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Microclimatic conditions in the poultry houses

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Abstract. The aim of this paper is to present the results of microclimatic research focused on the indoor conditions in several agricultural buildings used for fattening of chicken broilers. The attention is paid mainly to the construction of the building and its position in the farm area, which together with technological equipment of the building, floor covering, and system of ventilation, can influence the microclimatic conditions inside the halls. In the frame of this research main parameters of internal and external properties of climate were measured and evaluated. The measurement results of the air temperature, humidity, globe temperature, concentration of CO_2, dust pollution and surface temperatures show rather important role of the overall layout of buildings, influence of the wind and solar radiation together with surroundings. The research results show that to the improvement of internal microclimate can contribute significantly the use of principles of passive air conditioning. The acquired new knowledge can be useful not only to improve the current situation on the farm, but mainly for the improvement of the building constructions in similar new farms.

Key words: air temperature, air pollution, solar radiation, passive air conditioning.

INTRODUCTION

Poultry housing technology, external climatic conditions and weather influence the indoor microclimate during different periods of the year, which needs different methods of ventilation control (Kic et al., 2007a; Kic et al., 2012). Creation of internal environment in the halls for poultry housing in summer 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 and high heat gains due to solar radiation. Problems occur particularly towards the end of fattening. Chickens have a large mass, they produce large quantities of pollutants (Aarnink et al., 2009; Kic & Růžek, 2014) and a lot of metabolic heat. Usually this problem is solved by intensive ventilation and sometimes by cooling of supplied air (Šottník, 2007; Zajíček & Kic, 2013a).

Technological equipment including the ventilation, heating and lightening is energy consuming which should be reduced by different approaches (Kic et al., 2007b; Rajaniemi & Ahokas, 2012). To improve microclimate conditions inside the buildings can help different methods for reduction of pollution (Kic & Liška, 2009; Liška & Kic, 2010; Liška & Kic, 2011), but for thermal state of the air the use of principles of so-called passive air conditioning systems that are energy-saving, could be useful like in the other buildings (Zajíček & Kic, 2014). Some of publications present the methods of calculation of main parameters of ventilation system (Gűrdil et al., 2001;) and simulation indoors conditions (Mistriotis et al., 1997; Mutai et al., 2011; Zajíček & Kic, 2012; Zajíček & Kic, 2013b; Zajíček & Kic, 2013c).

The aim of this paper is to show the measurement results of internal environment in poultry houses and verify the influences on the indoor climate of the halls in summer, particularly the possibility of influencing the inside thermal comfort with shading the buildings by surrounding vegetation and appropriate solution of the ventilation system.

MATERIALS AND METHODS

This research work and measurements were carried out in three buildings for fattening of broilers. All poultry houses are situated in one farm (Fig. 1), and they have the same internal dimensions: length 100 m, width 11.5 m, height 2.7 m, and inside each hall is housing of 23,000 chickens on the floor. The measurements were carried out during the 26^{th} to 33^{rd} days of fattening when the chicken have average weight about 1.5 kg.

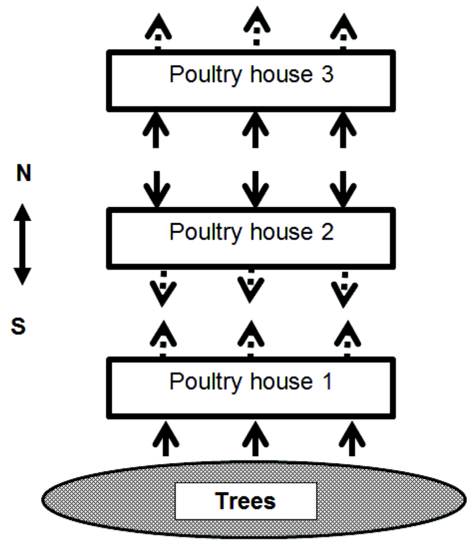

Figure 1. Ground plan of the poultry farm with three poultry houses, where N is the north; S is the south; → is the air inlet; and - - → is the air outlet.

Air temperatures and relative humidity were measured by data loggers ZTH65 outside and inside the poultry houses with registration at intervals of 15 minutes during one week (long-time measurement). Parameters of ZTH65 are: temperature operative range –30 to +70 °C with accuracy ± 0.4 °C and operative range of relative humidity 5–95% with accuracy ± 2.5%.

