RESEARCH OF YELLOW-FEATHER CHICKEN BREEDING MODEL BASED ON SMALL CHICKEN CHAMBER
/
基于小型鸡舍的黄羽鸡精细化养殖模式研究

MAE. Stud. Heyang Yao [1], Ms. Qiyue Sun [1], Assoc. Prof. Ph.D. Xiuguo Zou *[1], MEE. Stud. Siyu Wang [2], Senior Exper. Shixiu Zhang [1], MAE. Stud. Shikai Zhang [1], Ms. Shuyue Zhang [1]

[1] College of Engineering, Nanjing Agricultural University / China;

[2] School of environmental science and Engineering, Nanjing University of Information Science and Technology / China

Tel: +862558606585; E-mail: xiuguozou@gmail.com

Keywords: *small chicken chamber, yellow-feather chicken, heat stress, ammonia, fine particulate matter*

ABSTRACT

Yellow-feather chicken is a common breeding chicken in China. In view of the uncontrollable factors of pasture-raised chickens, the team proposes a precise breeding method of small chicken chamber. In this way, two problems are solved, including heat stress and the effects of environmental factors, such as bedding, fodder, water, wind speed, ammonia and fine particulate matter ($PM_{2.5}$) on chickens. This experiment studies heat stress and air quality during the 20-day experiment period using the method of a negative pressure fan controlled by an inverter. The experimental results show that under design conditions, all the environments are up to standard, and the weight gain efficiency of chickens is higher than that of free-range chickens and no death is witnessed. This experiment proposes a new breeding model which has been approved by some breeding companies and thus has a broad application prospect.

摘要

黄羽鸡是中国常见的一种养殖鸡，针对散养鸡各方面因素不可控，团队提出小型鸡舍精细化养殖方式，在这种养殖方式下，重点解决两个问题，一是热应激，二是垫料、饲料、水、风速、氨气和 $PM_{2.5}$ 等环境因素对鸡的影响。本次实验采用变频器控制负压风机的方案，在为期 20 天实验时间内研究热应激和空气质量情况。最终实验结果表明，在设计的条件下各方面环境均达标，鸡增重效率高于散养，没有鸡死亡。本实验提出一种新型的养殖模式，已经得到部分养殖基地认可，有很好的推广前景。

INTRODUCTION

With the popularization of the scientific concept of “animal welfare”, environmental quality is an important factor that restricts the health welfare and production performance of chickens (*Liu Y., 2015*). In Jianghuai Region of China, it often appears high temperature and high humidity in summer. Due to the lack of sweat glands and the difficulty in heat dissipation of chickens, different heat stress response occur at this time (*Farooqi H., 2005*). The heat stress response of chicken refers to a series of abnormal reactions caused by temperature regulation and physiological dysfunction under high temperature conditions, which have different effects on feed intake, production function and feed conversion rate of chickens, and even causes shock and death of chickens (*Yuan J., 2007*). Saffar and Rose (2002) studied that the physiological function of poultry was greatly influenced by environmental factors, among which ambient temperature was one of the most important factors (*Al-Saffar A., 2002*).

At the same time, air quality in the chicken house also affects the health of chickens. For traditional chicken houses in China, a scraper-type defecating system is used for dung removal, which has problems such as long cleaning cycle, incomplete cleaning and water leakage of drinking water equipment. As a result, the fecal fermentation in the chicken house is easy to occur, resulting in high temperature, humidity and ammonia concentration in the chicken house (*Kocaman B., 2006*). In chicken house, ammonia is produced by microorganisms degrading substances such as feces. Higher concentrations of ammonia may damage the respiratory lining of chickens, decrease their immune function, increase their risks of infectious and respiratory diseases, and adversely affect their weight gain, feed conversion rates, carcass quality, thereby reducing their breeding benefits (*Beker A., 2004; Lin T., 2016; Xing H., 2015*). Studies show that the dust in chicken house mainly comes from feed, feces, chicken skin, feathers, the foam produced during cackling, airborne microorganisms and fungus (*Chen F., 2014*). Ammonia is also an important source of $PM_{2.5}$ (*Li Q.,* *2014*). Only a small amount of pathogenic microorganism inhaled by chickens can lead to airborne infection, affecting normal life and health of chickens, and leading to the decline of production performance (*Yang W., 2016*). In order not to affect the health and normal production performance of chickens, China's livestock and poultry farm environmental standard (*NY/T 388-1999*) stipulates that the concentration of ammonia in chicken houses shall not exceed 10mg/m^3.

