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AIR IONIZATION IN LIVESTOCK BUILDINGS – A REVIEW*

Eugeniusz Herbut, Ewa Sosnówka-Czajka, Iwona Skomorucha

Department of Poultry Breeding, National Research Institute of Animal Production,
32-083 Balice n. Kraków, Poland
Corresponding author: ewa.sosnowka@izoo.krakow.pl

Abstract

Research has shown that microclimate is determined not only by air microparticles, but also by the degree of air ionization. Ions affect the body through the respiratory tract and skin. Exposure of reared chickens to elevated air temperature (37°C–23°C) was found to accelerate the breakdown of negative ions compared to temperature lower by 10°C. Negative air ionization offsets the adverse effect of elevated temperature on chickens. Higher (85%) air humidity during rearing of chickens was also observed to destroy negative ions. Research findings indicate that air ionization is an environmental element that contributes to improving performance in broiler chickens. Many studies have also confirmed a positive effect of air ionization on the body weight and health of piglets.

Key words: air ionization, temperature, air humidity, health, productivity, poultry, pigs

Air ionization is caused by the electromagnetic interaction of two particles, as a result of which one particle gains energy sufficient to release an electron. The electron released by ionization combines in a very short time with an electrically neutral particle to form a negative ion, or with a positively charged particle to neutralize its charge (Kolarž et al., 2012; Pająk, 2012; Wiszniewski and Suchanowski, 2008). Electric discharges that occur during a thunderstorm as lightning produce a high concentration of negative ions, at first depolarizing the particles and later charging them negatively. In nature, this process is not only associated with electric discharges but occurs continuously as a result of alpha and beta radiation, X-ray radiation, or cosmic radiation. It also occurs as a result of much less energetic ultraviolet radiation, and even wind, friction, and rapid swirling of water droplets, e.g. in waterfalls (Kolarž et al., 2012). In the lower and medium atmosphere, ions move in response to variable electric fields. Moving ions collide with neutrally charged particles, which

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inhibit their movement. The ability of ions to move in a neutral particle environment is known as mobility (μ) and depends on ionic mass and charge, density of neutral particles, humidity, and temperature (Goel et al., 2005). Ionized particles are classified depending on their mobility as small ($\mu > 0.01 cm^2/V \cdot s$) and large ($\mu < 0.01 cm^2/V \cdot s$) (Wiszniewski et al., 2014). According to the current state of knowledge, only small air ions have a considerable effect on living organisms, and their optimal concentration in the human environment (according to standard PN-80/Z-08052) should be 3000–5000/cm^3 for negative ions and 1500–3000/cm^3 for positive ions. To date, no recommended standards for the concentration of negative ions have been proposed for different livestock species, although the concentration of negative ions in large-scale commercial farms is known to fall dramatically, especially in closed buildings. Ionic concentration is subject to regular daily and annual changes. By way of example, in the daily cycle increased concentration of small ions usually occurs in the afternoon, and during the year in the summer months (Skromulis and Noviks, 2012). Changes in meteorological conditions have significant consequences for the concentration of ions. On cloudy days, this is generally lower than on sunny days. Rain and atmospheric discharges increase the proportion of small ions, both positive and negative. The number of negative ions in empty rooms with natural ventilation does not differ significantly from that outside the building. When the rooms are used, the concentration of negative ions markedly falls. The extent of change also depends on the number of users and the type of pollutants, e.g. toxic gases and dust (Asaj, 1987; Gast et al., 1999; Hagen, 2012; Moga and Małecka, 2011; Mitchell et al., 2000). The application of electrostatic particle ionization (EPI) technology is efficient in reducing pathogens in pigs, such as influenza A virus (IAV), porcine reproductive and respiratory syndrome virus (PRRSV), porcine epidemic diarrhea virus (PEDV) and *Staphylococcus aureus* (Alonso et al., 2016) as well as reducing pathogenic microflora in poultry buildings (Banhazi et al., 2018).

Therefore, the aim of this study was to review the effect of negative air ionization on organisms and the environment, as well as the effect of thermal and humidity conditions on the concentration of negative ions in animal houses.

Effect of negative air ionization on the animal organism

In the present housing systems of animals, including poultry, in particular chickens for fattening, high production levels are possible only when they are provided with appropriate microclimate conditions, especially in the initial period of rearing. Research has shown that microclimate is determined not only by microparticles in the air, but also the degree of its ionization (Arnold, 2004; Herbut et al., 1995; Janowski et al., 1989; Kellog, 1984; Nizioł, 1987).

