AUTOMATIC FAN CONTROL TO REDUCE FAN RUN TIME DURING WARM WEATHER VENTILATION

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Primary Audience: Ag Extension Agents, Poultry Company Service Managers

SUMMARY

Every summer in the southeastern U.S., many broilers die from heat stress due to a combination of high temperature and high humidity. Managers tend to ventilate open-sided broiler houses during summer primarily with large fans that use a large amount of electricity. In theory, if the wind velocity in the houses exceeds 2.0 miles per hour (mph), broilers receive adequate natural ventilation and can be reared safely without fans. However, a system is needed to activate fans when wind speed and direction are inadequate to remove metabolic heat and moisture production. Research was initiated to develop a system for summer rearing that could automatically turn fans off when the wind velocity exceeded 2.0 mph. Two separate wind monitoring devices were interfaced with fans of a curtain-sided broiler house that turned fans off when sufficient wind was present for natural ventilation. Proper interior conditions (monitored continuously during testing) were maintained while the recorded average fan run-time was reduced by as much 50%.

Key words: Broiler house, electric power, ventilation

DESCRIPTION OF PROBLEM

Summertime ventilation of open-sided broiler houses is accomplished primarily with large fans. Years ago, fans were commonly set to push air across the house or diagonally at 45-degree angles and air changes occurred continuously. However, fans today are sometimes aligned with the long axis of the house. With this arrangement, the fans are being used as circulation fans (or stirring fans) with air changes occurring when sufficient wind is present [1]. In both cases, fans are primarily controlled by thermostats traditionally set at 80 to 85°F. In poultry-producing southern states, recorded weather [2] indicates that frequently, summer temperatures remain close to fan setpoints and fans run almost continuously even at night. Also, recent suggestions, if followed, would have fans running continuously for the final weeks of rearing during the summer. Hunton [3] stressed the importance of

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moving air continuously through the house into the cool night and recommended a fan thermostat setting of 68°F to ensure that fans run long into the evening and provide extra cooling. Mauldin et al. [4] reiterated this line of thought and stated that during hot weather, it was critical to continue to move air through a broiler house during the cool parts of the day and night. With a 68°F setting, fans would run all night on many summer nights in the South. In a Poultry Times article by Moore [5], a service representative was quoted as saying that during the heat of summer in their conventional houses "we have to run the fans all night."

A broiler house commonly used to rear 20,000 birds in the southeastern U.S. is 40 ft wide, 400 ft long, and has a 5 to 6-ft curtain opening the full length of the house. In theory, the natural ventilation rate equals the area of side opening multiplied by the wind velocity. However, an additional factor must be included for the effectiveness of the side opening. For winds perpendicular to the wall, this factor is between 0.5 and 0.6 [6]. For example, with a wind of 2.0 mph and an effectiveness factor of 0.5, each bird in a typical broiler house would receive approximately 10 cubic feet per minute (cfm) of ventilation air. This value is above any recommendation or design criteria [1, 6, 7]. This situation would suggest that with a sustained 2.0 mph or greater wind, fans would not be needed. A 2.0 mph wind may not provide the high velocity experienced in front of a fan, but not all birds have access to the area directly in front of a fan at any one time. The 2.0 mph criteria is just the minimum, and a wind of much higher value may provide a velocity sufficient to enhance heat loss. The design velocity for a tunnel house (400 ft/min) is only 4.5 mph and, with a normal velocity profile, is somewhat less at bird level.

A steady, constant wind is not common because it often swirls, gusts, and changes direction. Therefore, natural ventilation is inherently both unreliable and inconsistent and should never be relied upon entirely. Dykes [8] doubted the feasibility of using natural ventilation and stated that no one can advise exactly how and when to use natural ventilation. Only a limited ability in predicting natural ventilation rates has been provided to date [7, 9, 10]. Yet there are times when wind speed remains above an acceptable minimum and also within an acceptable angle to the side of the building. In the poultry-producing states of the Southeast, the annual wind speed averages over 8 mph [2], and research has shown [11] that when the wind is in excess of 2.0 mph, the potential exists to operate safely without fans. However, what is needed is a sensing and control system to automatically interrupt power to fans when both wind speed and direction are adequate to remove the heat and moisture produced by the birds. Hybrid ventilation systems employing automatic control of natural ventilation have been reported [12, 6]. These systems were comprised of automatic inlet slots or hinged panels controlled by thermostats or differential pressure sensors. Controlling fan operation was of secondary importance with these systems.

It should be noted that the concept being discussed does not universally apply to all the broiler houses in the country. While most newly constructed houses in the southern broiler-producing states are curtain-sided houses, a majority of these houses are not being operated as open-sided houses. They are being operated as tunnel-ventilated houses. But the newer houses that are not operated in the tunnel mode still amount to a substantial number of houses, and there are many thousands of older houses that have not been converted to tunnel ventilation. Also, some small percentage of tunnel-ventilated houses are versatile enough to operate as open-sided (fan-ventilated) houses during mild times of the year. The concept applies to these houses.

