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Full Length Research Paper

Ventilation system design for poultry buildings

Ali Abdulqader Mohammed Ali Al-Zaidi

Al-Qasim Green University, Iraq.

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ABSTRACT

The environmental conditions inside the poultry building have a significant impact on animal health. The ventilation system is a key factor in the environment features. This work seeks to find a standard method to calculate the main aspects of ventilation systems. A building (120 m long, 12 m wide and 4 m average height) was selected as an example in this research. As the fans were the key elements of the ventilation system so there is an essential request to define the number of fans and their capacities. These fans running are controlled by either timer or thermostat. Selecting the inlets gates will encourage a significant impact on ventilation efficiency. The translation ventilation and tunnel ventilation were calculated. The evaporative cooling was investigated and the size pads were determined as well as considered as a part of the ventilation system.

Keywords: Ventilation, poultry building, fans, inlets, tunnel, thermostat.

Email: ali1010400@gmail.com.

INTRODUCTION

Poultry production is one of the most important aspects that hold too much significance in developing the living level for people (Ali and Al-Shuhaib, 2021). As a consequence of the increasing population over the world, the request for poultry production has increased rapidly. The successful poultry productions project depends on many factors such as feeding, water supply, diseases, vaccines, and the chicken house environment. The house environment parameters for poultry like spaces, light, humidity and fresh air have a significant effect on the production efficiency (Alchalabi, 2013). Ventilation is the key factor in the chicken house environment. In addition to aiding on decrease the extravagances of humidity, temperature, and air pollution to an acceptable rate for kept birds (Esmay, 1978). Perfect quality ventilation systems aid to increase the density of animals per square meter in poultry buildings; consequently, it has a positive economic impact by declining production costs and efforts (Cao et al., 2017). The ventilation system takes away extra heat, moisture, odors, and dust from the house and also, reduces airborne disease viruses and bacteria. However, it changes with the season, wind, hour of the day, humidity, temperature, chicken density and age (Reece and Lott, 1982). When air is not interchanged in a closed construction where chickens are kept, the air composition will defect and this will affect animals' health (Andersson, 2014). The rate of CO_2, ammonia and other deleterious gases will upsurge to undesirable heights. The main job of the ventilation system is to bring oxygen required to sustain life from the outside and elimination of lethal gases.

Ventilation ought to be utilized to remove extra moisture from the poultry court. Good ventilation promotes health by decreasing relative humidity and avoids condensing the moisture on the ceiling and walls (Augsburger et al., 1980). When the house is heated, the air volume is expanded in and can carry extra moisture. The amount of supplementary heat and ventilation requests are affected dramatically by insulation type. It decreases heat gains or losses via the ceiling and walls preventing condensation and decreasing the extra heat necessities. The insulation efficiency is defined by its insulating capability(R) -value as shown in the equation below:

$$R= \frac{1}{f_i} + \frac{x}{k} + \frac{1}{f_o}$$

The optimum insulation for a chicken building is governed by many factors, like the kind of materials and its thermal conductivity (K) and thickness of walls and ceiling(x) and they have a strong relation to local climatic conditions thereby the fuel cost (Big Dutchman, ND).

There are generally two types of ventilation systems (natural air movement system and mechanical air flow (fans)). Depending on variable ventilation requirements, both systems are an attempt to offer comfort to the birds all through variable climatic circumstances at the lowest cost.

Powered air drive is a compulsory ventilate of court in different climatic conditions. This system uses fans which consider a key element to refresh the air in the chicken house. They can be classified into two kinds, positive and negative pressures (Purswell et al. 2011).

In the system of negative pressure, electric fans are designed to expulse air from the house, they make a negative pressure or partial vacuum in the building. The pressure difference drives new air via inlets gates into the building. The inlets must distribute equally from place to place on the walls of the house. The place, size and spreading of the inlets and fans are critical to ensure that all parts of the building are to be ventilated. While the positive pressure system utilizes electric fans to deliver air into the house. The pressure relief causes air movement via louvers or other outlets. Many positive pressure systems are applied in the buildings. One of these drives warm air into the building and mixes it with internal air all over the building. In another type, push the warm air around the house via plastic or metallic ducts with outlets.

This work aims to:

i. Calculate the minimum ventilation?
ii. Calculate the transition ventilation?
iii. Calculate the tunnel ventilation?
iv. Calculate the number of inlets?
v. Calculate the size of pad cooling?

