DUST POLLUTION IN BUILDINGS FOR HOUSING OF MEAT CHICKENS

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Abstract. The aim of this paper is to present the results of microclimatic research focused on dust pollution in agricultural buildings used for fattening of chickens. The attention is paid mainly to the construction and influence of the ventilation system. The overall layout of the farm and the ventilation system solutions significantly affect the quality of the indoor climate in terms of dust in the halls for poultry. In the frame of this research the concentration of air dust was measured by exact instrument Dust-Track aerosol monitor. Using the special impactors the PM_1, $PM_{2.5}$, PM_4, PM_{10} size fractions were also measured. The obtained results of measurements were evaluated and concentrations of different size of dust particles were analysed. Results of different indoor conditions were generalized. Based on the results of the measurements practical recommendations for the design, use and ventilation of these types of buildings were summarized in the conclusions.

Keywords: air, design, dust fractions, efficiency of dust removal, measurement.

Introduction

Poultry housing technology, external climatic conditions and the weather influence the indoor microclimate during different periods of the year. It needs different methods of ventilation control [1; 2]. Creation of internal environment in the halls for poultry housing is complicated mainly because of the high biological load of indoor environment, resulting from the large number of chickens per 1 m^2 of the floor area. Problems occur particularly towards the end of fattening. Chickens have a large mass; they produce large quantities of pollutants [2; 3]. Usually this problem is solved by intensive ventilation [4; 5], but it has a rather negative influence also on the technical equipment [6].

Dust particles which are smaller than 10 microns occur in the air in small amounts, but they have a great biological importance. They are inhaled, but for the most part they are already captured in the upper respiratory airways. Here, they are deposited as a film of mucus, which is moved by cilia toward the nasopharynx. Smaller particles with an aerodynamic diameter of about 0.003 to 5 μm are deposited in the tracheobronchial and alveolar regions. Particles of the size of about 1 micron permeate bronchioles until the alveoli, where they are captured sometimes more than 90 %. These particles are therefore in the terms of retention of aerosol in the lungs the most dangerous [7; 8]. One of the best known diseases caused by organic dust is the so called Farmer's lung [9; 10].

Different methods for reduction of noxious gases concentration or bad odor pollution can help improve the internal conditions inside the buildings [11; 12], but dust pollution can be by these methods hardly reduced. The source of dust is the poultry feather, particles of feed and bedding on the floor. Dust pollution can be reduced either by reduced production of dust at the source, which is in this case rather difficult, or by intensive ventilation. Some of publications present the methods of calculation of the main parameters of the ventilation system [13] and simulation of indoor conditions [14-18].

The aim of this paper is to characterize particulate matter (PM) contamination and to show the measurement results of dust pollution in poultry houses and to study the influences of indoor dust pollution by the hall construction and the farm design, particularly the possibility of influencing the dust pollution inside by surroundings and appropriate solution of the ventilation system.

Materials and methods

This research work and measurements were carried out in three buildings for fattening of meat chickens. All poultry houses are located parallel to each other in one farm, and they are situated on a small slope, the 1st building is on the top, the 3rd hall is in the bottom part of the farm. All halls have the same internal dimensions: length 100 m, width 11.5 m, height 2.7 m, and inside each hall there is housing of 23,000 chickens on the floor. The measurements were carried out during the 26th to 33rd days of fattening when the chicken have average weight about 1.5 kg. The floor in the halls is covered by the bedding material from a mixture of chopped straw and sawdust.

The cross ventilation of production buildings is transverse, with under-pressure created by the axial fans in the side wall in outlets, with a total maximum air flow of 230,000 $m^3.h^{-1}$. The fresh air is sucked in the 1st hall from its opposite wall into the inlets from the open area, which is covered with trees and shrubs, and which is followed by the field. Into the 2nd and 3rd halls the air is sucked from the space between these halls, in the middle part of the farm. Because of this arrangement of buildings and ventilation system the main attention is paid to the first hall with fresh air inlet.

The total concentration of air dust was measured by special exact instrument Dust-Track™ II Aerosol Monitor 8530. After installation of different impactors the PM_{10}, PM_4, $PM_{2.5}$, PM_1 size fractions of dust were also measured.

According to the type of the material, dust has specific characteristics to which the properties respond. According to [19], this type of dust has irritating effects (poultry feather, particles of feed, straw and sawdust from the wood). For this type of dust the prescribed Occupational Exposure Limits (OEL) are permissible exposure limits of total concentration. There are Exposure Limits of some noxious gases in the animal houses from the animals' point of view, but there are not the limit values for the dust concentrations. The Occupational Exposure Limits are listed in Table 1.