To solve the above mentioned problems, this paper studies the precise breeding mode of yellow-feather chickens based on small chicken chamber and analyzes the effects of heat stress, $PM_{2.5}$ and ammonia on the growth performance of yellow-feather chickens in terms of colour of excreta, feed and water, wind speed in the chamber, concentration of ammonia and $PM_{2.5}$ particles.

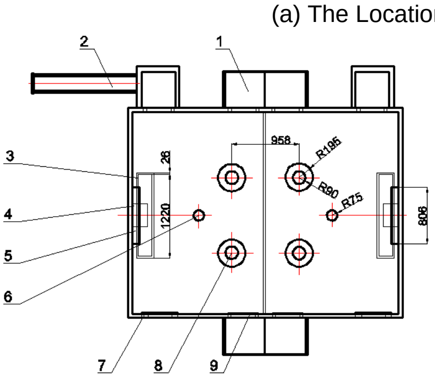
MATERIALS AND METHODS

The experiment was conducted at Jinniuhu Street, Luhe District, Nanjing City, Jiangsu Province, China. The geographical coordinates of the chicken house are 32°26'77"N in latitude and 118°52'64"E in longitude. The chicken house has two symmetrical structure chambers and the walls of chambers are designed by two layers of steel plate with heat insulation cotton in the middle. Each chamber is 1.9m in width, 2.9m in length and covers a total area of 5.51m^2. The roof is a slope, and its west side is 1.88m in height and east side is 1.77m in height, which makes rain drain easy. In the chamber, temperature and humidity monitoring system, ammonia monitoring system, inner and external circulated ventilation system, and video monitoring system were equipped.

The experiment began on July 20, 2018, and the yellow-feather chickens were 24-day old. The experimental period is 20 days. On the first day of the experiment, each chicken was numbered. The yellow-feather chickens after registration were put into two chambers for feeding according to their identifications. The 35 chickens in Chamber 1 are numbered consecutively from the number of 101 and a plastic ring is put on their feet for identification, while the 35 chickens in Chamber 2 are numbered consecutively from the number of 201.

Figure 1 (a) shows the location and surrounding environment of the chicken house. The red frame the red arrow points at is the chicken house used in the experiment. The internal structure of the two chambers and their internal landscape are shown in Figure 1 (b) and Figure 1 (c).

(a) The Location of the chicken house



(b) The internal structure of the chambers

(c) The internal landscape of one chamber

Fig. 1 - Overview of the experimental chicken house

1. internal circulated air outlet, 2. external circulated air outlet, 3. Drinking water pipe, 4. water tank, 5. air conditioner, 6. camera, 7. internal circulated air inlet, 8. feeder, 9. external circulated air inlet

During the 20-day experiment, the water trough in the chicken chamber is cleaned every morning to avoid water contamination problems caused by clogged water outlets or the accumulation of the bedding in the water trough as a result of movement of yellow-feathered chickens.

At the same time, temperature changes in the chicken chamber also need to be recorded in the control room many times per day. If the temperature exceeds 30°C, the inlet air brake of the chicken chamber needs to be adjusted to the largest degree to speed up heat dissipation and slow down temperature rise speed in the chamber, and when the temperature in the chamber exceeds 34°C, the air conditioner will be open (set to 30°C) for cooling until the external temperature of chicken chamber drops to lower than 34°C to avoid mortality of chickens because of heat stress.

The daily work is arranged as follows:

(1) Daytime (6:00 AM - 11:00 PM): check the status of the chicken every hour, record the temperature of the chicken chamber and check every half hour when the temperature is high at noon. The recording time shall be precise to minute.

(2) Adjust the frequency of variable frequency fan according to the temperature reference table.

(3) At high temperature: C1, C2 > 34°C, use inner cycle fan, close damper, open air conditioning, air conditioning set at 30°C, set frequency converter of internal cycle fan to 30Hz, frequency converter of external cycle fan to 0HZ, constantly monitor temperature. When the temperature outside the chicken chamber drops to 34°C, open frequency converter of the external cycle, frequency converter of the internal cycle and the external cycle are set to 50Hz, close air conditioning.

(4) Other arrangements are as follows:

11:00 PM ~ 5:00 AM (the next day): Detect particulate matter mass and ammonia concentration at night.

6:00 AM ~ 8:00 AM: Check and clean the chicken chambers, and check feed and water to ensure water level is no less than 70cm.

