Polish J. of Environ. Stud. Vol. 19, No. 1 (2010), 15-19

Mini Review

Microbiological Air Contamination in Poultry Houses

Elżbieta Lonc*, Kinga Plewa

Institute of Genetics and Microbiology, Departament of Microbial Ecology and Environmental Protection, University of Wrocław, Przybyszewskiego 63, 51-148 Wrocław, Poland

Received: 2 February 2009
Accepted: 11 August 2009

Abstract

Since intensive poultry production is accompanied by as high as possible densities of birds within buildings, this exposes poultry house workers to elevated concentrations of bioaerosol that is mainly emitted by birds. Exposure to dust containing pathogenic microbial and parasitic agents may cause asthma, asthma-like syndrome, mucous membrane irritation, chronic bronchitis, and allergic alveolitis organic dust toxic syndrome, as well as chronic obstructive pulmonary diseases. Since the microbial air pollution data base of poultry houses is insufficient at present, and poultry production is increasingly widespread, it is important to collect, compare and update the available data.

Keywords: airborne bacteria, airborne fungi, airborne microorganisms, bioaerosol in poultry farming, poultry house

Introduction

In recent decades, intensive poultry production has become more common in many countries, including the Netherlands, Denmark, France, USA, Canada, China, and more recently, Poland. Such production that deals with large densities of animals in small areas is a significant source of microbial air contamination that may constitute a considerable risk to human health [1-5]. It has been proven that exposure to organic dust may exacerbate asthma, asthma-like syndrome, mucous membrane irritation and chronic bronchitis. Inhalation of noninfectious microorganisms and their components may cause inflammation of the respiratory system, while antigens and allergens may activate the immune system and cause allergies. Firstly, this is a health hazard to poultry house workers and rural residents living in close proximity to the farms. Secondly, this dust may also transfer different microorganisms from one livestock building to another, or from a livestock building to a farmhouse and nearby houses [6-12].

*e-mail: lonc@microb.uni.wroc.pl

Health Hazards

It is known that air in poultry houses is polluted with large quantities of different microbial components and metabolites, i.e. aggregation of bacterial and fungal cells, endotoxin (lipopolysaccharide, LPS) of Gram-negative bacteria, 1,3-beta-glucan of fungi, fungal spores and fragments of mycelium [13-16]. They are suspended as bioaerosols and can occur as liquid droplets or as dry particles. This bioaerosol may contain representatives of bacterial genera: *Pseudomonas, Bacillus, Corynebacterium, Pasteurella, Vibrio, Enterobacter, Salmonella, Brucella, Leptospira, Haemophilus, Mycoplasma, Yersinia, Staphyloccocus, Streptococcus, Micrococcus, Pantoea,* and *Sarcina* [2]. Bacteria in poultry dust bioaerosols may be derived from soil, feed, bedding and from the birds themselves (faecal or skin microflora). Their presence in large numbers may represent a significant immunological challenge to the human respiratory system. Bacteria are classified according to their cell wall components and cell shape. Gram-positive bacteria have a thicker cell wall and are generally more robust and therefore capable of surviving

longer in bioaerosols. On the other hand, Gram-negative bacteria are mainly rod shaped, less robust and capable of surviving for limited periods in bioaerosols [17]. According to Crook, endotoxins are also present in poultry dust samples collected at all stages of the poultry production cycle. The term endotoxins found in literature means the definition of lipopolisaccharide complex (LPS) related to the outer membrane of Gram-negative bacteria. LPS is composed of two major parts, the hydrophobic lipid A and the hydrophilic polysaccharide part (commonly called the "O" region). Most biological effects of LPS are due to the lipid A part, but the O-region plays an important role in effective colonization of host tissues. Inhalation of organic dust contaminated by endotoxin may cause chronic bronchitis and inflammatory reaction in the lungs [17-19]. Due to its proinflammatory properties, high endotoxin exposure is considered to be associated with acute inflammatory processes that are known as ODTS (organic dust toxic syndrome) as well as chronic obstructive pulmonary diseases (COPD) and asthma-like syndrome. Such diseases are common in poultry workers [20].

