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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

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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).