Emission of materials of biological origin in laying hens houses with different technologies of rearing

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ABSTRACT: The aim was to determine the conversion of alimentary substances of laying hens (nitrogen, phosphorus, potassium) into the production of eggs and to determine the emission of nitrogen, air pollution by dust and microorganisms in accordance with different technologies of layer rearing. The studies were conducted in 6 poultry houses. The birds were kept in premises in cage batteries BKN-3, "Spech", OBN-1, OBN-3 or on littered floor. It was found out that there was 1.6 times more dust in the air of poultry house where laying hens were kept on litter and the total number of bacteria was 2.4 times higher than in the bird cages ($P < 0.001$). The laying hens assimilated 21.95–28.42% of nitrogen, 19.63–31.25% of phosphorus, 6.04–8.33% of potassium for egg production and weight gains when feed is balanced. If cage technologies are applied, over a year, there is a loss of 6.7 ± 1.4% of nitrogen through the excrements because of nitrogen emission. When the technologies of littered floor are used, there is a loss of 18.5 ± 4.8% of nitrogen extricated with the excrements ($P < 0.025$). When the birds were kept in cages, 0.059 ± 0.011 kg of nitrogen per each bird evaporated because of ammonia emission, while in the case of littered floor – 0.227 ± 0.126 kg of nitrogen.

Keywords: laying hens; poultry houses; ammonia; nitrogen emission; air pollution

Nowadays in agricultural production the main attention is paid to the protection of air, soil and water. On farms the air is polluted by dangerous gases, dust, smells and microorganisms which diffuse in the environment while ventilating the premises. It is accepted that the portion of excreted ammonia in stockbreeding and aviculture in the total world emission of the above-mentioned gases is rather high and should be controlled (ECETOC, 1994; EPA, 2003) and minimised. The results of research on ammonia extrication in Europe show that in the industries of stockbreeding and aviculture it reaches 80–90% of the total emission of gases (Buijsman et al., 1987; Turner, 1999). In the poultry houses of laying hens the emission of ammonia is one of the largest (Turner, 1999) and its range is just increasing. According to statistical data, in 2003–2004, in the world there were 5 383 million laying hens and 55.8 million tons of eggs were produced. It means that in the last decade the number of layers in the world increased by 29.5% (Anonymous, 2004). The increase in the number of laying hens in this aviculture industry stimulates the expansion of observation programmes of dangerous gases, dust emission and research on microbiological pollution.

At present, in the world 70–80% of laying hens are kept in cages, in EU countries the same technology is applied to 90% of laying hens (Williams, 2000; Duncan, 2001). In Europe other alternative ways of laying hen keeping are spreading. The way of bird keeping directly influences the pollution with dangerous compounds, dust emission and microbiological pollution on farms. Chemical pollutants are risk factors for the health of human beings and animals. The identification of the emission and its spreading and the search for means for the decrease are the priority directions of scientific research. The General Directive of Air Quality of EU requires the control of the quantity of 13 kinds of pollutants in the air. Among them the suspended particles – dust – that have a global influence on the environment are also mentioned. The emission of suspended particles (dust, bioaerosol and microorganisms) is dangerous for animals and human beings in such an environment. The concentration of dust in the premises where the layers live is from 0.75 to 8.78 mg/m^3 (Takai et al., 1998), the average annual dust emission varies from 1.1 ± 0.3 g/day/AU (grams per day per animal unit, where AU is the number of birds equated to 500 kg of live weight) to 65 ± 15 g/day/AU (Lim et al., 2003) and it directly depends on the technology of bird keeping. When the litter technologies of animal keeping prevail, higher concentrations of dust occur in premises, at the same time the microbiological pollution in the environment increases. Depending on the technology of animal keeping in the stable, disposal and storage of manure, the level of ventilation of premises, the season (Shakarjan et al., 1987) and many other factors, the microbial pollution in the air of stables can vary from 100 to 5 × 10^5 CFU (colony forming units) per 1 m^3. In poultry houses, the quantity of dust in the air is usually higher than in the stables of other farm animals. However, until now the scientific literature has lacked exact data on the influence of bird species and technologies of their keeping on the general number of microorganisms in the air of premises and the existing data is controversial.