Numerous fungal spores, because of their dimensions (several micrometers) are classed as a bioaerosol. They are always observed in the atmosphere and their concentration changes depending on environmental conditions [21]. Like bacteria the fungi (e.g. *Stachybotrys chartarum, Alternaria alternata, Aspergillus fumigatus, Cladosporium herbarum, Fusarium sp., Penicillium* sp., *Rhizopus* sp., *Mucor* sp., *Trichoderma* sp., and *Trichothecium* sp.) may be derived from soil, dust, feed and bedding, but to a lesser extent from the birds themselves. According to Crook, long-term or repeated exposure to high concentrations of airborne fungal spores in a range of agricultural environments is recognized as contributing to a decline in lung function and allergic reactions such as asthma and allergic alveolitis known as farmer's lung disease [20]. Despite their occurrence at high concentrations in the air, fungal spores have not been subject to any detailed or ongoing studies. In Europe, including Poland, only a few laboratories conduct aeropalynological and aeromycological analyses. Difficulties in identification of spores and different investigation methods limit the knowledge of their occurrence in the air [21]. Another biological potent agent is 1,3-beta-glucans in the cell walls of fungi. Beta (1→3)-glucan have proinflammatory properties that have been suggested to play a role in indoor-related respiratory health effects [22, 23].

It is worth mentioning the role of parasites as part of biological air pollution. Poultry dust mites are the best known allergens that have a direct link to allergy and asthma. Mites belong to acarids and the most common species in poultry houses are *Dermanyssus galline, Ornithonyssus sylvarium, Dermatophagoides farinae, Dermatophagoides pteronyssinus, Knemidocoptes mutans* and *Acarus siro* [24, 25]. Some of these, as well as poultry lice (*Mallophaga*), are reported as pathogenic vector agents in parasitological textbooks [25, 26].

Microbiological Air Contaminations in Poultry Houses in Poland and Other Countries

Only the last decade has brought a significant increase in the worldwide scientific database on air contaminations in poultry houses and other environmental farming [7, 13, 14, 19, 27-32]. According to these studies, for example, the number of airborne bacteria in animal houses ranges from 10^3 to 10^9 cfu/m^3 and the concentrations of airborne fungi from 2.5×10^1 to 4.9×10^6 cfu/m^3 [21]. Development of new sampling techniques and analytical methods as well as advances in human exposure determinations have also allowed more precise identification of the sources and contents of microbial contaminations and an assessment of their potential biohazard. In Poland, Kurnatowska lists several dozen pathogens present in the atmosphere as well in the hydrosphere and lithosphere (Table 1), some of which are present in the air in poultry houses [33, 34]. In the mid-1980s Dutkiewicz and co-workers were the first to investigate air contamination in different agricultural buildings for vegetable and animal production (e.g. poultry breeding, cowsheds, facilities for storing grain) located in Eastern Poland. From the bacteria found in the air of the farm environment a few dominant groups were more prominent. Three of them were Gram positive (cocci, spore-forming bacilli and corynebacteria) and one was Gram negative rods. These, together with actinomycetes and fungi of the family *Aspergillaceae*, are known as the most dangerous groups of microorganisms that may cause occupational respiratory diseases in farmers [13]. Air quality of Polish farms has been described by Karwowska. Air sampling was carried out in different farms (poultry houses, cow shed and pigsty) in rural areas in Podlasie. Tests were done using the modern sampling equipment MAS-100 air sampler based on the Anderson Impaction Principle accepted and proven worldwide. According to the author, the number of microorganisms (as cfu/m^3) in poultry houses ranged within: 1.7×10^3 - 8.8×10^3 for mesophilic bacteria; 3.5×10^1 - 8.3×10^2 for hemolytic bacteria; 1.5×10^3 - 4.6×10^4 for staphylococci; 5.0×10^0 - 2.0×10^2 for coli-group bacteria and 1.7×10^2 - 2.4×10^4 for fungi of the genus *Aspergillus* (*A. niger, A. nidulans. A. ochraceus*), *Penicillium notatum, Penicillium sp., Cladosporium sp.* and *Alternaria sp*. The presence of high numbers of potentially pathogenic staphylococci was emphasized as a negative phenomenon. Moreover, the majority of these identified fungal species are described as potential allergens and exposure to their spores may provoke immune responses in susceptible individuals. As a result, diseases such as allergic rhinitis, bronchial asthma or extrinsic allergic alveolitis may develop in certain individuals [27].

In Lithuania, Lugauskas detected thirty-one species representing 13 fungal genera in poultry house air. Six species of the genus *Aspergillus* were isolated and identified; among them *Aspergillus oryzae* and *A. nidulans* prevailed and comprised 15.1% and 9.7% of all the identified isolates, respectively. Fungi of the genus *Penicillium* were represented by 12 species, with predominance of *Penicillium*

Table 1. Lists of bacteria pathogenic to humans and transmitted in the air according to Kurnatowska [33].