Ions affect the body through the respiratory tract and skin. Different authors provide a growing body of evidence that negative ions have a positive effect on the animal organism (Asaj, 1987; Iwama, 2004; Krueger, 1985; Laza and Bolboacă, 2008; Lenkiewicz et al., 1989). Herbut et al. (1995) observed both the haematocrit and haemoglobin levels to be higher in chickens housed in facilities with air ionization, but the sex of the birds did not play an important role. Khrenov (1987) found air ionization to positively influence the cow's organism, productivity and reproduction.

The same author also showed improvements in haematological parameters based on increased erythrocyte count and haemoglobin content. The body's overall immunity improved as a result of higher phagocytic activity of neutrophils and lysozyme activity of blood serum. Poultry research showed that negative air ionization has a beneficial effect on almost all functions of the studied birds (Lenkiewicz et al., 1989). Asaj (1987) reported 9.8% better feed conversion in broiler chickens in response to negative air ionization. In turn, Herbut et al. (1995) do not seem to support this observation. They observed that chickens, and especially cockerels, reached higher body weights when exposed to ionized air. This could possibly be associated with better cardiovascular function and air exchange as a result of higher haematocrit and haemoglobin levels. The above chickens were also characterized by better survival. Thus, Herbut et al. (1995) demonstrated that negative air ionization prevents the sudden death syndrome, and consequently reduces rearing losses in chickens for fattening. Based on dissection analysis, this factor was also found to reduce carcass fatness. However, Cambra-López et al. (2009) concluded that air ionization had no significant effect on broiler chicken performance, ammonia levels, emission of odours, and broiler house microorganisms. In turn, Patil et al. (2014) established that negative air ionization in the second period of incubation has a beneficial effect on hatchability of chickens. Laza and Lotrean (2009) investigated the impact of ionization on living organisms through experiments with chick embryos and laboratory animals. They observed that negative air ions have a normalization effect, facilitating a return to the normal haematological parameters or histological structure of modified organs. According to Laza and Bolboacă (2008), ionization has either a positive or a negative effect on hatchability and embryonic development depending on the duration and intensity of negatively charged air. With long-term use, moderate concentrations can be detrimental to development, although short exposure has beneficial effects. Large doses have a bipolar action depending on the period of development when they are applied (Laza, 2010).

Air ionization may be an environmental element that contributes to improving performance in housed animals. According to Ritz et al. (2006), the effect of ionized air on the animal's body depends on the size, polarity and concentration of ions in air, and also on the physicochemical properties of ion carriers. Negative ions in air accelerate biological reactions in the body, which improves the well-being of both humans and animals. In a study with piglets, Hagen (2012) reported that daily weight gain changed considerably (by 12.2%) to the advantage of animals exposed to ionized air compared to control animals. Ionization also had a positive influence on the weaning weight of the piglets, which increased by 9.3%. Piglet health improved, translating into 2.61% lower mortality.

In addition, negative air ionization improves microclimate conditions in livestock buildings, which translates directly into improved health and productivity of farm animals. Mitchell et al. (2004) demonstrated that the electrostatic space charge system (ESCS) based on negatively charged air reduced the concentration of airborne dust by an average of 61%, ammonia by an average of 56%, and airborne bacteria by 67% in poultry houses. In turn, the use of electrostatic particle ionization (EPI) by Rademacher et al. (2012), in addition to more favourable rearing performance of the piglets (up to day 45), caused a significant reduction in the concentration of gases (mainly hydrogen sulphide) and a reduction in the concentration of dust particulate matter. Meanwhile, Richardson et al. (2003) found no effect of negative air ionization on laying performance, mortality, reproductive ability, and body weight of hens and roosters. However, the same authors showed that air ionization reduces by 61% the concentration of airborne dust, which is an excellent vector for horizontal disease transmission. The reduction in airborne dust decreased the level of total airborne bacteria by 76% and Gram-negative bacteria by 48%. Furthermore, Gram-negative bacteria were reduced by 63% on the egg collection belts, which resulted in a 28% reduction of Gram-negative bacteria on the eggshell surface. Positive effects of air ionization were also noted by Hagbom et al. (2015) in a facility for laboratory animals. The negative ions produced by the ionizer effectively removed airborne influenza A virus (strain Panama 99), which protected all of the laboratory guinea pigs from infection. However, according to Bailey et al. (2018), data collected from the experimental research provide no conclusive evidence for either a positive or a negative effect of positive and negative air ions on the health and behaviour of laboratory animals exposed to these ions.