The thermal comfort in the space was continuously measured during the short-time experiments by globe temperature which includes the combined effect of radiation, air temperature and air velocity (measured by globe thermometer FPA 805 GTS with operative range from –50 to +200 °C with accuracy ± 0.1 °C and diameter of 0.15 m) together with temperature and humidity of surrounding air measured by sensor FHA

646–21 including temperature sensor NTC type N with operative range from –30 to +100 °C with accuracy ±0.1 °C, and air humidity by capacitive sensor with operative range from 5 to 98% with accuracy ±2%. Furthermore the concentration of CO_2 was measured by the sensor FY A600 with operative range 0–0.5% and accuracy ± 0.01%. All these data were measured continuously in the poultry houses 1 and 2 as well as outdoor in the installed meteorological station and stored at intervals of one minute to measuring instrument ALMEMO 2590–9, ALMEMO 2690–8 and ALMEMO 5990–2 during approximately five hours (short-time measurement).

The surface temperatures outside and inside the poultry houses were measured by thermographic camera IR Flexcam Pro with operative range from –30 to + 350 °C with accuracy ± 2 °C. Instantaneous values of surface temperatures (thermograms) were stored in the device memory and then analysed in a PC using a special software Infrared Solutions FlexView 1.2.2 designed for this thermographic camera.

The concentration of air dust was measured by special exact instrument Dust-Track aerosol monitor. After the installation of impactors the PM_{10} and PM_1 size fractions of dust were measured and compared in all three poultry houses. The 90 data of dust concentration PM_{10} and PM_1 size fractions in each building were collected. The position of measuring instrument was usually at 30 cm above the floor.

RESULTS AND DISCUSSION

The main objective of this article is a presentation of results of measurement of main microclimatic parameters in poultry houses, a comparison of obtained results with values recommended in relevant standards, and an analysis if the use of principles of passive air conditioning can contribute to the improvement of internal microclimate.

The results of long-time measurement of temperature and relative humidity of the air in three poultry houses are presented in Table 1. The results of this measurement show that the most favourable conditions in terms of air temperature in summer are in the poultry house 1 with an average temperature of 28.7 °C.

Table 1. Average values and standard deviation of the air temperature t and relative humidity RH in three poultry houses and outside in meteorological station during the long-time measurements

Place of measurement	t	RH
-	°C ± SD	% ± SD
External	21.6 ± 3.1	72.7 ± 13.5
House 1	28.7 ± 0.9	66.2 ± 1.8
House 2	30.9 ± 1.0	57.3 ± 3.2
House 3	32.5 ± 1.2	46.4 ± 3.5

SD – Standard deviation

The air temperature in this hall was during the whole measured period lower than in the other two halls (the average temperature in the house 2 was 30.9 °C and in house 3 was 32.5 °C). The optimal temperature for chickens during the period 4th to 6th week of fattening is usually recommended between 19 to 22 °C, which has not been reached in this period even during the cooler outdoor air in the night. The course of the air temperature and relative humidity of air during the whole long-time measurement is in Figs 2 and 3.

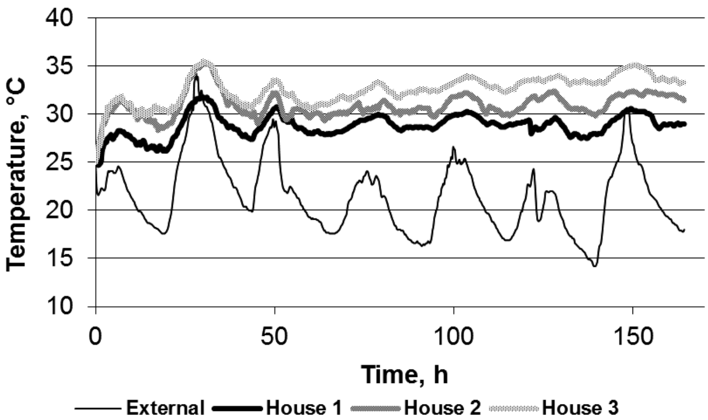

Figure 2. The course of the air temperature outside and inside the poultry houses 1, 2 and 3.

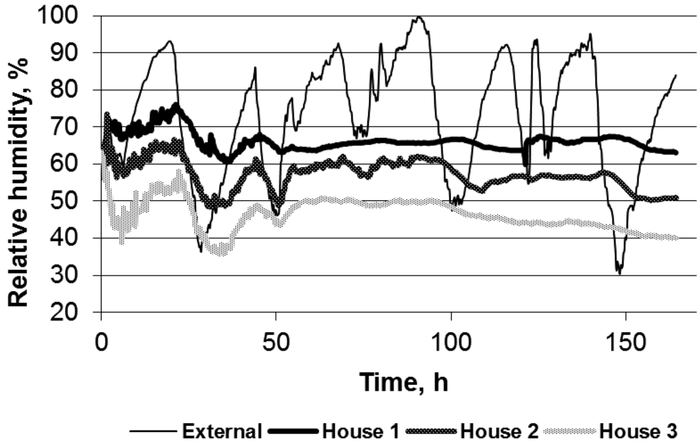

Figure 3. The course of the air relative humidity outside and inside the poultry houses 1, 2 and 3.