Table 1

Types of dust and occupational exposure limits (OEL)

Dust	OEL, $mg \cdot m^{-3}$
Feather	4.0
Feed	6.0
Straw	6.0
Sawdust	5.0

Measured dust inside this type of buildings is not aggressive, therefore, as a criterion for comparative evaluation of the measured values the limit level of outdoor dust can be also used.

Measuring devices and equipment technology environment continues to improve and provide a larger volume and more accurate results. New studies are constantly providing fresh information, but there are still many uncertainties. Maybe, new and more precise ideas about the influence on the human health or on the animals can be discovered.

Very helpful and also important it is to know the details about the composition and size of dust particles from the point of view of technical equipment and technology of indoor environment. This is important among other things for the selection of appropriate filters, scheduling maintenance and cleaning, and overall management options how to reduce the dust inside the buildings.

One of the possibilities how to use the measurement results of dust concentrations is an assessment of the effectiveness of ventilation. Air moves inside a ventilated hall due to the pressure gradient between the air inlets and outlets. Location of air inlets and outlets together with the other factors inside the ventilated space affects the final effect of ventilation and manifests purity of the air.

The final effect can be assessed as dust removal efficiency, calculated according to equation (1). The maximum of dust removal efficiency could be theoretically $e_v = 1$, if the concentration of dust in the outgoing air is the same as the concentration inside the building. The same evaluation principle can be used not only for the total dust, but also for the calculation of a removal efficiency of dust particles, probably influenced also by the air velocity, properties of particles and other factors. These results could be useful for improvement of ventilation system designs.

$$e_V = \frac{(k_o - k_e)}{(k_i - k_e)}, \tag{1}$$

where e_V – dust removal efficiency of ventilation;
k_o – concentration of dust in the outgoing air, $\mu g \cdot m^{-3}$;
k_e – concentration of dust in the incoming air, $\mu g \cdot m^{-3}$;
k_i – concentration of dust inside the poultry house, μgm^{-3}.

Therefore, the dust measurements have been provided in the hall 1 not only according to the prescribed normal national or international standards (e.g., PM_{10} and $PM_{2.5}$), but the total dust concentration and particulate matter by all available impactors PM were also measured. Larger amounts of information allow to obtain more detailed information on the composition and percentage of the size fractions of dust.

According to [20], the PM_{10} limit value in 24 hours is 50 $\mu g \cdot m^{-3}$, 1 year limit value is 40 $\mu g \cdot m^{-3}$. 90 data of dust concentration for total dust as well as of each fraction size in each room were collected. The obtained results of dust measurements were processed by Excel software and verified by statistical software Statistica 12 (*ANOVA* and *TUKEY HSD Test*).

The concentration of dust pollution inside the poultry houses can be influenced also by the activity of poultry, especially during the feeding, manipulation with litter material etc. Therefore, the measurements were provided in two steps. The first measurements were focused on measurement of dust distribution inside the hall 1 and evaluation of dust particle removal by ventilation.

The other measurements of PM_{10} and PM_1 were provided during the same technological situation in all three halls, with the aim to recognize the differences of dust pollution between them.

Results and discussion

Principal results of dust measurement in the hall 1 are summarized and presented in Figs. 1 and 2. The total dust concentration and concentration of the measured size particles PM_{10}, PM_4, $PM_{2.5}$ and PM_1 are presented in Fig. 1. OEL limits are not over crossed, but the concentrations of all dust particles are very high, only the concentration of the smallest particles (< 1 μm) is under 50 $\mu g \cdot m^{-3}$.

