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Research Paper

# Reducing dust deposition and temperature fluctuations in the laying hen houses of Northwest China using a surge chamber

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For the poultry houses in Northwest China, the local aeolian sandy soil which is carried into by the ventilated air and large air temperature fluctuations have multiple adverse environmental and bird health effects, resulting in considerable losses in egg production. New approaches are desired for these poultry houses to mitigate the air temperature differences and reduce dust deposition rates. A novel ventilation system is developed to make the fresh air go through a surge chamber before entering the houses. The surge chamber can be considered as a particle separator that reduces suspended particulate matter in the air stream using gravity and inertial forces. It can also provide a thermally comfortable intermediate environment, which has cooler air in the summer than the atmospheric air. The performance of a poultry house with the new ventilation system and a house with the standard ventilation system were evaluated, examining the air temperature difference, dust deposition rates, and layer performance. The results showed that the new ventilation system had much lower maximum horizontal and vertical air temperature differences (1.4 °C and 0.9 °C), compared to the standard house (6.4 °C and 5.4 °C). The new ventilation system with a surge chamber effectively reduced the amount of aeolian sandy soil carried into the houses by ventilation, reaching an efficiency of 95%. Egg production rates and hen body mass were greater in the modified house and feed consumption and mortality were lower in modified house than the standard house.



## 1. Introduction

Hot and dry summers with little precipitation, cold winters with large variations between daytime and night-time temperatures and sudden changes in temperatures are the most pronounced characteristics of temperate continental climates (Olgun, Çelik, & Polat, 2007). Being far from the ocean, Northwest China has a continental climate and much of it is an arid area (Zheng, Hong, Zhi, Gang, & Drake, 2007). Dust

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**Nomenclature**

| | |
|---|---|
| $A_0$ | Area of the air inlet, $m^2$ |
| C | Aerodynamic resistance coefficient |
| d | Diameter of dust, m |
| $d_o$ | Diameter or the circular equivalent of the supply air inlet, $d_0 = 1.128\sqrt{A_0}$, m |
| g | Gravitational acceleration constant, m $s^{-2}$ |
| H | Height of surge chamber, m |
| $H_i$ | Height of the sidewall inlets, m |
| h | Height of the top layer cages, m |
| K | Experimental constant |
| M | Total dust deposition rates, t $km^{-2}$ $(30)^{-1}$ |
| n | Number of sampling days, accurate to 0.1 day, d |
| Re | Reynolds number, dimensionless |
| s | Areas of the dust-collecting receptacle mouth, $cm^2$ |
| $t_i$ | Air temperature in the poultry house, °C |
| $t_1$ | Retention time of air stream in surge chamber, s |
| $t_2$ | Time of particle dust from the inlets to the bottom of surge chamber, s |
| $\Delta t_s$ | Temperature difference between supply air at inlet and air in the poultry house, °C |
| $\Delta t_x$ | Decay of the air temperature in poultry-occupied zones, °C |
| u | Aerodynamic viscosity, Pa s |
| v | Velocity of the air stream, 0.3~2 m $s^{-1}$, m $s^{-1}$ |
| $v_c$ | Terminal velocity of dust, m $s^{-1}$ |
| $v_o$ | Air velocity at supply inlet, m $s^{-1}$ |
| $v_x$ | Centreline velocity of jet, m $s^{-1}$ |
| W | Width of surge chamber, m |
| $W_o$ | Mass of the kiln-dried porcelain crucible at about 105 ± 5 °C, g |
| $W_1$ | Mass of the dust, porcelain crucible and dry ethylene glycol solution dried to constant mass at 105 ± 5 °C, g |
| $W_2$ | Mass of kiln-dried ethylene glycol solution dried to constant mass at 105 ± 5 °C, g |
| x | Horizontal distance between the surface of the air inlet and poultry-occupied zones, m |
| y | Descent of cold air jet, vertical distance between horizontal axis of air inlet and poultry-occupied zone, m |
| β | Experimental constant |
| $\rho_c$ | Dust density, kg $m^{-3}$ |
| ρ | Air density, kg $m^{-3}$ |
| θ | Angle between centreline of wall inlets and horizontal axis of air inlet, ° |

storms occur over large areas of arid and semi-arid China, and aeolian sandy soils are widely distributed in this part of the country (Zhu, Liu, Wu, & Di, 1986, p. 132). Aeolian sandy soils are those soils which are typically developed from sandy parent material through the action of wind. Such soils generally consist mainly of well-sorted fine sand, with over 80% of the particles in the size range 0.25–0.05 mm (Zhao et al., 2007). In the context of laying hen farming, hot and dry summers coupled with cold winters with overall large temperature differences point to the significance of having an effective ventilation system to produce a relatively stable indoor thermal environment (Olgun et al., 2007). Moreover, various infectious agents (i.e., bacteria and fungi) are known to travel along with dust, the blowing aeolian sandy soils and particles can act as a major vector for disease transmission. Therefore, the sandy soils that enter into laying hen buildings have been considered as an important factor for pathogens and epidemic infections (Simmons et al., 2006), and they have also damaged the poultry facilities.

Farm animals are usually kept in isolated structures constructed by people (Olgun et al., 2007). The basic requirement of a poultry house is to provide a suitable inner environment for maintaining and growing the flock contained within (Reece & Lott, 1982). Maintaining a comfortable temperature, relative humidity and air quality (e.g., total suspended particulate) for the birds is essential to ensure their well-being, maximum productivity, and efficient feed utilisation (Dawkins, Donnelly, & Jones, 2004; Li, Ito, Nishibori, & Yamamoto, 1992; Zhao, Xin, Shepherd, Hayes, & Stinn, 2013). The design of laying hen house ventilation systems is thus of great importance in providing birds with a suitable living environment, in improving their well-being and performance. Here, the mitigation of the air temperature difference and dust deposition is a problem for the existing ventilation systems in laying hen houses and providing a suitable living environment for laying hens in Northwest China is a significant issue (Olgun et al., 2007).

The typical tunnel ventilation systems have been shown to be incapable of maintaining a uniform thermal environment in both hot summers and cold winters, especially during the dust storms in Northwest China. In the summer, tunnel ventilation and the wet-pad evaporative cooling system are typically installed in laying hen houses to provide a wind chill effect in the house (Hui et al., 2016; Tong, Hong, & Zhao, 2017). However, for the hot and dry climate in Northwest China which has a large difference between dry and wet bulb temperatures, the use of this system is limited, because large diurnal temperature variations and heat stress are found for the birds near to the fans. Intermittent partial surface sprinkling, misting or fogging has reduced the body temperature rise, raised the lethal heat load threshold, increased survival time, and reduce mortality (Chepete & Xin, 2000; Ikeguchi, 2001). But misting and sprinkling systems can cause problems with wet litter, equipment, and/or feed, because such systems attempted to mist the air of the entire house volume instead of promoting localised wetting of the bird (Timmons, Baughman, & Murray, 1980). In addition to heat stress, the birds may also suffer from cold stress in winter, or during cold nights, because these poultry houses are not equipped with heating systems and operate ventilation systems with baffle inlets in the sidewalls.

Wang (2001) indicated that if pathogenic microorganisms attached to the aeolian sandy soils enter the poultry houses with the ventilated air it can cause disease outbreaks, leading to high mortality and reduced production performance. Burley et al. (2011) demonstrated that aeolian sandy soils can not only transmit these infectious agents from commercial