8:00 AM ~ 2:00 PM: Detect particulate matter mass and ammonia concentration etc.

2:00 PM ~ 4:00 PM Check feed, water and chickens status.

4:00 PM ~ 10:00 PM Detect particulate matter mass and ammonia concentration etc.

The whole experiment mainly consists of the following aspects.

The experimental plan of bedding

Good quality bedding encourages yellow-feather chickens to engage in some natural behaviours and physiological activities, such as foraging for water, combing their feathers and walking back and forth. In this experiment, wood chip is used as bedding. Wood chip bedding is flat and loose, not prone to agglomeration, and can effectively absorb the excreta of yellow-feather chickens (*Robins A., 2011*).

On the day when the experiment ends (Day 20 of the experiment), a small amount of the bedding samples will be collected at 2 points at external and internal circulated air outlets of the chicken chamber (10 cm from the air outlet), 2 points at external and internal circulated air inlet (10 cm from air inlet), 2 points at water area centre and feed area centre, and 1 point at the centre of chicken chamber. These samples will be analyzed and tested.

The experimental plan of feed and water

This experiment adopts Zhengda 511 chicken feed (suitable for 22-day chickens to chickens 7 days before yielding). Ingredients: corn flour, soybean meal, protein powder, rice bran, fish meal, calcium phosphate, copper sulfate, ferrous sulfate, compound vitamin, amino acid, etc., and it contains all the nutrients required for the growth of chicken. This product is puffed and thus easier to intake.

Studies show that the addition of vitamin C can maintain a normal body temperature and normal concentrations of calcium, protein and cortisol in the blood, thus relieving heat stress response of the chickens. Addition of vitamin C to daily ration is good for chickens at high or low temperatures to maintain body temperature *(Al-Masad M., 2012)*. Therefore, vitamin C is added to feed in 1‰ or drinking water in 0.5‰.

The experimental plan of real-time environmental monitoring

Temperature and humidity monitoring system, ammonia monitoring system and video monitoring system are installed in chicken chambers.

Temperature and humidity monitoring system: temperature and humidity sensor of Swiss Sensirion SHT11 is adopted, and the maximum temperature error: ±0.4°C, and the maximum humidity error: ±3%RH. Four temperature and humidity sensors monitor the temperature and humidity in Chamber 1 and Chamber 2, in front of the chambers and in back of the chambers.

Ammonia monitoring system: Daan Instruments gas monitoring host and electrochemical ammonia gas sensor are adopted. The sensor range is 0-200ppm and the resolution is 1ppm. The sensor is mounted (equipped) on a wall 30cm above the top of the chambers.

Video monitoring system: HIKVISION N1W monitoring host and hemispheric network camera are adopted, and the camera focus is 2.8mm and pixel is 2 million.

The control room with the control system is shown in Figure 2.

Fig. 2 - Control room and control system

The experimental plan of ventilation system

A small chicken chamber for precise breeding mode must have a perfect ventilation system. A reasonable ventilation system can promote indoor gas flow and exchange indoor and outdoor air to a certain extent, and has the effect of eliminating harmful gases, lowering temperature, and improving the environment inside the chamber (*Cheng L., 2015; Wu P., 2013; Zhao F., 2014*). The ventilation system adopted in the experiment is mainly composed of frequency converter and negative pressure fan. Each chamber has two sets of frequency converter and fan, including internal and external circulated ventilation systems, and cycle power is driven by negative pressure fan controlled by frequency converter. The negative pressure fan of external circulation exhausts directly to outside and the air inlet directly intakes fresh air from outside. For external circulation, the negative pressure fan returns the air through the air passage under the floor is used to complete the internal air circulation. The return air passage has a length to width ratio of 2900mm*550mm*270mm.

The plan of negative pressure fan controlled by the inverter is shown in Table 1 (*Du Y., 2016*). It is proved by literature and pre-experiment.

Table 1

The plan of negative pressure fan controlled by the inverter

Temperature	The frequency of external circulated inverter	The internal circulated air inlet	The frequency of internal circulation inverter	The air conditioner
Less than 24°C	10 Hz	Open to 30%	0	OFF
24°C~26°C	20 Hz	Open to 30%	0	OFF
26°C ~28°C	30 Hz	Open to 60%	10Hz	OFF
28°C ~30°C	40 Hz	Open to 60%	20 Hz	OFF
30°C ~32°C	50 Hz	Open to 100%	30 Hz	OFF
32°C ~34°C	50 Hz	Open to 100%	50 Hz	OFF
Greater than 34°C	0	Close	30 Hz	Turned on to 30°C

The experimental plan of wind speed detection

15 detecting points are set in Chamber 1 and Chamber2, respectively. The first detecting point starts from the air inlet and the points set in the two chicken chambers are symmetrical. The positions of the specific detection points are shown in Figure 3. The high precision hand-held anemometer of Testo 405i with the precision of ±0.1m/s is used for wind detection and the results are transmitted to the smartphone via Bluetooth.

