Journal of Integrative Agriculture 2017, 16(8): 1653–1658

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REVIEW

# Effects of relative humidity on animal health and welfare

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**Abstract**

Farm animals are sources of meat, milk and eggs for the humans, and animal health ensures the quality and security of these agricultural and sideline products. The animal raising conditions in livestock stations and poultry houses play vital roles in both animal health and production. One of the major factors affecting raising conditions, relative humidity, has not received much attention even though it is important for animal husbandry. In this review, we summarize the impacts of relative humidity on animal health and welfare to draw attention for its importance in the improvement of animal raising conditions in the future.

**Keywords:** relative humidity, animal, health, welfare

## 1. Introduction

Humidity is essential for life. It is often expressed as relative humidity, which is the ratio of the current absolute humidity relative to the maximum humidity at a specific temperature, indicating the amount of water vapor in the air at that temperature. As a key environmental factor, it plays an important role in air quality (Tian *et al.* 2014; Cheng *et al.* 2015) and climate control (Sherwood and Fu 2014). Additionally, epidemiological investigation has revealed that relative humidity variation is associated with human health. For example, the prevalence of diabetes is higher in elders living in areas of high relative humidity (Tyrovolas *et al.* 2014); low relative humidity results in the dryness of the ocular mucosa and the stratum corneum of the skin along with decreased skin temperature (Sunwoo *et al.* 2006), and high relative humidity leads to high mean humidex values, which increases the heat stroke risk (Orosa *et al.* 2014). Moreover, a significant impact of ambient humidity on child health was also observed, especially for climate-sensitive infectious diseases, diarrheal diseases, respiratory system diseases, and pediatric allergic diseases where high relative humidity made children to be more vulnerable to disease (Gao *et al.* 2014); and evidences also show an increase in cardiovascular mortality at low relative humidity (Ou *et al.* 2014).

Similarly, risks to animal health due to relative humidity were also found in livestock and poultry. For example, over hydration increased the mortality of chicken embryos during incubation (Noiva *et al.* 2014), and inspired air with abnormal humidity contributed to pulmonary inflammation in ventilated lambs and dogs (Pillow *et al.* 2009; Hernandez-Jimenez *et al.* 2014). However, to date, no specific review has summarized on animal health and welfare affected by relative humidity, and it is important that the changes and risks in

Received 27 June, 2016 Accepted 23 November, 2016
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doi: 10.1016/S2095-3119(16)61532-0

physiological processes by relative humidity should be taken into consideration. Therefore, this review primarily focuses on the effect of relative humidity on animal health and welfare to improve our understanding and promote additional research into relative humidity management on raising conditions for livestock and poultry.

## 2. Relative humidity and infectious diseases

Previous investigations have indicated that the occurrence and prevalence of climate-sensitive infectious diseases are significantly associated with ambient humidity (Gao *et al.* 2014). Additionally, relative humidity also contributes to respiratory damage; studies on histological features revealed that the respiratory epithelium of calves appeared variable damage under different levels of humidity, which impairs mucociliary clearance (Jericho and Magwood 1977). The occurrence and prevalence of infectious diseases is sensitive to relative humidity, not only because the impaired trachea and bronchi in respiratory system provides an environment favorable for pathogen infection, but also because the abnormal levels of humidity increase the infectivity of pathogens.

### 2.1. Virus

Infectious diseases can be transmitted by contact with diseased animals or by airborne pathogens, which include viruses, bacteria and fungi. Airborne pathogens can be spread by means of aerosols, which are defined as colloidal systems of solid or liquid particles in a gas and include both the gas and suspended particles. The relative humidity probably acts as a determinant of the incidence of disease by changing the aerosols settling rate, which in turn affects the amount of pathogens attached to aerosols (Couch 1981). Previous results have shown the stability of influenza virus in an aerosol varies with relative humidity (Hemmes *et al.* 1960). At low relative humidity, the rate of water evaporation from aerosols is high, which leads to the formation of droplet nuclei less than 5 μm in diameter that remain airborne for an extended period of time, increasing the risk of virus transmission. On the other hand, the setting rate of aerosols is higher at high relative humidity which decreases the opportunity for virus transmission (Hänel 1977; Weinstein *et al.* 2003; Tellier 2006). Therefore, the stability of the virus in aerosols is a key factor for influenza transmission (Noti *et al.* 2013). It has been found that flu virus stability is the highest at low relative humidity (Schaffer *et al.* 1976; Yang and Marr 2012; Noti *et al.* 2013). And an independent study of the effects of relative humidity on influenza virus spread also revealed a favorable level of transmission at 20–35% relative humidity, while transmission was completely blocked at a high relative humidity of 80% (Lowen *et al.* 2007). In addition to an increased incidence of disease, most respiratory diseases caused by viruses with lipid envelopes, such as influenza viruses, corona viruses, and parainfluenza viruses tend to have a longer survival duration at low relative humidity (Webster 1975; Yoder *et al.* 1977; Mullis *et al.* 2012).