Over a year, the layers extricate from 0.37 to 0.85 kg of nitrogen with excrements (Turner, 1999; Bonazzi et al., 2005) the loss of which because of ammonia emission can amount up to 30% or even 40% (Lockyer and Pain, 1989). The comparative emission of ammonia in aviculture is almost the highest: 1 AU (equating to 500 kg of live weight) in an aviary reaches 0.5–10.0 g/hour, while in cow stables it is 0.12–1.50 g/hour, in pig stables 0.20–5.00 g/hour (Hatfield and Prueger, 2003). The emission of ammonia directly depends on the technologies of layer keeping and disposal of manure from premises.

At present, suppression of nitrogen and appropriate utilization are the priority direction of scientific research. The Baltic States have the plans to reduce the emission of ammonia in agriculture from the existing 50% to 30% by 2010 and 25% by 2 030 (HELCOM, 1998). It could be impossible if the real range of gas emission were not evaluated in the most polluted industries of national economy.

The aim of our study was to investigate the balance of nutrients and the losses in poultry houses taking into consideration different technologies of keeping, breeding, disposal and storage of manure; evaluation of levels of emissions of ammonia nitrogen, bacterial pollutants and dust.

MATERIAL AND METHODS

In 2004 a study was conducted on 5 farms in 6 stables: Zarasai District Poultry Farm SPARNAI (V1), Ukmerge District LIOMPOLIO Poultry Farm (2 stables: V2 and V3), Rokiskis District Poultry Farm AUDRUPYS (V4), Kaisiadoriai District, Zasliu Ward, Poultry Farm of the farmer S. Morkunaite (V5) and Silutė District, Kintai Ward, Poultry Farm of the farmer Cirulis (V6). The general characteristics of the above-mentioned farms are presented in Table 1. Birds were kept in cages on 4 poultry farms (V1–V4) and littered floor technology was applied on 2 poultry farms (V5–V6).

Periodic records were done on each poultry farm once in three months. The number of birds, the amounts of used feed and litter, and the quantity of stored manure in 24 hours were recorded. Parameters of the microclimate of stables were also taken into consideration. The productivity of laying hens (lay of eggs in 24 hours, total accumulation of laid eggs, and average weight of layers) and mortality of birds were registered during our research. Ammonia emission was investigated and losses of nitrogen on poultry farms were calculated. The samples of feed, litter and manure were taken for laboratory analyses and the balances of nutrients were calculated.

Concentrations of NH_3 and CO_2 in the air of premises were determined at 3 points along the diagonal of the premises at a height of 50 and 150 cm. The concentrations of ammonia and carbon dioxide were determined on the devices Drager Multivarn II, Drager Pac III, Gastec and Gas Data Ltd PCO2 IAQ (portable carbon dioxide indoor air quality analyzer). The total count of microbes and *E. coli* in the air was identified by Koch's plate method. The speed of air movement was measured with globular catathermometer and wing anemometer. The tests of air temperature, humidity and pressure were done on the devices Testo 175 and Ama Digit. The concentration of dust in the air was identified by a gravimetric method using Migunov electric aspirator in the central part of the premises at a height of 0.5 and 1.5 m where the birds were kept (Onegov et al., 1984).

Table 1. Description of laying hen houses

Description	Laying hen houses					
	V1	V2	V3	V4	V5	V6
Crosses of laying hens	Haise × White Haise × Brown	Isa Brown	Isa Brown	Haise × White Haise × Brown	Dominant	Haise × Brown
System of poultry housing	BKN-3 cages	"Spech" cages	OBN-1 cages	BKN-3 cages	groups on littered and plastic grid floor	groups on littered floor
Space of poultry house (m^2)	1 079	1 020	1 020	1 710	720	750
Capacity of poultry house (m^3)	3 021	4 080	4 080	8 550	2 520	1 875
Ventilation	automatic	automatic	automatic	automatic	automatic	natural
AU per 1 m^3 house	0.011–0.014	0.012–0.019	0.009–0.010	0.010–0.016	0.0051–0.0055	0.0020–0.0024
Poultry in cage or group	4	4	4	4–5	1 750	500
Poultry on	wire net	wire net	wire net	wire net	sawdust and plastic grids	sawdust
Turnover of air per 100 kg of live weight of poultry (m^3/h)	520 ± 110	300 ± 60	840 ± 320	145 ± 15	110 ± 35	340 ± 200
Exercise yard	No	No	No	No	No	Yes
Feeding level per day/hen (g)	121.7 ± 1.7	116.6 ± 0.2	116.5 ± 0.3	127.5 ± 1.6	153.8 ± 38.4	142.5 ± 2.5