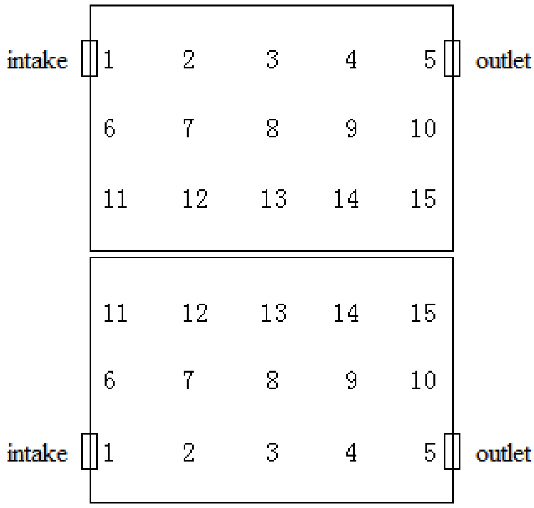


Fig. 3 – The distribution of the wind speed detecting points in Chamber 1 & Chamber 2

The experimental plan of ammonia concentration detection

ZG-1 gas sampling pump and ammonia detection tube made in the Research Institute of Beijing Labour Protection Science are used for ammonia detection. During the experiment, ZG-1 sampling pump is stopped after extracting 100ml air and kept still until the indicator in the tube stops changing colour. The data can be read from the scale corresponding to the yellow column. 9 detecting points are set in Chamber 1 & Chamber 2, respectively. The first detecting point starts from the air inlet and the points set in the two chicken chambers are symmetrical. The positions of specific detection points are shown in Figure 4.

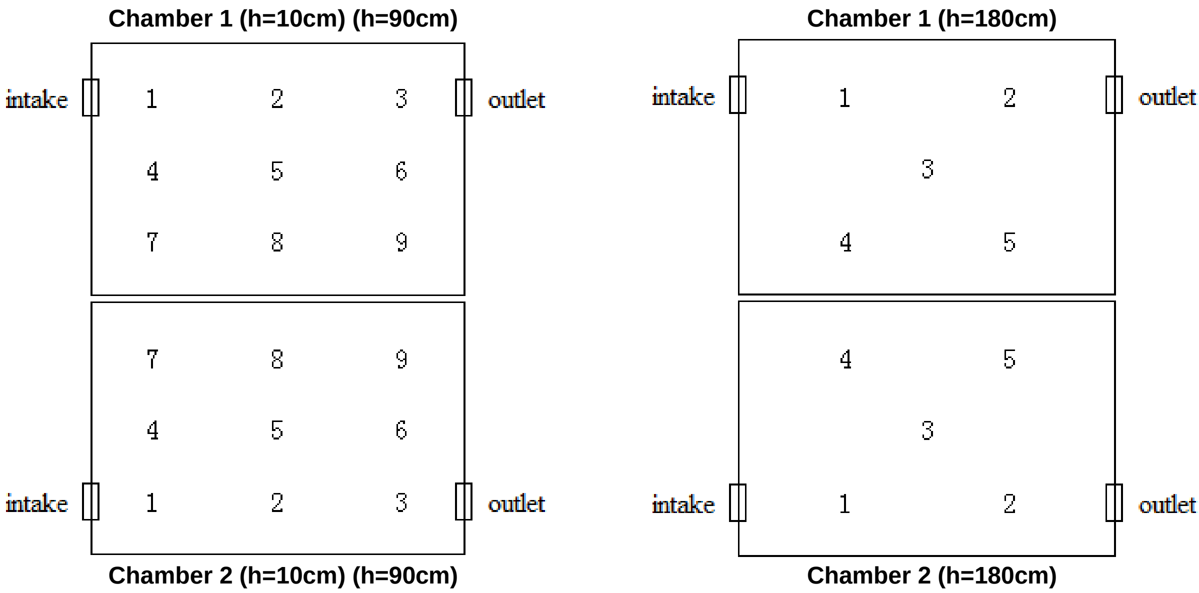


Fig. 4 - The distribution of the ammonia detecting points in Chamber 1 & Chamber 2

The experimental plan of $PM_{2.5}$ mass detection

The lighting time of chicken chamber is from 5:00 AM to 11:00 PM and the lights-out time is from 11:00 PM to 5:00 AM. LB-120F $PM_{2.5}$ sampler in an intermediate flow produced by Qingdao Lubo Weiye Environmental Protection Technology co., LTD is used during the lighting and lights-out time, and the collection of $PM_{2.5}$ is implemented by Φ90mm super fine glass fibre filter membrane working for 6 hours at the sampling rate of 100 litres per minute.