Bacteria species	
*Staphylococcus aureus** [13]	*R. typhi*
S. haemolitycus	*R. quintana*
*S. epidermidis**[13]	*Coxiella burnetii*
Streptococcus pyogenes	*Escherichia coli** [13, 29, 32]
S. pneumoniae	*Shigella sonnei*
*S. faecalis** [13]	*S. dysenteriae*
Haemophilus influenzae	*Citrobacter sp.** [13]
Pasteurella pneumotrica	*Salmonella typhi*
P. multocida	*S. paratyphi*
Legionella pneumophila	*S. typhimurium*
Mycobacterium tuberculosis	*S. enteritidis*
M. bovis	*S. hirschfeldii*
M. pneumoniae	*Klebsiella pneumoniae** [29]
M. urealitycum	*E. aerogenes*
Bordetella pertussis	*E. cloacae*
Franciscella tularensis	*Proteus mirabilis*
Corynebacterium diphteriae	*P. vulgaris*
*Pseudomonas sp.** [13, 29]	*Proteus sp.** [13]
Pseudomonas aeruginosa	*Morganella morgani*
Borellia reccurentis	*Yersinia enterocolitica*
B. burgdorferi	*Y. pestis*
Treponema pallidum	*Campylobacter jejuni*
Neisseria meningitidis	*C. coli*
N. gonorrhoae	*Bacillus anthracis** [13]
Chlamydia psittaci	*B. cereus** [13]
C. trachomatis	*Clostridium tetani*
Rickettsia provazekii	*C. perfringens*
Fungi species	
Absidia	*C. quilliermondii*
*Mucor** [27, 28]	*C. humicola*
*Rhizopus** [9, 27, 28]	*Cryptococcus neoformans*
*Aspergillus sp.** [9, 14, 29]	*Rhodotorula rubra*
A. fumigatus	*Histoplasma capsulatum*
A. flavus	*Blastomyces brasiliensis*
*A. niger** [27]	*B. dermatidis*
*Penicillium** [9, 27, 28]	*Sporotrichum schenckii*
*Scopulariopsis** [28]	*Geotrichum candidum*
Candida albicans	*Microsporum canis*
C. glabrata	*M. gypseum*
C. famata	*Trichophyton sp.** [28]
C. tropicalis	*T. mentagrophytes* [9]
C. psedotropicalis	*T. rubrum*
C. krusei	*T. terrestre*
C. pulcherrima	*T. tonsurans*
C. pseudotropicalis	*T. violaceum*
C. inconspicua	*T. ajjeloi*
C. quilliermondii	*T. schoenleinii*
C. humicola	*Alternaria** [27, 28]
C. inconspicua	*Cladosporium** [27, 28]

In parenthesis the literature sources confirming the presence of pathogens in the farming environment.

expansum, P. olivinoviride, P. claviforme and *P. viridicatum*. *Rhizopus oryzae, R. stolonifer* and *R. nodosus* - agents of zygomycosis were also isolated. Also keratinophylic fungus *Trichophyton mentagrophytes* causing dermatophytosis in farm workers was isolated from the poultry house air. The presence of opportunistic pathogens of the genus *Aspergillus* increases the risk of invasive aspergillosis in farm workers [9]. The air quality in some Swiss, Danish, German and Spanish farming objects has been described by Radon. According to that author, in Switzerland the total number of fungi in poultry houses ranged from 2.0×10^7 to 1.1×10^9 cfu/m^3; whereas the number of bacteria was higher and ranged within 4.7×10^9 to 4.2×10^{10} cfu/m^3 [14]. Air quality of Australian poultry buildings has been described by Agranovski et al. Their study showed the concentrations of bacteria ranged from 1.12×10^5 - 6.38×10^6 cfu/m^3. Approximately 85% of bacteria were Gram positive species and no thermophilic actinomycetes were detected. Concentrations of airborne fungi ranged from 4.4×10^3 - 6.2×10^5 cfu/m^3. Only the following genera were recorded: *Cladosporium, Aspergillus, Penicillium, Scopulariopsis, Fusarium, Epicoccum, Mucor, Trichophyton, Alternaria, Ulocladium, Basidiospores, Acremonium, Aureobasidium, Drechslera, Pithomyces, Crysosporium, Geomyces* and *Rhizomucor* [28]. Progress in diagnostic testing, especially in mycology, gives a chance for real health risk assessment because the application of molecular methods, such as PCR, offers a rapid route of diagnosis with increased sensitivity and specificity [35, 36].