The courses of relative humidity correspond to the internal conditions in halls and to the changes in external and internal environment. As in other farms with similar technological equipment, the air moisture does not cause major problems in terms of microclimatic comfort. Recommended maximum relative humidity 70% was exceeded only in exceptional cases and for a short time in the house 1.

Average values and standard deviation of the globe temperature, internal air temperature, relative humidity and concentration of CO_2 in poultry house 1 and 2 during the short-time measurements are presented in Table 2. The results of short-time measurements in houses 1 and 2 confirm the results of long-time measurements. There is a very positive effect that the fresh air sucked into house 1, is from the cold zone near the house 1, which is shaded by trees. Therefore it is cold and fresh air, although it is on the south side of the hall. This also reflects a greater difference between the average globe temperature and the average air temperature in the house 1 than in the house 2.

Table 2. Average values and standard deviation of globe temperature t_g, air temperature t, relative humidity RH and concentration of CO_2 in two poultry houses and outside in meteorological station during the short-time measurements

Place of measurement	t_g	t	RH	CO_2
-	°C ± SD	°C ± SD	% ± SD	% ± SD
External	-	24.2 ± 1.2	59.4 ± 2.8	0.033 ± 0.000
House 1	25.1 ± 0.9	24.7 ± 0.1	63.1 ± 1.5	0.044 ± 0.006
House 2	25.3 ± 0.6	25.3 ± 0.7	62.8 ± 1.2	0.060 ± 0.020

SD – Standard deviation

From the measurement results it is evident the positive effect of suction of fresh air from the cold shaded part of the farm. To maintain better thermal comfort inside the house 1 significantly contributes partial shading by trees on the south walls and also partly shading the roof of this building. This contributes to reduce the impact of solar radiation on the indoor thermal comfort and reduce the inside temperature during the highest external temperatures. The comparison of the surface temperatures of terrain near air inlets measured by thermographic camera is summarized in Table 3.

Table 3. Surface temperatures of the soil (terrain) in the place of the fans suction into the poultry houses 1, 2 and 3

Suction area of	House 1	House 2	House 3
-	°C ± SD	°C ± SD	°C ± SD
Average temperature	23.29 ± 0.38	29.45 ± 1.60	29.52 ± 1.19

SD – Standard deviation

The worst conditions in terms of the air temperature are in the poultry house 3. This is mainly due to the fact that the air is sucked from the middle part of a farm, from the south side of the house 3 which is not overshadowed and therefore the supplied air has a higher temperature than the air supplied into the house 1 or 2. Ventilation air which is supplied into the hall 2 is also sucked from the middle of the farm, but is drawn from the north side, partially shaded by the hall 2. Therefore, the temperature in the house 2 is higher than in the house 1, but lower than in the house 3. Therefore it can be said that even in this case, shading of buildings helps to improve indoor thermal comfort of the internal microclimate.

The thermograms of the surface areas inside the poultry houses 1 and 2 are shown in Fig. 4. The results of surface areas of chickens on the floor, south wall, north wall and ceiling selected from thermograms in Fig. 4 are summarised in Table 4. There is obvious lower temperature of surrounding surfaces in the house 1 than in the house 2. Thanks mainly to the lower temperature of the inlet air and the surface areas inside the building also the average surface temperature of the chickens on the floor in the house 1 (33.39 ± 1.40) is lower than in the house 2 (34.15 ± 1.57).

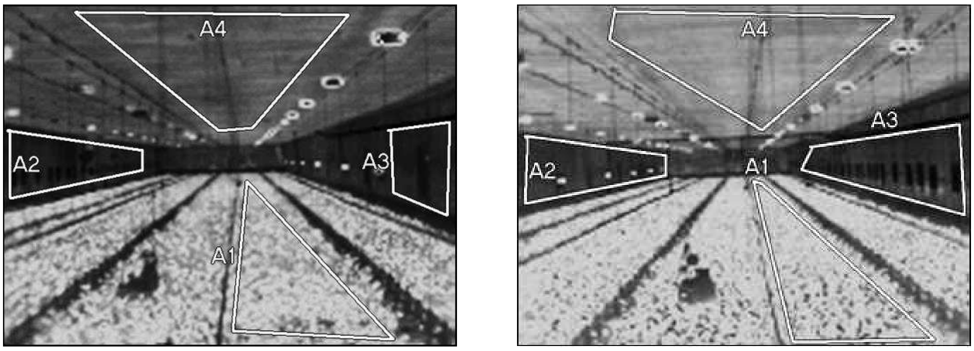

Figure 4. The thermograms of the surface areas inside the poultry house 1 (left) and 2 (right). Where A1 is the evaluated surface area of the chickens on the floor; A2 is the south wall; A3 is the north wall; A4 is the ceiling.