MATERIALS AND METHODS

In any ventilation system, there are three major elements: (1) the required fans to transfer the air through the building, (2) air outlets and inlets in addition to (3) controls (timers and thermostats) to control fan operation.

When selecting fans for a precise ventilation system, the differences in climatic conditions ought to be considered as well as the type of ventilation system that they will be utilized. Good-quality devices should be selected that can operate under hard conditions. Generally, it is recommended to choose bigger rather than smaller fans to provide the necessary ventilation. A safety factor is ensured in situations with any emergency fan stopping during the operating period. Also, costs of operating can be decreased by selecting superb quality motors of the fans.

Inlets and outlets

The amount of air exchange is defined by the fans however; the uniformity of air distribution is determined by the design, location and adjustment of the air inlets.

Controls

Fans are commonly controlled by thermostats or thermostats in arrangement with timers. One or more single-speed fans are controlled by a single-stage thermostat and will run the fan when the temperature rises and then switch off when the air temperature decline to a required level. Fans with motor-operated shutters must be controlled by the exact thermostat to guarantee their working at the same time.

Due to the fans are not normally run always in a cold climate, the interval timer allows discontinuous running of one or more fans. A thermostat connected with the timer overrun the system at what time more ventilation is required to eliminate extra heat.

RESULTS AND DISCUSSION

A chicken house with stander dimensions (120 m long, 12 m wide and 4 m average height) was selected as a sample in this research. The results are shown below:

Minimum ventilation

The minimum quantity of ventilation (air volume) is to preserve excellent vital activities by guaranteeing an acceptable amount of oxygen with eliminating the waste gases from the house. The requirements of an acceptably run minimum ventilation system include moisture extraction, the oxygen provision to ensure the animals' metabolite requirements and, the relative humidity control. The minimum ventilation should be self-regulating of any control system of temperature and done best if worked a cycle timer by a temperature exceeded.

In the first stage, the air must be changed every 8 minutes to avoid an increase in toxoid gases over the acceptable vale (Table 1) that has a negative impact on birds' health and activity.

House volume = 120 × 12 × 4 = 5760 m^3
House air change every 8 minutes = house volume / 8 = $\frac{5760}{8}$ = 720m^3/min
If fan with 900 mm (36 inch) capacity was chosen = 345 m^3/min
So the number of fans required = amount of air change in 8 min/ fan capacity = $\frac{720}{345}$ = 2.08

Therefore, two fans (900 mm running) in the first stage of minimum ventilation are needed. The fans should work not on a thermostat but on a timer. These fans should have a specific capacity and not changeable the running speed. The fans' capacity on the timer must be capable to offer a full air exchange every eight minutes.

The second stage of minimum ventilation ought to be capable to do an air exchange every five minutes and work not on a timer but a temperature thermostat only. These fans must be a 900 mm stable volume and not changeable speed. The number of fans must be defined at this stage.

Table 1. Gas concentrations in a chicken building.

Gas	Dangerous	Needed
Carbon dioxide (CO_2)	<30%	>1%
Methane (CH_4)	<5%	>1%
Ammonia (NH_3)	<500 ppm	>40 ppm
Hydrogen Sulfide (H_2S)	<500 ppm	>40 ppm
Oxygen (O_2)	>6%	<16%

In this step, the air exchange every 5 min = house volume/ 5 min = 5760 m^3/ 5 min=1152
If fan capacity is chosen, it should be 900 mm (36 inches) fan to provide 345 m^3/min.
So the number of fans required = 1152/345 = 3.3 or 4 fans

The highest level of Co_2 at any time in the birds' building should not exceed 3000 ppm if the house environment exceeds this value, then the ventilation rate ought to be bigger. It is very important to ensure that there is no infiltration of air from the walls or doors because this penetration can cause a drop in temperature and increase wetness near the ground

Inlets

The inlets should open sufficient size to reach the required airflow and static pressure. The smallest opening size of 2.5 to 5 cm is recommended. Inlet drive motors must be fixed in the center of the sideways wall and the wire should be with solid 8 mm (0.3) inch steel rods. The inlet trap should be at least thirty percent bigger than the inlet cross-sectional area to avoid the request to open the whole inlet. It is essential to ensure that the air moves to the center of the building where without that the cold air will move directly to the chickens and causes several problems including the request for extra heat power as shown in Figure 1.

