzną). W poszczególnych cyklach wystąpiły również nieznaczne różnice w ilości wstawianych brojlerów. W długości trwania cykli również odnotowano nie wielkie różnice.

Oszacowano średnie stężenia amoniaku (NH_3), siarkowodoru (H_2S), dwutlenku węgla (CO_2), które uzyskano w poszczególnym cyklach produkcyjnych. Oszacowano również różnice badanych gazów [ppm] przypadające na poszczególne serie badawcze w hali, w której stosowano preparat zawierający pożyteczne mikroorganizmy i porównano z wynikami uzyskanymi w hali kontrolnej. W pracy zmierzono także ogólny spadek stężeń badanych gazów w [ppm] z ośmiu serii produkcyjnych, których emisja okazała się niższa od emisji uzyskanej w hali kontrolnej. Zwrócono uwagę na zanieczyszczenia powietrza atmosferycznego fetorami oraz na równoległą możliwość redukcji nieprzyjemnych doznań zapachowych przez zastosowanie nowej metody z wykorzystaniem dodatku mikrobiologicznego.

Przedstawione w artykule zagadnienia stanowią podstawę do dalszych wnikliwych badań, które pomogą przybliżyć skuteczność dodatku mikrobiologicznego, stosowanego przy produkcji drobiarskiej oraz w innych produkcjach związanych z chowem inwentarza żywego, w celu ograniczenia emisji szkodliwych gazów do środowiska.

Abstract

The emission of harmful gases from livestock production, including poultry, is growing due to the increasing consumption of poultry meat in the world. This process is inherent to the adverse effects of gases on the environment. Thus, the removal of micro-pollutants becomes a leading task for environmental engineering.

Taking into account the problem of harmful gases emission, the article focused on the analysis of gas concentrations in production of the poultry. The concentrations of ammonia (NH_3), hydrogen sulfide (H_2S) and carbon dioxide (CO_2) were shown together with their impact on the environment and the quality of human life. The attention was directed to this growing problem and the search for new solutions the implementation of which could prevent environmental degradation. This disadvantageous phenomenon is mainly due to the impact of gases produced by the agricultural industry and animal production (80%).

Current activities, which are aimed at reducing greenhouse gases generated at source during the production of animals, such as ammonia (NH_3), hydrogen sulfide (H_2S) and carbon dioxide (CO_2), are focused on maintaining high welfare in the livestock room. Therefore, this article presented a method in which the microbial additive was used to minimize the concentration of harmful gases and emission to the natural environment.

The study, which used a new method, was carried out during eight series of production on the poultry farm located in the Opole province. The battery farm consisted of two halls of the same area and with the same forced mechanical ventilation system.

The article presents detail characteristics of the tested production cycles conducted under different atmospheric conditions (taking into account mean daily outdoor temperature). Individual cycles also slightly differed in terms of the number of inserted broilers. Small differences also related to the duration of cycles.

The study estimated the mean concentration of ammonia (NH_3), hydrogen sulfide (H_2S) and carbon dioxide (CO_2) obtained in each production cycle. The test gases were also assessed in terms of differences [ppm] per individual test series conducted in the control hall and the hall where the formulation containing beneficial micro-organisms was used. The study also measured the overall decline in the concentrations of the tested gases [ppm] in eight production series. Their emission turned out to be lower than the amounts generated in the control hall. The attention was directed to air pollution with offensive odours and the parallel possibility of reducing unpleasant scents by applying the new method using the microbial additive.

Słowa kluczowe:
dodatek mikrobiologiczny, produkcja drobiarska,
szkodliwe gazy – (NH_3), (H_2S), (CO_2)

Keywords:
microbial additive, poultry production, harmful gases – (NH_3), (H_2S), (CO_2)