The filter membrane is weighed by ESJ182-4A automatic electronic analytical balance with the accuracy of 0.01mg and maximum range of 30g before and after sampling. For each weighing, the analytical balance is first internally calibrated. The filter membrane is weighed three times after zero clearing and the mean value of the weighting values is taken as the mass. The mass of $PM_{2.5}$ can be calculated by calculating the mass difference of each filter membrane before and after sampling.

Figure 5 (a) shows the working condition of $PM_{2.5}$ sampler in the chamber and Figure 5 (b) shows the experimenter weighing the filter membrane at a certain temperature (26~30°C) and humidity (45~55%).

(a) $PM_{2.5}$ sampler in the chamber (b) The experimenter weighing the filter membrane

Fig. 5 - The experiment of $PM_{2.5}$ mass detection

RESULTS

During the 20 days of the experiment, a large number of yellow-feather chickens gathered at the air outlet of chicken chamber each day at the high temperature of 32~34°C and their body got close to the bedding, with their mouth open for breathing and reluctant to move. It suggests that when the temperature reaches 32°C, yellow-feather chickens have already had heat stress symptoms. Once the temperature drops below 32°C, life condition of chickens will restore to a relatively normal state. They will move actively in the chicken chamber, increase water drinking and food intake.

In this experiment, HOBO temperature and humidity instrument, Testo 405i high-precision hand-held anemometer, ZG-1 gas sampling pump and sampling tube and LB-120F $PM_{2.5}$ sampler are used. The collected data are analyzed by software to provide the following results.

Temperature and humidity recording results

In the experiment, the HOBO thermo-hygrometer is set to collect temperature and humidity per minute. After the data collected, the HOBOware Software is used to read data that can be visualized to view the data or stored as CSV format for further analysis. Graphical results in HOBOware are shown in Figure 6.