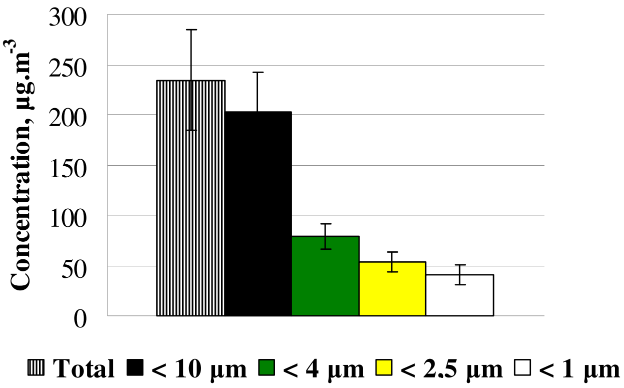

Fig. 1. **Dust concentration total and size fractions inside the hall 1**

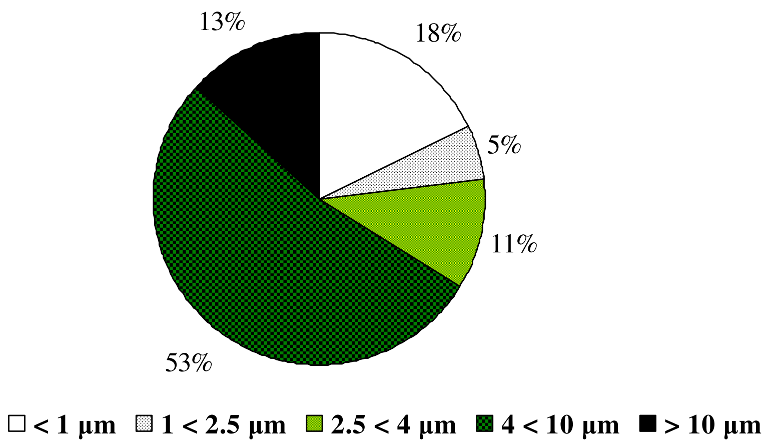

Fig. 2. **Distribution of dust size fractions inside the hall 1**

The distribution of dust size fractions inside the poultry houses is presented in Fig. 2. The biggest percentage (53 %) of dust are the dust particles from 4 to 10 μm. Rather big portion of dust (18 %) is created by the dust particles smaller than 1 μm. Dust particles of these dimensions are very dangerous from the point of the respiration system of living organism.

The results of dust concentrations in the inlet, inside the hall 1, in the outlet of air and the dust removal efficiency of ventilation calculated according to equation (1) are presented in Table 2. The results of these measurements and calculations show that the dust removal efficiency of ventilation is rather dependent on the size of the dust particles. If it is calculated for the case of total dust removal, the efficiency is e_v = 0.22. The most efficient e_v = 0.80 is dust removal in the case of the smallest particles PM_1.

Table 2

Dust concentrations and dust removal efficiency of ventilation in the hall 1

Dust	Inlet, $\mu g \cdot m^{-3}$	Inside, $\mu g \cdot m^{-3}$	Outlet, $\mu g \cdot m^{-3}$	e_v
Total	29.56	234.08	75.16	0.22
PM_{10}	29.47	203.16	58.23	0.17
PM_4	29.42	79.04	45.26	0.32
$PM_{2.5}$	27.88	53.79	39.09	0.43
PM_1	21.71	41.33	37.37	0.80

The comparison of dust pollution in all three buildings is presented in Table 3. As the main parts of dust create particles PM_{10} and PM_1, the attention is paid to the dust particles PM_{10} and PM_1. The concentration of particles PM_{10} is in all cases several times higher than the recommended limit 50 $\mu g \cdot m^{-3}$ for dust in outside air. The significant difference between the halls shows the influence of the suction of fresh air from the clean open space into the hall 1 and suction of partly polluted air sucked from the central part of the farm into the halls 2 and 3.

Table 3

Total dust concentration and concentration of dust fractions PM_{10} and PM_1 in the hall 1. Different letters (a, b, c) in the superscript are the sign of high significant difference (ANOVA; Tukey HSD Test; $p \leq 0.05$)

Hall	PM_{10}	PM_1
-	$\mu g \cdot m^{-3} \pm SD$	$\mu g \cdot m^{-3} \pm SD$
1	148 ± 25^a	31 ± 3^a
2	186 ± 38^b	33 ± 4^a
3	257 ± 76^c	54 ± 11^b

The relations between the data from the measurements of PM_1 size fraction are similar to the previous results of PM_{10}, but the difference between the hall 1 and 2 is not statistically significant.

The worst dust pollution is in the 3rd hall. The inlets are situated in the central part of the farm, partly polluted with the discharged air from the outlet from all three halls. As the hall 3 is in the lowest part of the farm, the dust pollution in the inlet of this building can be more concentrated than in the suction into the hall 2.

Conclusions

1. The results of measurements in poultry houses show that it is necessary to pay the attention to the problems of position of the buildings in the locality area surrounding, winds and inclination of the surface.
2. The poultry houses are characterized by huge ventilation rates, therefore, it is necessary to strictly separate the areas of air inlets (suction of fresh air) and outlets (discharged of polluted air).
3. The dust removal efficiency by ventilation is more efficient in the case of smaller particles.
4. The suitable location of air outlets should prevent undesired recirculation of exhaust air from the house.
5. The most suitable dissipation zone of polluted air seems to be the outlet above the building.