### 2.2. Bacteria

Bacteria are another family of pathogens that cause infectious diseases. There is a strong correlation between the bacterial populations, including *Escherichia coli* and *Salmonella* species, and relative humidity (Hirai 1991; Adell *et al.* 2014). Most bacteria can survive for a short period of time at a relative humidity of 55–75% (William 2001). The survival rate of bacteria, such as *Enterococcus faecalis*, is inversely proportional to the relative humidity, with low mortality observed at lower relative humidity (Robine *et al.* 2002). The predominant airborne Gram-negative bacteria in animal houses is Pseudomonadaceae, and a high concentration of airborne Pseudomonadaceae seems to be related to high air humidity (over 85% relative humidity) (Zucker *et al.* 2000). A delay in colonization of *Campylobacter jejuni* at low relative humidity conditions was also observed in broiler chickens (Line 2006), suggesting that, similar to Pseudomonadaceae, high relative humidity is conductive to bacterial suvival. Given the contrasting effects on different bacterial populations as shown above, the effect of relative humidity on the survival of airborne bacteria is much more complicated than that with viruses. Therefore, it is vital to control relative humidity to minimize risk based on the types of bacteria that are present.

### 2.3. Fungi

Humidity also plays an important role in fungi development and mycotoxin production (del Pilar Monge *et al.* 2012), and in turn fungal/mycotic diseases caused by fungi affect animal health. Many investigations have explored the relationship between humidity and fungi. It is reported that high humidity increases fungal growth and proliferation in poultry feed (Greco *et al.* 2014). The viability of fungi also depends on relative humidity, and the optimal level for the survival of most fungi is 55 to 75% (Vučemilo *et al.* 2008). Further, changes in humidity fluctuate with climate, which seems to be a potent cofactor for emerging infectious diseases. Even though it is strange that when relative humidity is low in early spring and winter, fungi are more abundant (Plewa and Lonc 2011), it is clear that chytridiomycosis is linked to environmental factors such as humidity (Fisher *et al.* 2012).

### 2.4. Relative humidity and other impacts on animal health

In addition to the incidence of infectious diseases, relative humidity is also associated with other abnormalities in other aspects of animals health. Skin is an important avenue of water loss in terrestrial birds, and either high or low relative humidity causes a reduction in cutaneous water loss through the stratum corneum, which impairs skin resistance (Cox *et al.* 2008). It's also known that along with high temperature, high relative humidity decreased the evaporation rate and increased animal heat stress. In 4-week-old broiler chickens, relative humidity above 60% at high temperature impaired the heat transmission (Lin *et al.* 2005). Previous result showed that the syndromes of anasarca and myopathy in ostrich chicks, were related to high relative humidity during incubation (Philbey *et al.* 1991). Additionally, relative humidity has an effect on the animal respiratory system; high humidity in evaporative cooling systems in evaporative cooling system may cause respiratory stress (Berman 2006).

### 2.5. Relative humidity and animal welfare

Animal welfare is described as the state in which an animal lives harmoniously with its environment. It reflects animal physical health and psychological well-being. Due to the increase in world population and the demand for animal-derived protein, a higer quantity and quality of animal products is required. Therefore, to meet this demand, the conditions for raising animals should be optimized to maximize animal welfare. Obviously, animals in good welfare benefit animal health and production. Animal welfare is affected by environmental conditions, and proper environmental conditions are required to allow animals to display all of their natural behaviors (Koknaroglu and Akunal 2013). In 2012, the World Organization for Animal Health, formulated the 'General Principles for the Welfare of Animals in Livestock Production Systems', which provided the guidelines of specific standards for various animals (OIE 2012). Among the General Principles, one of the key points is that abnormal humidity has adverse effects on animals.