At places of manure storage on the farm the losses of nutrients accumulating in 6 months were identified. On poultry farms the emission of ammonia was investigated and the losses of nitrogen were calculated. The factor of ammonia emission of the stable was determined in accordance with its concentration in premises and the calculated level of air exchange once in three months. The level of air exchange and ammonia emission were calculated in accordance with the methods of international agricultural engineering commission prepared by Pedersen and Sallvik (2002).

The amounts of nitrogen in feed, manure and sewage were determined using the Foss-Tecator equipment. The quantity of potassium and phosphorus was measured with Perkin-Elmer 603 spectrophotometer of nuclear absorption, dry materials – the samples were dried in a thermo starter at the temperature of 75°C.

The research data was processed by the methods of statistical biometry (Snedecor and Cochran, 1989), using the Statistica Ver. 6.0 Computer Programme. The results are accepted as reliable when $P < 0.05$.

RESULTS AND DISCUSSION

The microclimate of poultry premises influences not only the health of birds and their productivity but also the emission of ammonia and other gases. The parameters of microclimate determined during research on poultry farms are provided in Table 2.

During research the temperature of outdoor air was 6.5–18.2°C, the relative outdoor humidity was 52.4–94.1%. When the technology of layer keeping outdoors is applied, the average air temperature is 20.5 ± 0.7°C and does not mostly differ from other technologies of bird keeping. Taking into consideration the data of T. R. Morris, if there is such a temperature, the laying of eggs and input of feed is optimal (Morris, 2004). On typical poultry farms where the laying hens are kept in cage batteries, the average air temperature was 15.2–21.8°C and directly depended on the number of birds in premises. The relative humidity on all poultry farms was similar and varied from 57.0% to 94.9%. The indicators of the microclimate

Table 2. Environmental parameters in laying hen houses

Poultry houses	Air temperature (°C)	Relative humidity (%)	Air movement (m/s)	CO_2 concentration (ppm)	NH_3 concentration (ppm)
V1	21.8 ± 1.4	85.4 ± 1.6	0.22 ± 0.18	750 ± 125	2.3 ± 1.8
	Cv 11.1%	Cv 3.3%	Cv 138.5%	Cv 28.9%	Cv 136.1%
V2	14.1 ± 1.9	75.8 ± 4.3	0.11 ± 0.02	1 081 ± 106	1.1 ± 0.5
	Cv 35.0%	Cv 15.0%	Cv 43.1%	Cv 26.0%	Cv 112.2%
V3	15.2 ± 3.9	73.0 ± 1.2	0.04 ± 0.003	780 ± 115	0.8 ± 0.1
	Cv 51.7%	Cv 3.3%	Cv 10.8%	Cv 29.6%	Cv 38.5%
V4	18.7 ± 1.5	80.5 ± 4.0	0.07 ± 0.02	1 597 ± 167	8.3 ± 1.1
	Cv 22.2%	Cv 14.0%	Cv 72.9%	Cv 29.5%	Cv 37.1%
V5	19.8 ± 1.1	71.3 ± 7.4	0.043 ± 0.008	1 717 ± 509	23.3 ± 11.6
	Cv 9.6%	Cv 17.9%	Cv 33.3%	Cv 51.3%	Cv 86.2%
V6	20.5 ± 0.7	85.6 ± 2.4	0.04 ± 0.001	1 007 ± 243	9.4 ± 4.2
	Cv 5.9%	Cv 4.8%	Cv 2.0%	Cv 41.9%	Cv 77.8%
Cage housing	17.5 ± 1.8	78.7 ± 2.7	0.11 ± 0.04	1 052 ± 197	3.1 ± 1.7
	Cv 20.1%	Cv 6.9%	Cv 70.2%	Cv 37.3%	Cv 111.8%
Littered housing	20.2 ± 0.4	78.5 ± 7.2	0.042 ± 0.002	1 362 ± 355	16.4 ± 6.9
	Cv 2.6%	Cv 12.9%	Cv 5.7%	Cv 36.9%	Cv 59.9%