Effect of thermal conditions on air ionization

Livestock buildings should be autonomous enough to ensure an optimal and stable microclimate, including thermal conditions. These have an effect not only on the comfort of the animals, but also on the concentration of ions. Herbut et al. (1997 b) observed that air ionization applied during the rearing of chickens in a house with temperature decreased by 10°C caused the concentration of negative ions to increase by around 50% compared to a house with elevated air temperature (37°C–23°C). This shows that elevated air temperature is a factor that adversely affects the concentration of negative ions. This information is crucial for keeping the physical environment of the air properly ionized. The higher the temperature in a livestock building, the shorter the life, and thus the lower the concentration of negative ions. If so, this means a less positive impact on the well-being and health of animals (Wakamura et al., 2004).

According to Walczak and Herbut (2000), out of all microclimate conditions, ambient temperature has the most significant impact on production. The effect of temperature, as a result of the changes in metabolic rate, is reflected in the amount of heat exchanged between the animal and the surroundings. In practice, failure to observe parameters of the thermal neutral zone leads to increased morbidity, higher feed intake, lower weight gains and lengthening of the fattening period along with higher fat content, greater fatness, reproductive problems, respiratory alkalosis, and electrolyte disturbances. In the study by Herbut et al. (1997 b), chickens raised in a facility with a higher air temperature and lower concentration of negative ions were characterized by a significantly lower level of thyroid hormones compared to birds housed at a reduced temperature. These findings support the results of Brigmon and Mather (1992), who showed that elevated air temperature reduces thyroid activity. It is noticeable that negative ionization of air offsets the adverse effect of elevated temperature on chickens, which is of great practical importance. On the other hand, Wallner et al. (2015) reported that increases in the number of negative ions from 367 to 866/cm^3 and in positive ions from 671 to 1328/cm^3 causes a reduction in air temperature by 0.5°C.

Effect of air humidity on the concentration of negative ions

In livestock buildings, almost 75% of total air humidity comes from water vapour produced by animals. Increased room humidity influences body thermoregulation and water evaporation rate, which disturbs metabolism and lowers productivity as well as immunity. Elevated humidity may increase feed intake by 30% and decrease weight gains by 25% in fattening pigs (Huynh et al., 2005). It may also cause a decline in the concentration of negative ions.

Few studies have examined the effect of ionization on the humidity parameters of air or the effect of water vapour content on the concentration of ions. Wallner et al. (2015) showed, for example, that increasing the number of ions from 1038 to 2194/cm^3 reduces relative air humidity from 48 to 46.3%, with a slight decline in temperature (by 0.5°C). This issue is difficult to interpret due to the complex physico-chemical processes that occur in air. In the study by Herbut et al. (1997 a), the use of artificial air ionization in poultry buildings with decreased (55%) and increased (85%) air humidity results in an around 50% lower concentration of negative ions at higher humidity. This means that high air humidity also negatively affects the concentration of negative ions. However, in the case of low air humidity, higher concentration of negative ions persists until the third week of rearing. From week 4, the concentration of ions clearly decreases. This is probably related to increased particulate pollution at low air humidity. In the control building with high humidity and without artificial air ionization, there was the lowest proportion of negative ions, while positive ions were also present, both less and more mobile ions. During the first rearing period, chickens from this group were also characterized by a significantly higher concentration of triiodothyronine and a lower thyroxine content. These differences disappeared in the second rearing period, which shows that young birds are more sensitive. Negative air ionization was observed (Herbut et al., 1997 a and b) to reduce the negative effect of non-optimal environmental factors.

Animal research published to date has shown that negative air ionization has a positive effect on almost all bodily functions (Herbut et al., 1995; Janowski et al., 1989; Jovanić and Jovanić, 2001; Pawar et al., 2012, Wakamura et al., 2004). This is confirmed by the results obtained for body weight, feed intake, and health. The carcasses of chickens exposed to a higher concentration of negative ions were characterized by a higher percentage of muscles and lower fatness.

Conclusions

Negative air ionization as a physical microclimate factor largely depends on thermal and humidity conditions in buildings. It has a considerable effect on the organism, which translates into the health, well-being and productivity of animals.

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