To determine the number of inlets needed take the number of fans and multiply by the amount of air in one fan capacity:

If you choose fan capacity for 900 mm (36 inches) fan = 345 m^3/min
So the number of fan required = 1152/345 = 3.3 or 4 fans.
Quantity of fans approximately of fan capacity = 4 × 345 = 1380 m^3/min
1380 × 60 = 82800 m^3/hr

In this case, we will use an inlet capacity of 1420 m^3/hr (light trap) from Table 2. Where the light trap provides less amount of air compared with other types.
So, 82800/1420 = 58.3 inlets approximately 58 inlets, you need to spec inlet 25% higher to prevent inlet from ever reaching 100% of capacity

$$58 \times \frac{125}{100} = 72\ inlet/2 = 36\ inlet\ in\ each\ side$$

In the ventilation system, the cold air coming from outside must move to the highest point of the building to mix with the warm air and then move down (Figure 2), whereas if the cold air move directly to the floor that will increase the heating energy cost (Figure 3).

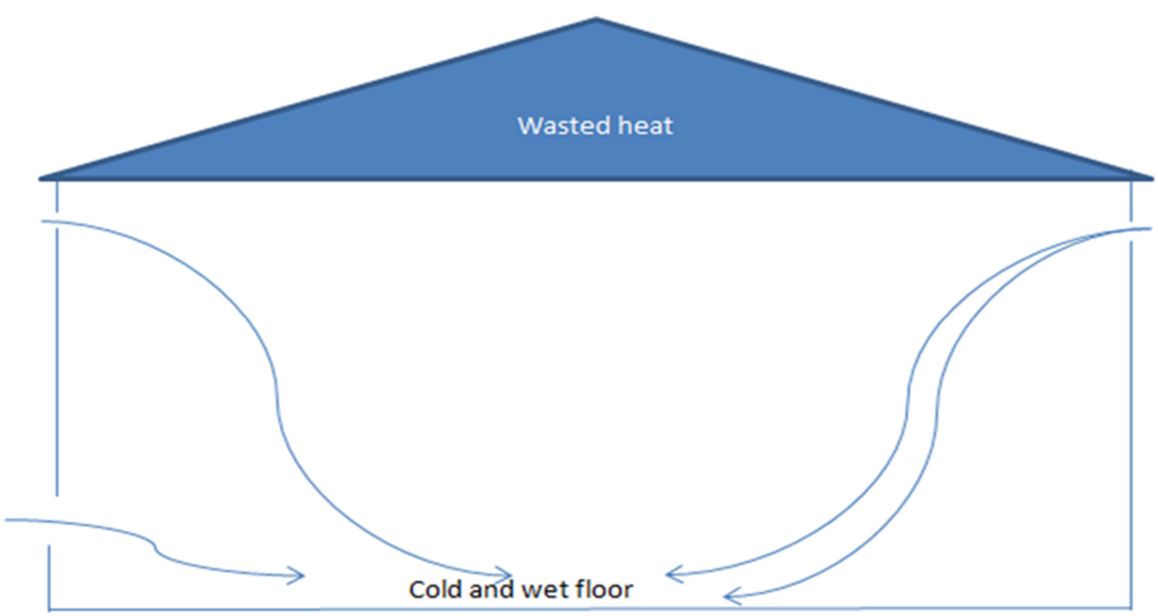

Figure 1. Effect of air movement to the floor.

Table 2. Types of inlets performance with different pressure value (m^3/h).

Type	CL1911F	CL1233	CL1229	CL1224	CL1220	CL 1200B/F	CL1211F	With light trap*
Code no.	**60-44-31**	**60-44-3153**	**60-44-3149**	**60-44-3149**	**60-44-3140**	**60-43-3009**	**60-44-311**	**60-43-3064**
10 pa	1750	1350	1280	1250	1200	1000	1000	990
20 pa	2500	2500	1940	1800	1700	1450	1450	1420
30 pa	3050	2300	2170	2120	2050	1700	1700	1680
40 pa	3550	7000	2550	2490	2400	2000	2000	2000

With light trap all inlets of CL1200 series have the same air performance.