of poultry farms were little dependent on climate conditions and on the season but they depended on the technologies of bird housing and ventilation of premises to a larger extent. Air exchange per 100 kg of the weight of birds where cage technologies were applied reached 451 ± 151 m^3/hour (difference $P = 0.25$).

If the concentration of carbon dioxide on poultry farms was relatively the same taking into consideration different technologies of bird keeping (the differences were not reliable $P = 0.46$), then the concentration of ammonia when birds were kept on littered floor was 5 times higher. However, the difference was not reliable as well ($P = 0.080$). In some cases, zoohygienic norms were exceeded on poultry farm V5 (the norm of NH_3 is 20 ppm). Different concentration of ammonia when the layers are kept in cages is explained by irregular disposal of manure, different technologies, the influence of which on the diversification of ammonia concentration on poultry farms from 1 to 108 ppm was fixed by Liang Y. and others (Liang et al., 2003) in their investigations, and by different intensity of ventilation of the premises. The relative humidity was similar on poultry farms with cages and with littered floor. During the time of investigation, the air temperature was higher on poultry farms where laying hens were kept outdoors. However, the difference was not statistically reliable.

The air pollution by dust and microorganisms in stables is shown in Table 3. Dust concentrations in the air of investigated poultry farms were higher than mentioned in the works of other authors. Bigger highest norms (80.33 mg/m^3) than mentioned by (Ellen et al., 2000) and bigger than mentioned by (Takai et al., 1998) lowest norms (8 mg/m^3) were identified. However, during our investigations the samples of dust were taken when the activity of birds was the highest. Dust concentration in the air of poultry farms with cage technologies was almost twice lower ($P = 0.41$) than on poultry farms with the technologies of littered floor. Birds kept outdoors during the daytime are active; by moving and scratching the litter enhance the flow of dispersive particles of organic origin.

Total number of bacteria in the air of poultry farms with littered floor technologies is 2.4 times higher than on the poultry farms with cage technologies ($P < 0.001$). It is explained by the fact that microorganisms are carried on the surface of dust (direct correlation with the air dustiness in the premises) and by the larger air exchange in the premises where cage technologies are used. Clark et al. (1983) stated that the general microbial pollution

Table 3. Dust concentration and microbiological air contamination in laying hen houses

Laying hen houses	Dust concentration in air (mg/m^3)	*E. coli* count in air (CFU/m^3)	Total count of micro-organisms in air (thousand CFU/m^3)
V1	107 ± 58	1 163 ± 1 108	62.3 ± 27.5
	Cv 94.7%	Cv 134.8%	Cv 62.4%
V2	122 ± 39	3 295 ± 3 120	44.1 ± 31.5
	Cv 71.8%	Cv 164.0%	Cv 124.0%
V3	231 ± 70	34 ± 33	12.9 ± 11.4
	Cv 60.2%	Cv 96.0%	Cv 125.6%
V4	46 ± 4	6 917 ± 4 809	64.5 ± 23.8
	Cv 23.0%	Cv 155.5%	Cv 106.9%
V5	280 ± 121	2 752 ± 1 311	98.9 ± 20.6
	Cv 74.9%	Cv 82.5%	Cv 36.1%
V6	123 ± 121	2 401 ± 2 187	94.1 ± 35.9
	Cv 70.9%	Cv 157.8%	Cv 66.0%
Cage housing	127 ± 39	2 852 ± 1514	40.9 ± 10.3
	Cv 60.9%	Cv 106.2%	Cv 50.2%
Littered housing	202 ± 79	2 576 ± 175	96.5 ± 2.4
	Cv 55.1%	Cv 9.6%	Cv 3.6%

in the premises of laying hens is one of the highest in comparison with other animals and reaches 4 to 5 log CFU and the group of *endo* bacteria reaches 3–4 log CFU. The data of our investigation was similar: with the laying hens the total number of bacteria in the air was from 4.51 to 5.19 log CFU, with cage technologies from 3.16 to 5.06 log CFU. The respective counts of *endo* bacteria varied from 2.05 to 3.85 log CFU and from 1.04 to 4.41 log CFU.