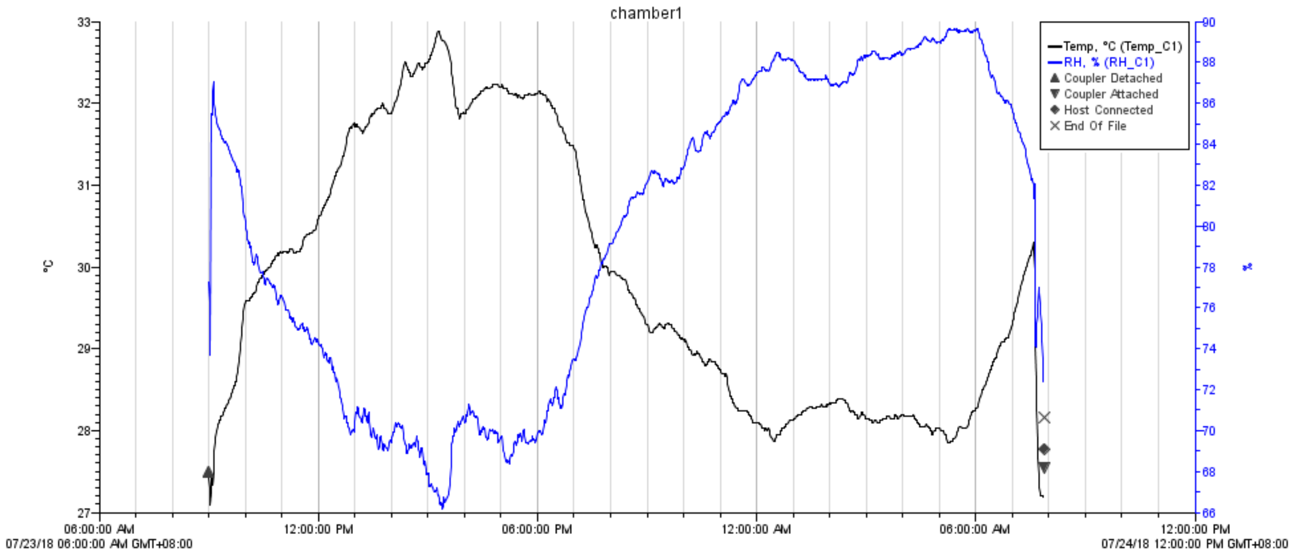


Fig. 6 – The result of HOBO thermo-hygrometer

After statistics in HOBOware, the number of minutes in Chamber 1 where the temperature is greater than 32°C is 3,844 minutes while that in Chamber 2 is 2,854 minutes during the 20-day experiment. The time of high temperature experienced by the chickens of Chamber 1 is 1.35 times as large as that of Chamber 2.

Wind speed measurement results

The wind speed data are measured at 30 points in Chamber 1 and Chamber 2 with Testo 450i and the specific results are shown in Table 2 and Table 3.

Table 2

The results of the wind speed measurement in Chamber 1 related to the inverters

Point	FOECI:10HZ FOICI: 0HZ	FOECI:20HZ FOICI: 0HZ	FOECI:30HZ FOICI: 10HZ	FOECI:40HZ FOICI: 20HZ	FOECI:50HZ FOICI: 30HZ	FOECI:50HZ FOICI: 50HZ
1	0.17	0.24	0.48	0.74	1.13	1.44
2	0.12	0.17	0.29	0.34	0.36	0.48
3	0.04	0.04	0.08	0.11	0.23	0.32
4	0.05	0.15	0.06	0.16	0.25	0.36
5	0.25	0.45	0.86	1.13	1.50	1.77
6	0.01	0.01	0.01	0.04	0.04	0.07
7	0.09	0.13	0.18	0.28	0.39	0.46
8	0.08	0.06	0.10	0.22	0.46	0.60
9	0.05	0.03	0.12	0.16	0.35	0.38
10	0.00	0.01	0.02	0.02	0.03	0.03
11	0.02	0.07	0.41	0.71	1.25	1.74
12	0.01	0.01	0.07	0.20	0.60	0.71
13	0.04	0.01	0.09	0.13	0.44	0.58
14	0.01	0.01	0.06	0.17	0.41	0.49
15	0.02	0.04	0.22	0.60	0.97	1.81

FOECI: frequency of external circulation inverter
FOICI: frequency of internal circulation inverter

Table 3

The results of the wind speed measurement in Chamber 2 related to the inverters

Detecting point	FOECI:10HZ FOICI: 0HZ	FOECI:20HZ FOICI: 0HZ	FOECI:30HZ FOICI: 10HZ	FOECI:40HZ FOICI: 20HZ	FOECI:50HZ FOICI: 30HZ	FOECI:50HZ FOICI: 50HZ
1	0.21	0.44	0.51	1.02	1.73	1.79
2	0.13	0.35	0.52	0.84	0.90	1.55
3	0.08	0.23	0.24	0.25	0.34	0.59
4	0.02	0.16	0.24	0.39	0.26	0.19
5	0.22	0.48	0.81	1.26	1.81	1.97
6	0.01	0.01	0.01	0.02	0.04	0.12
7	0.03	0.01	0.07	0.14	0.18	0.46
8	0.01	0.06	0.04	0.29	0.33	0.40
9	0.04	0.04	0.05	0.11	0.25	0.34
10	0.00	0.01	0.01	0.04	0.05	0.06
11	0.03	0.04	0.36	0.59	1.24	2.32
12	0.01	0.02	0.18	0.44	0.41	0.95
13	0.01	0.02	0.15	0.24	0.08	0.67
14	0.02	0.03	0.07	0.05	0.13	0.59
15	0.01	0.06	0.13	0.43	0.96	1.59

FOECI: frequency of external circulation inverter
FOICI: frequency of internal circulation inverter

Wind speed at air inlet and outlet during heat stress response at 32~34°C meets ventilation requirements of 1.78 ~ 2.03 m/s; this is also the reason why the chickens gather at air inlet and outlet during heat stress response.

Ammonia detection results

Ammonia is not detected since insufficient chicken excrement accumulates on the bedding at the early stage of the experiment. Table 4 shows the concentration of ammonia measured at each test point in Chamber 1 at a height of 10 cm from the ground on August 2, 2018. Table 5 shows the concentration of ammonia measured in chambers at a height of 10cm, 90cm and 180cm from the ground on August 6, 2018.