Table 4. Average surface temperatures inside the poultry houses evaluated from the thermograms according to the Fig.4

Surface	Area	House 1	House 2
-	–	°C ± SD	°C ± SD
Chickens on the floor	A1	33.39 ± 1.40	34.15 ± 1.57
South wall	A2	27.57 ± 0.60	28.08 ± 0.69
North wall	A3	27.73 ± 0.41	27.73 ± 0.70
Ceiling	A4	29.31 ± 0.64	30.58 ± 0.38

SD – Standard deviation

The results of measurement of the CO_2 concentration in houses 1 and 2 (Table 2) are quite surprising. The recommended maximum concentration of 0.25% was not exceeded in any house, but this was measured in the summer season with a maximum flow of ventilation air. Surprising is the difference between the CO_2 concentration measured in these two buildings. This can be explained partly by the fact that chickens produce more CO_2 in the house 2 due to the stress from higher temperatures and generally less favourable microclimate conditions.

Furthermore, lower average CO_2 concentrations in house 1 can be due to the fact that the air is sucked into the hall clean and colder from the area of surrounding trees and fields. Houses 2 and 3 have a common zone from which the air is supplied into the halls. Therefore, the higher average concentration of CO_2 in house 2 can be explained partly by the fact that this suction zone of air is in the centre part of the farm. This area is partly influenced by the overall environment of farms, and exhausted air from outlets of poultry houses could be partly sucked by inlets again into the houses 2 and 3.

These conclusions correspond with the results of dust measurements (Fig. 5 and 6). Concentrations of PM_{10} and PM_1 size fractions of dust were the lowest in the house 1 and the biggest in the house 3. From the viewpoint of dust pollution, the problems of the hall 2 and hall 3 can be explained also by the outside recirculation of air which is partly contaminated by dust particles.

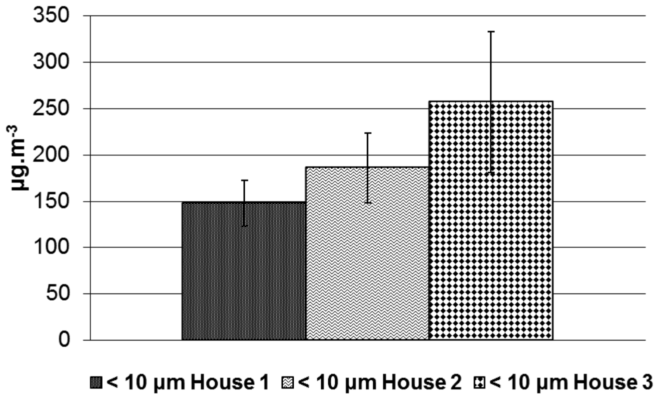

Figure 5. Concentrations of measured dust fraction PM_{10} inside the poultry houses 1, 2 and 3.

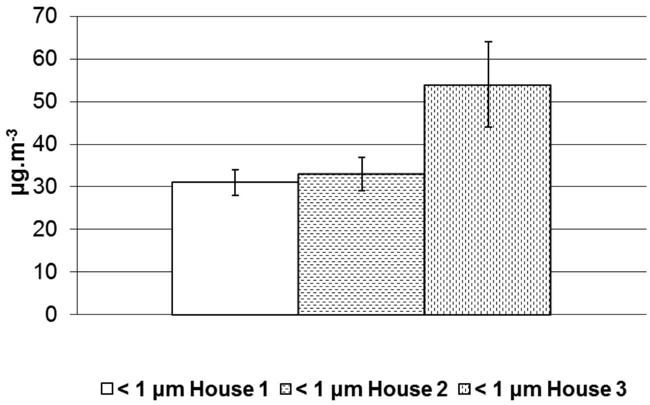

Figure 6. Concentrations of measured dust fraction PM_1 inside the poultry houses 1, 2 and 3.

CONCLUSIONS

The results of measurements in the poultry houses showed that principles of passive air conditioning can contribute significantly to the improvement of internal microclimate, especially:

- high trees growing around the poultry houses significantly reduce external heat load of construction, reduce heat gains and improve the summer heat balance of the building,
- air intake from the places protected from direct sunlight e.g. by shading trees significantly reduces the temperature of the inlet air to the hall and contribute to the thermal comfort in the building during the summer months,

- regarding to the orientation of building, the best solution is to situate the air inlets on the north side of the building, because the assumption is that it will be sucked cold air into the hall in summer,
- a significant effect on air cleanliness in terms of gaseous pollutants and dust has the air intake from areas protected against external pollution,
- a suitable location of air outlets should prevent undesired recirculation of exhaust air from the poultry house.

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