A few authors have assessed the content of air pollution on poultry farms with regard to poultry age and productivity [29-31]. For example, Vucemilo et al. have found the concentration of airborne microorganisms in a poultry house to rise with poultry age. The highest bacterial concentrations of 6.40×10^6 cfu/m^3 in the air was found in five-week-old chickens. Microbial air contamination increases simultaneously with a fattening period. During the first fattening week concentration of bacteria was 2,998.3 cfu/m^3 with dominating species such as *Serratia ficaria, S. odorifera, S. plymuthica, S. amarescens, Pseudomonas sp., Pantoea sp.* and *Micrococcus sp*. Concentrations of fungi was 98.0 cfu/m^3 with dominating yeasts and *Mucor sp*. During the fifth fattening week they were 5,401.3 cfu/m^3 and 300.5 cfu/m^3 for bacteria (dominating species: *E. coli, Pantoea sp., Serratia plymuthic* and *S. amarescens*) and yeasts, respectively [30].

Summary

Poultry production methods have moved towards industrial large-scale production and studies have demonstrated that poultry workers are greatly exposed to bioaerosol. Farm workers and animals can be exposed to large quantities of dust microorganisms (bacteria and fungi) and parasites, which form a potential risk for diseases, mostly due to their immunomodulatory action. Studies of airborne microflora in poultry houses are still limited. The reasons are seen in the relatively high costs of

modern sampling equipment and still widespread use of old methods to evaluate microbiological air quality as well as in the very low number of institutions interested in environmental monitoring of air pollution.

The concentration of airborne microorganisms in poultry housing reported in literature varies greatly, which could in part be explained by different sampling methods used in different studies.