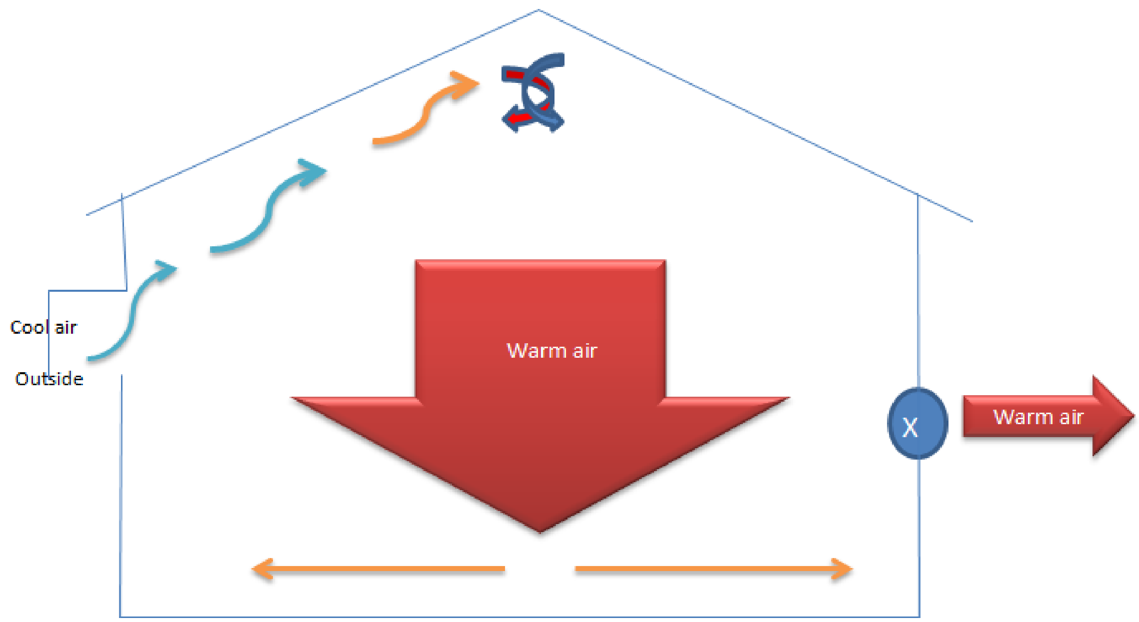

Figure 2. Crossflow for minimum ventilation (correct).

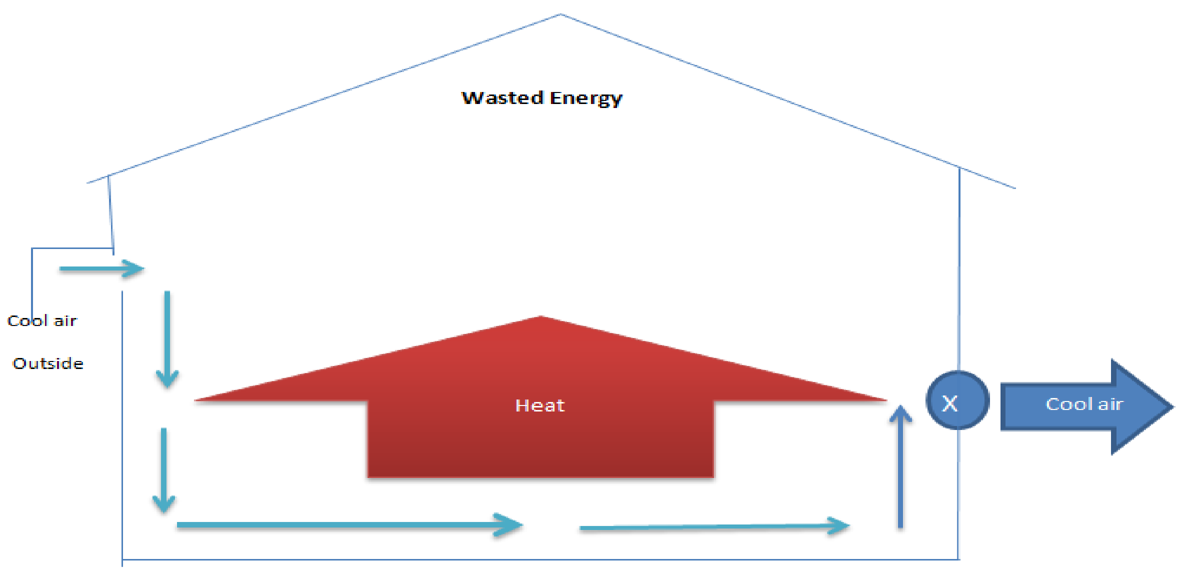

Figure 3. Crossflow for minimum ventilation (incorrect).