From Table 4 and Table 5, the ammonia concentration distribution also indicates that the chickens prefer to gather at the air inlet and outlet. According to the environmental quality standard of livestock and poultry farm of the Ministry of Agriculture, the ammonia gas concentration in the chicken chamber for chickens within 50 days should be less than 10ppm. After multi-point detection, the ammonia concentration value is less than 10ppm, meeting the breeding requirements.

Table 4

The ammonia concentration in Chamber 1 on Aug. 2, 2018

Height	Detecting point	Detecting value (unit: ppm)
10cm	1	2.5
10cm	2	1.5
10cm	3	2.0
10cm	4	1.5
10cm	5	0.5
10cm	6	1.5
10cm	7	1.5
10cm	8	1.0
10cm	9	1.5

Table 5

The ammonia concentration in Chamber 1 & 2 on Aug. 6, 2018

Height (cm)	Detecting point	Detecting value (unit: ppm)	
		Chamber1	Chamber2
10	1	6.0	4.5
10	2	3.5	3.8
10	3	4.5	4.5
10	4	4.5	5.0
10	5	5.5	4.0
10	6	5.0	4.0
10	7	4.0	6.0
10	8	4.0	4.5
10	9	4.5	4.0
90	1	4.0	4.2
90	2	3.8	3.8
90	3	3.0	4.0
90	4	3.8	4.0
90	5	3.5	3.8
90	6	3.0	4.0
90	7	3.8	4.5
90	8	3.5	4.0
90	9	3.0	4.0
180	1	4.0	4.0
180	2	3.8	4.0
180	3	4.0	4.5
180	4	4.0	3.8
180	5	4.0	4.0

$PM_{2.5}$ detection results

Statistical results after measuring $PM_{2.5}$ mass are shown in Table 6. Table 6 shows that in the daytime when chickens are active, the mass of $PM_{2.5}$ in the chicken chamber is much higher than that outside the chicken chamber, which is about three times higher. In the lights-out time for 6 hours when the chickens are sleeping, the $PM_{2.5}$ mass is measured to be much less than that of the chickens when they are active during the day, which is less than 10% of that during the daytime. Moreover, in the lights-out time at night, the $PM_{2.5}$ mass inside and outside of the chicken chamber is similar under the effect of air exchange.

Table 6

$PM_{2.5}$ mass per hour both inside and outside of the chambers during the daytime and lights-out time

Chamber Number	Daytime		Lights-out time	
	$PM_{2.5}$ mass per hour inside the chamber (unit: g)	$PM_{2.5}$ mass per hour outside the chamber (unit: g)	$PM_{2.5}$ mass per hour inside the chamber (unit: g)	$PM_{2.5}$ mass per hour outside the chamber (unit: g)
1	0.00180	0.00066	0.00015	0.00021
2	0.00249	0.00074	0.00020	0.00021

Weight of chicken

At the end of 20 breeding days, the yellow-feather chickens in Chamber 1 and Chamber 2 are weighed and the weight of yellow-feather chickens measured on the 1st and 20th day in each chamber is averaged, thus the weight gain rate is obtained using formula (1) as follows.

$$Growth\,rate = \frac{W_{after} - W_{before}}{W_{before}} \times 100\% \tag{1}$$

where:

Growth rate denotes the growth rate of chickens, W_{before} denotes the average weight of chickens before being put in Chamber 1 or Chamber 2, W_{after} denotes the average weight of chickens after being bred in Chamber 1 or in Chamber 2 for 20 days.

After calculation, the final result is obtained as shown in Table 7.

Table 7

Statistical result of chickens weight gain in Chamber 1 & Chamber 2

Chamber number	The average weight of chickens on the 1st day (unit: g)	The average weight of chickens on the 20th day (unit: g)	Growth rate
Chamber 1	217.0	399.7	84.22%
Chamber 2	215.9	420.2	94.64%

CONCLUSIONS

At the end of the 20-day experiment, there is no mortality of yellow-feather chickens due to heat stress or air quality problems and the following conclusions are obtained via the experiment.

(1) The heat stress response will slow down the growth of broilers and change the colour of excreta. Under the effect of the ventilation system, yellow-feather chickens will have slight heat stress response at 32 ~ 34^{o}C, but not life-threatening. If the ambient temperature of the chicken chamber keeps 32^{o}C above for a long time, the chickens grow slowly. If the ambient temperature is controlled within 32^{o}C, the chickens grow faster.