The emission of ammonia nitrogen ($N\text{-}NH_3$) in different poultry houses was calculated taking into consideration the air quality investigation (Table 4). The highest possible error of nitrogen emission was in poultry house V6 as birds could freely stay outdoors and at the same time the calculated indicator of air exchange HPU (heat producing unit) is distorted. In the calculations of $N\text{-}NH_3$ emission we assumed that the birds would be outdoors half a day (or half a year). However, the outdoor part also belongs to the poultry house, the total (premises or outdoors part) ammonia emission is calculated for the poultry house. When calculating the air exchange in accordance with HPU, it is necessary to improve the classical methods for this type of poultry houses.

During the period of investigation, when laying hens were in cages, the emission of ammonia from the area of 1 m^2 of poultry house was 0.093 ± 0.017 (from 0.014 to 0.271) g/hour/m^2. If the technology of littered floor was applied, the emission of ammonia from the area of 1 m^2 of poultry house was 0.118 ± 0.057 (from 0.003 to 0.281) g/hour/m^2. When hens are kept in cages, the annual emission of ammonia per bird was 0.065 ± 0.014 kg (from 0.006 to 0.187 kg), with littered floor 0.307 ± 0.149 kg (from 0.005 to 0.801 kg). Similar results of researches were published by other authors: Kroodsma and Huis (1988) determined 0.109 kg of annual ammonia emission per laying hen, Hartung and Philips (1994) 0.082–0.141 kg, Valli et al. (1998) 0.395 kg, Yang et al. (2000) 0.408 kg, and Battye et al. (2003) 0.370 kg. Groot Koerkamp et al. (1998) calculated the annual ammonia emission per laying hen with littered floor technologies to amount to 64.6–95.3 kg, for the cage technology to 5.11 to 80.7 kg. According to our data of investigations 1 AU annual ammonia and ammonia nitrogen emission when birds are kept on littered floor was 3.4 times higher than in the cage technology. However, in this case it should not be forgotten that when cage technologies are applied, rather high losses of ammonia occur not only in premises but also at storage places of manure. That is why while making comparisons it is necessary to evaluate the total ammonia emission in premises and at storage places of manure.

Table 4. Nitrogen emission due to ammonia evaporation in laying hen houses

Laying hen houses	Ammonia (NH_3) emission in poultry house (g/h)	Annual N-NH_3 emission (kg/bird)	Annual N-NH_3 emission per AU (kg/AU)
V1	101 ± 78	0.065 ± 0.044	17.6 ± 12.5
	Cv 133.7%	Cv 118.1%	Cv 122.5%
V2	108 ± 62	0.033 ± 0.019	9.7 ± 5.3
	Cv 151.1%	Cv 158.2%	Cv 146.1%
V3	55 ± 16	0.034 ± 0.010	11.2 ± 3.4
	Cv 60.1%	Cv 3.3%	Cv 60.1%
V4	373 ± 64	0.092 ± 0.016	26.0 ± 4.3
	Cv 48.4%	Cv 47.6%	Cv 46.6%
V5	146 ± 73	0.353 ± 0.190	78.9 ± 39.1
	Cv 86.7%	Cv 93.1%	Cv 85.9%
V6	18 ± 10	0.101 ± 2.4	29.5 ± 15.3
	Cv 82.4%	Cv 4.8%	Cv 73.4%
Cage housing	159 ± 72	0.056 ± 0.044	16.1 ± 3.7
	Cv 20.1%	Cv 51.3%	Cv 46.2%
Littered housing	82 ± 64	0.227 ± 0.126	54.2 ± 24.7
	Cv 110.5%	Cv 78.8%	Cv 64.4%

The accumulation of nutrients (N, P, K) in fresh excrements of the investigated bird groups was calculated by the method of their conversion to production and balance. It is shown in Table 5.