### 2.6. Animal growth condition and relative humidity

For most mammalian species the acceptable range of relative humidity is 30–70% (NRC 2011), and the optimum range of relative humidity for chicken during and after brooding is 60–80 and 50–70%, respectively (Winn and Godfrey 1967). However, as it is not possible to control relative humidity as narrowly as temperature, relative humidity is seldom directly measured or managed (Dawkins *et al.* 2004). Growing chickens under low relative humidity (below 50%) in the first week can lead to dehydration (Aviagen 2009). And another investigation that included a total of 2.7 million birds in 114 houses on commercial farms found that low levels of relative humidity at one week of age was associated with poorer gaits at six weeks of age (Jones *et al.* 2005). These studies indicate the importance of relative humidity on the health and welfare of boilers, especially early in life. In a region of high relative humidity, pig welfare assessment showed moderate or poor feed quality (Renggaman *et al.* 2015), and high relative humidity was also a risk factor for ear necrosis (Mirt 1999). New born lambs exposed to high or low relative humidity displayed tracheobronchial damage, and the lower relative humidity, the worse the damage (Todd *et al.* 1991).

Additionally, high relative humidity affects animal bedding, which results in increased litter moisture and ammonia concentrations. This exacerbates the negative effects of humidity on animal growth condition and carcass characteristics (Weaver and Meijerhof 1991).

### 2.7. Animal production

Animal welfare contributes to animals' natural behaviors, which are beneficial for providing meat, eggs and dairy around the world. In line with the objective of promoting animal production, it is necessary to take animal welfare strategies into account. Therefore, as one of the key factors in raising environment quality, attention should be paid to relative humidity when developing strategies to increse animal production.

Previous results showed that during incubation, relative humidity influenced both water loss from the egg and embryonic mortality, and the high relative humidity appeared to have a detrimental effect on embryonic development (Buhr 1995; Bruzual *et al.* 2000). When exposed to high ambient temperature, body weight gain and feed intake of 5–8-week-old chickens varied with the relative humidity and reached maxima at around 60–65% relative humidity (Yahav *et al.* 1995). Under hot-humid environments, swine show reduced feed intake (Myer and Bucklin 2001) and there are higher sow culling rates (Zhao *et al.* 2015). In addition, dairy cattle produce milk with decreased milk fat and milk protein percentage (Gantner *et al.* 2011). When dairy cows are exposed to hot and humid climate, the intake and milk yield was increased by increasing the cooling frequency (Honig *et al.* 2012). To account for the combined effects of relative humidity and temperature, the temperature humidity index (THI) is widely used to provide an accurate assessment of the effects of the thermal environment on poultry and livestock (Berry *et al.* 1964; Gates *et al.* 1995; de Moraes *et al.* 2008). THI has also been used to establish thresholds for heat stress in domestic animals. For example, a THI of 72 is considered the set point for cow heat stress, and at this point milk production and feed intake begin to decrease when THI reaches 72 (Johnson 1987).

## 3. Conclusion

It is clear that the health of livestock and poultry is still a world-wide issue. It is necessary to investigate animal raising conditions in order to prevent the factors that are potentially harmful to animals. Relative humidity has been reported to pose adverse effects on animal welfare, affecting poor growth and development. Additionally, it is worth noting that unfavorable levels of relative humidity increase the prevalence of infectious diseases by impairing the animal respiratory tract and making pathogens more contagious. However, direct control or even measurement of humidity levels is not part of current practice and does not receive much attention. It may be that monitoring and directly controlling relative humidity could result in a significant improvement of animal husbandry in the future, and make a substantial contribution to animal welfare, as well as prevent infectious diseases.

## Acknowledgements

Fundings were provided by the National Key R&D Program of China (2016YFD0500501), the National Science and Technology Support Program of China (2012BAD39B02), and the Agricultural Science and Technology Innovation Program, China (ASTIP-IAS07).

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(Managing editor ZHANG Juan)