Transitional ventilation

Transitional ventilation usually includes about fifty percent of the full capacity of tunnel ventilation. These electric fans work with a thermostat. The operating capacity of these fans has capable to guarantee a building air exchange every two minutes. It uses sidewall inlets uniformly distributed on each sidewall. They are equally distributed on each side wall along the total length of the building. The inlets are best efficient when controlled using negative pressure. The inlets should transport the air into the top of the building to avoid cold air drive across the floor and the birds. Using fans on a single end of the building and inlets equally located on each side of the building, the higher velocity of air across the chickens will be a quarter of that reached in full tunnel ventilation. In the last step of transition or full transition, the channel inlet will open.

Translation ventilation calculation

The building volume 120 × 12 × 4 = 5760 m^3
The capacity of a fan for belt drive 1.2 m fan which is equal to 600 m^3/min
Building air exchange every two minutes

$\frac{5670 \text{ m}^3}{2}$ = 2880 m^3/min

4.8 m^3/minute or five fans (1.2 m fan) = $\frac{2880 \frac{m^3}{\text{min}}}{600 \frac{m^3}{min}}$

Tunnel ventilation

In tunnel ventilation systems, all fans are located at one end of the building and air suppliers on the opposite side. The air is defined at 2.5 m/s velocity over the length of the building removing dust, heat and moisture. A wind-chill effect is created by the airflow, which can decrease the effective temperature by about 5 to 7°C. The building's effective temperature should be kept at less than 30°C and a full air exchange should happen within 1 min. The best fans suitable for a tunnel ventilation system are great capacity belt-driven 1.2, 1.3 and 1.4 m diameter fans. Tunnel fans operate under high static pressure.

Tunnel ventilation calculation

Step 1: Determine basic house dimensions 1200 mm or 48 inches, operating capacity of 600 m^3/min. (about 21180 cfm)
Cross-section: 12 m wide × 4 m average height = 48 m^2
Necessary airspeed should be at 2.5 m/s
Necessary exchange should be less than 1 min

Step 2: The capacity of fan necessary for a maximum airspeed of 2.5 m/s
Required capacity of fan: 48 m^2 × 2.5 m/s = 120 m^3/s
The number of 1.2 fans required: $\frac{120m^3}{\frac{10m^3}{s}}$ = 12 fans

Evaporative cooling

Evaporating cooling must not be applied when the relative humidity is higher than 75%. The cool pad of the building house should not be smaller than 0.6 to 1 m wide. The cooling pads must be in a minimum of 30 cm (12 inches) from the inlet curtain. Keep erect water intake from direct daylight to decrease algae outgrowth. Connect the pump to the center of the pads to increase the uniformity of pressure and pad wetting. The evaporative system must not work before all the tunnel fans are running to guarantee accurate air distribution and evaporation. Evaporative cooling must only be used when the temperature is 28°C (82°F). Pad cooling at least 20.5 m for each side for all farms.

Calculation of evaporative pad air requirement

To find air speed requirement of a cool pad
15 cm pad - < 1.8 m/s
10 cm pad - < 1.25 m/s

Step 1: Determine basic house dimension
Cross-section = 4 m average height × 12 m wide = 48 m^2
Needed airspeed, 2.5 m/s
The needed air exchange should be least than 1 min.
The total fan capacity = 48 × 2.5 = 120 m^3/s
The total pad area required = 120/1.8 = 66.6 m^2
66.6/1.5 = 44.4 m^2/s = 22 m^2 for each side.

CONCLUSION

The fans in the ventilation system must be selected with an identified power and capacity. They should be distributed uniformity to ensure the at all air will exchange within the specific time. Thermostats and timers were used in the ventilation system. The main aim of this operation is to maintain the level of oxygen and other gases at an acceptable ratio. There are several kinds of the inlet are used in ventilation systems for poultry houses. The path of air movement from outside to inside the building has a significant impact on birds' health and heating costs. It is must move to the top of the building first and mix with the (warm) air then drop toward the floor.

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