References

1. Kic P., Hubený, M., Ledvinka Z., Tůmová E., Campos C.G., Martínez C.T. Control of indoor environment in housing of laying hens. Proceedings of International conference Trends in Agricultural Engineering, 2007, CULS, Prague, pp. 212-214.
2. Kic P., Růžek L., Ledvinka Z., Zita L., Gardiánová I. Pollution of indoor environment in poultry housing. Proceedings of International conference 11th International Scientific Conference Engineering for Rural Development. Latvia University of Agriculture, 2012, Jelgava, pp. 480-483.
3. Aarnink A.J.A., Van Harn J., Winkel A., De Buisonje F.E., Van Hattum T.G., Ogink N.W.M. Spraying rapeseed oil reduces dust in poultry houses. Proceedings of International conference Precision Livestock Farming 2009, 4th European Conference on Precision Livestock Farming, ECPLF, 2009, Elsevier, Wageningen, pp. 73-79.
4. Šottník J. Principles and experience of heat stress reduction in buildings for housing of animals. Proceedings of International conference Trends in Agricultural Engineering, 2007, CULS, Prague, pp. 441-446.
5. Zajíček M., Kic P. Longitudinal ventilation of broiler house – simulation of variants. Proceedings of International conference 12th International Scientific Conference Engineering for Rural Development, 2013, Latvia University of Agriculture, Jelgava, pp. 198-202.
6. Kic P., Kalvoda M., Zavadil V. Energy savings by heat recovery in ventilation. Proceedings of International conference Trends in Agricultural Engineering, 2007, CULS, Prague, pp. 215-218.
7. How are particulates deposited in the lungs? What are the factors influencing where particulates are deposited? [online][15.12.2015] Available at: http://www.ccohs.ca/oshanswers/chemicals/how_do.html
8. What are the diseases of dusty operations? What are the reactions of the lungs to dust? [online][15.12.2015] Available at: http://www.ccohs.ca/oshanswers/chemicals/lungs_dust.html
9. Sethi R.S., Schneberger D., Singh B. Characterization of the lung epithelium of wild-type and TLR9-/- mice after single and repeated exposures to chicken barn air. Experimental and Toxicologic Pathology, vol. 65 (4), 2013, pp. 357-364.
10. Viegas S., Mateus V., Almeida-Silva M., Carolino E., Viegas C. Occupational exposure to particulate matter and respiratory symptoms in Portuguese swine barn workers. Journal of Toxicology and Environmental Health, vol. 76 (17), 2013, pp. 1007-1014.
11. Liška R., Kic P. Drying process of poultry manure at various temperatures. Proceedings of International conference Trends in Agricultural Engineering, 2010, CULS, Prague, pp. 398-400.
12. Liška R., Kic P. Characteristics of drying process of poultry manure at various temperatures. Scientia Agriculturae Bohemica, vol. 42 (2), 2011, pp. 79-86.
13. Gűrdil G.A.K., Kic P., Dağtekin M., Yıldız Y. The determination of ventilation rates in poultry houses. Journal of Agricultural Faculty, vol. 16 (3), 2001, pp. 61-68. (In Turkish).
14. Mistriotis A., De Jong T., Wagemans M.J.M., Bot G.P.A. Computational Fluid Dynamics (CFD) as a tool for the analysis of ventilation and indoor microclimate in agricultural buildings. Netherlands Journal of Agricultural Science, vol. 45 (1), 1997, pp. 81-96.
15. Mutai E.B.K., Otieno P.O., Gitau A.N., Mbuge D.O., Mutuli D.A. Simulation of the microclimate in poultry structures in Kenya. Research Journal of Applied Sciences, Engineering and Technology, vol. 3 (7), 2011, pp. 579-588.
16. Zajíček M., Kic P. Improvement of the broiler house ventilation using the CFD simulation. Agronomy Research, vol. 10 (1), 2012, pp. 235-242.
17. Zajíček M., Kic P. CFD Analysis of Broiler House Ventilation Patterns with Respect to the Poultry Welfare. Proceedings of International conference The sixth international scientific conference Rural Development, 2013, Aleksandras Stulginskis University Akademia, Kaunas, pp. 151-156.
18. Zajíček M., Kic P. Simulation of Broiler House Ventilation. Scientia Agriculturae Bohemica, vol. 44 (1), 2013, pp. 32-37.
19. Act Government Regulation No. 361/2007 Coll. Laying down the conditions for the protection of health at work. Changes: 9/2013 Coll. (in Czech).
20. Act No. 201/2012 Coll. Air Protection Act. (in Czech).