In analysing the data of feed nutrient conversion to production, it was determined that in poultry houses with cage technologies, laying hens assimilated 28.42% of nitrogen, 31.25% of phosphorus, and 8.33% of potassium from feed for the production of eggs. On farms with littered floor technologies, laying hens assimilated 21.95% of nitrogen, 19.63% of phosphorus, and 6.04% of potassium from feed for the production of eggs. When nitrogen accumulation in fresh excrements was calculated, the factors of nitrogen emission were determined (Table 6).

After the evaluation of ammonia emission in the stable, it can be stated that during the period of laying hen keeping in cages there is an average loss of 0.056 ± 0.014% nitrogen per bird, which accounts for 6.7 ± 1.4% of nitrogen extricated with excrements. When littered floor technologies are applied, the average loss of 0.227 ± 0.126 kg of nitrogen per bird is incurred, corresponding to 18.5 ± 4.8% of nitrogen extricated with excrements. The difference was statistically reliable. Lockyer and Pain (1989) identified that the factor of nitrogen emission of laying hens is from 7 to 41.5%. According to the

Table 5. Nutrient (N, P, K) consumption and retention in fresh excrements

Nutrients (g)	Laying hen houses					
	V1	V2	V3	V4	V5	V6
Consumption of nutrients per day/hen						
N	3.5 ± 0.1	3.5 ± 0.04	3.6 ± 0.01	4.2 ± 0.30	4.6 ± 1.10	3.5 ± 0.50
P	0.75 ± 0.07	0.85 ± 0.08	0.77 ± 0.14	0.90 ± 0.05	1.1 ± 0.30	1.0 ± 0.10
K	1.80 ± 0.02	0.67 ± 0.03	0.67 ± 0.03	1.60 ± 0.25	1.8 ± 0.09	1.1 ± 0.30
Retention of nutrients in fresh manure of one hen per day/laying hen						
N	2.07 ± 0.11	2.65 ± 0.11	2.76 ± 0.01	2.97 ± 0.30	3.60 ± 0.60	2.30 ± 0.50
P	0.43 ± 0.07	0.65 ± 0.09	0.58 ± 0.14	0.58 ± 0.07	0.90 ± 0.20	0.70 ± 0.04
K	1.70 ± 0.02	0.59 ± 0.02	0.59 ± 0.03	1.48 ± 0.24	1.70 ± 0.80	1.00 ± 0.30

Table 6. Emission factors of nitrogen due to ammonia evaporation in laying hen houses (%)

Laying hen houses	V1	V2	V3	V4	V5	V6
Emission factors for poultry (%)	8.0 ± 5.1	4.0 ± 2.7	3.3 ± 1.0	8.9 ± 1.6	23.3 ± 13.0	13.7 ± 8.2
	Cv 110.9	Cv 178.4	Cv 60.6	Cv 50.1	Cv 96.8	Cv 84.4

data of other authors, when hens are kept in cages, it ranges from 9 to 15%, and when applying littered floor technologies from 15% to 24% (Poulsen and Kristensen, 1998). Cabera and others stated that when keeping hens on littered floor, the emission of nitrogen was 25.1% (Cabera et al., 1994).

So, having the climate conditions as we do, the identified ammonia nitrogen emission in the premises with laying hens does not exceed the applied basic values of factors of emission of EU and other countries. It is slightly lower than the recently applied norms for the calculations of environment pollution.

CONCLUSIONS

The total number of bacteria was 2.4 times higher in the air of poultry houses with littered floor technologies than in poultry houses with cage technologies ($P < 0.0001$).

When receiving balanced combined feed, laying hens assimilated 21.95–28.42% of nitrogen, 19.63–31.21% of phosphorus, and 6.04–8.33% of potassium from feed for the production of eggs and weight gain.

When cage technologies were applied, there was a loss of 6.7 ± 1.4% of nitrogen extricated with excrements over a year. The reason is the emission of ammonia. When the technologies of littered floor are applied, there is a loss of 18.5 ± 4.8% of nitrogen extricated with excrements ($P < 0.025$).

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