References

1. TOMBARKIEWICZ B., GRZYB J., PAW K., NIEDZIÓŁKA J., LIS M., NAJBOR I. Contaminations of air in the area of dairy cattle farm. Zesz. Nauk. AR Wroc. Zoot. **LI**, 331, **2004** [In Polish].
2. SIEMIŃSKI M. Environmental health threats. Wyd. Naukowe PWN. Warszawa. **2001** [In Polish].
3. BAROWICZ T. Livestock production and environmental protection. Wiad. Rol. **9**, 37, **2007** [In Polish].
4. TRAWIŃSKA B., POLONIS A., TYMCZYNA L., POPIOŁEK-PYRZ M., BOMBIK T., SABA L. Bacteriological and parasitologic pollution of the environment and birth health state around the reproductive layer farm. Ann. Univ. M. Curie-Skłodowska. Lublin-Polonia. **XXIV**, 1, **2006** [In Polish].
5. SCHULZE A., STRIEN R., EHREINSTEIN V., SCHIERL R., KŰCHENHOFF H., RADON K. Ambient endotoxin level in an area with intensive livestock production. Ann. Agric. Environ. Med. **13**, 87, **2006**.
6. MALMBERG P., RASK-ANDERSEN A. Natural and adaptive immune reactions to inhaled microorganisms in the lungs of farmers. Scand. J. Work. Environ. Health. **14**, 68, **1988**.
7. EDUARD W. Exposure to non-infectious microorganisms and endotoxins in agriculture. Ann. Agric. Environ. Med. **4**, 179, **1997**.
8. LACEY J., CROOK B. Review: Fungal and actinomycete spores as pollutants of the workplace and occupational allergens. Ann. Occup. Hyg. **32**, 515, **1988**.
9. LUGAUSKAS A., KRIKSTAPONIS A., SVEISTYTE L. Airborne fungi in industrial environments-potential agents of respiratory diseases. Ann. Agric. Environ. Med. **11**, 19, **2004**.
10. MATKOVIĆ K., VUČEMILO M., VINKOVIĆ B., ŠEOL B., PAVIČIĆ Ž., TOFANT A., MATKOVIĆ S. Effect of microclimate on bacterial count and airborne emission from dairy barns on the environment. Ann. Agric. Environ. Med. **13**, 349, **2006**.
11. HIRST J. M. Bioaerosols: Introduction, retrospect and prospect. In: Bioaerosol handbook. (Cox, C. S., C. M. Wathes, eds.). Lewis Publisher. New York, pp. 1-10, **1995**.
12. JACOBSON L. D., BICUDO J. R., SCHMIDT D. R., WOOD-GAY S., GATES R. S., HOFF S. J. Air emissions from animal production. Proceedings of the XIth International Congress in Animal Hygiene, 23-27 February. Mexico City, Mexico. CD-rom. **2003**.
13. DUTKIEWICZ J. Bacteria in farming environment. Eur. Respir. J. **154**, 71, **1987** [In Polish].
14. RADON K., DANUSER B., IVERSEN M., MONSO E., WEBER CH., HARTUNG J., PALMGREN U., NOWAK D. Air contaminants in different European farming environments. Ann. Agric. Environ. Med. **9**, 41, **2002**.
15. NEVALAINEN A. Bio-aerosols as exposure agents in indoor environments in relation to asthma and allergy. National Public Health Institute, Department of Environmental Health POB 95, FI-70701 Kuopio, Finland. **2007**.
16. STETZENBACH L. Airborne microorganisms. Harry Reid Center for Environment Studies-University of Nevada, Las Vegas. **1992**.
17. CROOK B., EASTERBROOK A., STAGG S. Exposure to dust and bioaerosols in poultry farming. Summary of observations and data. Prepared by the Health and Safety Laboratory for the Health and Safety Executive. **2008**.
18. POMORSKA D., LARSSON L., SKÓRSKA C., SITKOWSKA J., DUTKIEWICZ J. Levels of bacterial endotoxins in the samples of settled dust collected in animal houses. Bull. Vet. Inst. Puławy. **53**, 37, **2009**.
19. BAKUTIS B., MONSTVILIENE E., JANUSKEVICIENE G. Analyses of airborne contamination with bacteria, endotoxins and dust in livestock barns and poultry houses. Acta. Vet. Brno. **73**, 283, **2004**.
20. SCHIERL R., HEISE A., EGGER U., SCHNEIDER F., EICHELSER R., NESER S., NOWAK D. Endotoxin concentration in modern animal houses in southern Bavaria. Ann. Agric. Environ. Med. **14**, 129, **2007**.
21. KASPRZYK I. Aeromycology – main research fields of interest during the last 25 years. Ann. Agric. Environ. Med. **15**, 1, **2008** [In Polish].
22. RYLANDER R., CARVALHEIRO M. F. Airways inflammation among workers in poultry houses. Int. Arch. Occup. Environ. Health. **79**, 487, **2006**.
23. GEHRING U., DOUWES J., DOEKES G., KOCH A., BISCHOF W., FAHLBUSCH B., RICHTER K., WICHMANN H,E., HEINRICH J., HEINRICH J. (1→3)-Glucan in house dust of German homes: housing characteristics, occupant behavior, and relations with endotoxins, allergens, and molds. Environ. Health Persp. **2**, 139, **2001**.
24. FRANZ J., MASUCH G., MUSKEN H., BERGMANN K. Mite fauna of German farms. Allergy. **52**, 1233, **1997**.
25. MCREA B., JEFFREY J., ERNST R., GERRY A. Common lice and mites of poultry: identification and treatment. Agric. Nat. Res. pp. 1-7, **2005**.
26. LONC E., OKULEWICZ A. Parasitic diseases – parasitosis. In: Poultry Diseases (Mazurkiewicz M. Eds.). Wroclaw, pp. 472-491, **2005** [In Polish].
27. KARWOWSKA E. Microbiological air contamination in farming environment. Pol. J. Environ. Stud. **14**, 445, **2005** [In Polish].
28. AGRANOVSKI V., REPONEN T., RISTOVSKI. Survey of bioaerosol emissions from Australian poultry buildings. European Aerosol Conference. Salzburg, Abstract. **2007**.
29. VUČEMILO M., VINKOVIĆ B., TOFANT A., ŠIMPRAGA A., PAVIČIĆ Ž., MATKOVIĆ K. Microbiological air contamination in intensive poultry breeding. ISAH. Warsaw, Poland. **2**, 127, **2005**.
30. VUČEMILO M., VINKOVIĆ B., MATKOVIĆ K. Influence of broiler age on airborne pollutant content in poultry house. Krmiva. **48**, 3, **2006**.
31. VUČEMILO M., MATKOVIĆ K., VINKOVIĆ B., JAKŠIĆ S., GRANIĆ K., MAS N. The effect of animal age on air pollutant concentration in a broiler house. Czech. J. Anim. Sci. **52**, 170, **2007**.
32. NORTHCUTT J., JONES D., MUSGROVE M. Airborne microorganisms during the commercial production and processing of Japanese quail. Int. J. Pol. Sc. **3**, 242, **2004**.

33. KURNATOWSKA A. Rezervoirs of biological pathogenic agents in aerosphere, hydrosphere and lithosphere. In: KURNATOWSKA A. (Ed.). Ecology. Its connections with different scientific disciplines. Wyd. Naukowe PWN. **2002** [In Polish].
34. GÓRNY R., DUTKIEWICZ J. Bacterial and fungal aerosols in indoor environment in central and Eastern European countries. Ann. Agric. Environ. Med. **9**, 17, **2002** [In Polish].
35. KUBA K. Molecular and immunological methods applied in diagnosis of mycoses. Wiad. Parazyt. **54**, 187, **2008** [In Polish].
36. KURNATOWSKA A., KURNATOWSKI P. The diagnostic methods applied in mycology. Wiad. Parazyt. **54**, 177, **2008** [In Polish].