(2) When proper bedding and feed are selected and reasonable ventilation management system is set, the concentration of ammonia gas and $PM_{2.5}$ can be effectively reduced, the air quality in the chicken chamber can be improved, so that the normal growth of yellow-feather chickens can be guaranteed. It also suggests that this kind of small chicken chamber is easy to carry out precision control and the health of chickens can be further guaranteed.

ACKNOWLEDGEMENT

This work was supported by China Postdoctoral Science Foundation (2015M571782), the Fundamental Research Funds for the Central Universities of China (KYTZ201661), and Jiangsu Agricultural Machinery Foundation (GXZ14002).

REFERENCES

[1] Al-Masad M., (2012), Effects of Vitamin C and Zinc on Broilers Performance of Immunocompetence Under Heat Stress, *Asian Journal of Animal Sciences,* Vol. 6, Issue 2, pp. 76-84, Dubai/UAE;

[2] Al-Saffar A., and Rose S., (2002), Ambient temperature and the egg laying characteristics of laying fowl, *World's Poultry Science Journal,* Vol. 58, pp. 317-331, Cambridge/England;

[3] Beker A., Vanhooser S., Swartlzander J. et al., (2004), Atmospheric ammonia concentration effects on broiler growth and performance, *Journal of Applied Poultry Research,* Vol. 13, Issue 1, pp. 5-9, Savoy/USA;

[4] Chen F., (2014), Research on particulate matter and harmful gas concentration in cage layer house, *Kunming University of Science and Technology*, Kunming/China;

[5] Cheng L., Wu Y., Wang Y., et al., (2015), Effect of manure cleaning method on air quality in layer house and the physicochemical properties of manure, *China Poultry,* Vol. 37, Issue 18, pp. 22-27, Jiangsu/China;

[6] Du Y., Pang L. and Wang Y., (2016), Research and application of "precise" ventilation technology for laying hens, *Poultry Science,* Vol. pp. 25-27, Shandong/China;

[7] Farooqi H., Khan M., Khan M. et al., (2005), Evaluation of betaine and vitamin C in alleviation of heat stress in broilers, *International Journal of Agriculture & Biology,* Vol. 7, pp. 744-746, Faisalabad/ Pakistan;

[8] Kocaman B., Esenbuga N., Yildiz A. et al., (2006), Effect of environmental conditions in poultry houses on the performance of laying hens, *International Journal of Poultry Science,* Vol. 5, Issue 1, pp. 26-30, Dubai/UAE;

[9] Li Q., Wang-Li L., Shah S. et al., (2014), Ammonia concentrations and modeling of inorganic particulate matter in the vicinity of an egg production facility in southeastern USA, *Environ Sci Pollut Res Int,* Vol. 21, Issue 6, pp. 4675-4685, Berlin/ Germany;

[10] Lin T., Shah S., Wang-Li L., et al., (2016), Development of MOS sensor-based NH3 monitor for use in poultry houses, *Computers and Electronics in Agriculture,* Vol. 127, pp. 708-715, Oxford/England;

[11] Liu Y. and Li B., (2015), Research progress of welfare-oriented breeding mode and technical equipment for laying hens, *Transactions of the Chinese Society of Agricultural Engineering,* Vol. 31, Issue 23, pp. 214-221, Beijing/China;

[12] NY/T388-1999*, Ministry of Agriculture*, Beijing/China;

[13] Robins A. and Phillips C., (2011), International approaches to the welfare of meat chickens, *World's Poultry Science Journal,* Vol. 67, Issue 02, pp. 351-369, Cambridge/England;

[14] Wu P., (2013), Research about variation of semi-open sheds in different seasons on environmental parameters and its effect on the performance of laying hens *Hebei Agricultural University*, Hebei/China;

[15] Xing H., (2015), Effect of ammonia in house on lipid metabolism of broilers, *Chinese Academy of Agricultural Sciences*, Beijing/China;

[16] Yang W., (2016), Detection and analysis of components of airborne microbes and $PM_{2.5}$ in poultry house, *Shandong Agricultural University*, Shandong/China;

[17] Yuan J., Zhang K. and Hu X., (2007), Study on the effect of environment factors on the growth of broiler chickens, *Journal of Domestic Animal Ecology,* Vol. 28, Issue 16, pp. 135-138, Shaanxi/China;

[18] Zhao F., Luo Y., Zhang L., et al., (2014), Effect of roof with ceiling on air quality in laying house, *China Poultry,* Vol. 36, 10 10, pp. 25-28, Jiangsu/China.