The object of this research was to develop and test a system to be used during the final weeks of warm weather broiler rearing that could automatically turn fans off when wind velocity exceeded 2.0 mph. Conversely, the fans should be restarted when wind velocity drops below this level.

**MATERIALS AND METHODS**

Two separate wind-speed sensors were interfaced with the fan relays of a curtain-sided broiler house. The sensors and associated circuitry periodically interrupted the power to the large ventilation fans. The house used was a 36 x 80 ft curtain-sided broiler house with a 5.5 ft sidewall opening. The long axis of the house was oriented east and west, and four
fans were positioned to push air across the house with curtains kept open. In each of two trials conducted during consecutive summers, between 3250 and 3500 male broilers were reared during the hottest months of the summer. Mortality was recorded daily and a random sample of one hundred birds was weighed each week. Instrumentation for the house included an electric meter and a grid network of dual-function temperature and relative humidity sensors [13].

The first device (used in Trial 1), called a "sail switch," was a hanging pendulum or paddle which could operate switches at either end of its travel (Figure 1). The pendulum was made of 1/2" thick rigid styrofoam insulation measuring 5.75" x 4.25". Hung vertically from a shaft, it was free to swing both north and south, the predominant directions of wind at the location. The paddle was sized to swing over to a mechanical stop (at about 15 degrees from vertical) with a 2.0 mph wind blowing perpendicular to the paddle. A small magnet was embedded in the side of the styrofoam near the bottom so that when the pendulum would swing full (either direction), the magnet would close one of two small reed switches positioned alongside each mechanical stop. The reed switches controlled a large relay to interrupt power to the ventilation fans (Figure 2).

The action of the paddle in the wind was tested using a variable speed fan; and "wind speed" (air velocity) was checked with a hot wire anemometer. The pendulum assembly (with reed switches) was placed in a square wire cage and mounted outside the house above the peak of the roof. This device was constructed from items found in the shop and a few electronic components purchased from local vendors. The value of the materials (primarily electronics) has been estimated at about $100.00.

For this trial, 3250 male broilers were placed in the house in early summer at 3 wks of age and reared to 8 wks of age on litter with feed and water provided ad libitum. While most broilers are reared only 6 weeks, some are reared to much heavier weights for the "cut-up" market. These heavy birds presented challenging conditions to the concept of supplementing forced ventilation with natural ventilation. The stocking density was 0.82 ft²/bird. Four 30" diameter belt-driven fans were positioned to push air across the house with curtains open.

The second device (used for Trial 2) was a commercial wind speed and direction sensor (Figure 3). The device was a propeller-driven transducer which produced an AC voltage signal with a frequency proportional to wind speed. A signal conditioner converted the

FIGURE 1. Trial 1 wind sensor (sail switch) as mounted on the roof of the curtain-sided broiler house
FIGURE 2. Schematic diagram of the sail switch with the time delay relays used to shut fans off in the presence of a wind of at least 2.0 mph

FIGURE 3. Trial 2 wind speed and direction sensor (propeller device) as mounted on the roof of the curtain-sided broiler house
variable frequency to a voltage so that an output of 0 to 5 VDC corresponded to a wind speed range of 0 to 100 mph. The low-speed threshold of the transducer was 0.5 mph. A wind speed calibration curve was provided with the instrument and was confirmed using a variable-speed fan with "wind speed" (air velocity) measured with a hot-wire anemometer. The directional transducer was a potentiometer which produced 0 to 5 VDC corresponding to 0 to 360 degrees of rotation. These two outputs fed directly to the computer and were read continuously (Figure 4). Readings over a 15-second period were averaged to smooth gusting and brief direction changes. This device gave the added parameter of wind direction, in contrast to wind speed alone sensed by the sail switch. The device was a wind monitor model RE, manufactured by the R. M. Young Company, Traverse City, MI [14]. Its purchase price was $456.00. The price of the additional circuitry has to be included in any total cost estimate, and that cost may have been as much as an additional $100.00.

The averages of both parameters were analyzed by the computer to determine whether a sufficient combination of wind speed and direction were present to operate without fans. An arbitrary "window of acceptance" was established which would permit fans to be turned off if the wind speed was at least 2.0 mph and the wind direction was within 45 degrees from due north or due south (Figure 5). All other combinations were considered insufficient and fans remained running. The sensor assembly was mounted above the broiler house on the roof peak where the sail switch had been mounted.

For Trial 2, 3500 male broilers were placed in the house in early summer as day-old birds and were reared to 6 wks of age on litter with feed and water provided ad libitum. Stocking density was 0.82 ft²/bird. Included in a refurbish/upgrade measure, fans were changed. The new fans were 28" diameter direct-driven fans with plastic blades. Four of them were positioned to push air across the house with the curtains open.

![Figure 4. Schematic diagram of the wind speed and direction sensor (propeller device) with computer time delay relays used to shut fans off in the presence of a wind of at least 2.0 mph with an angle of 45 degrees from due north or south.](image-url)
Both systems were designed for the same purpose and therefore shared some common components in the control circuitry. Included in the circuitry of both systems were emergency override thermostats and time delay relays to preclude rapid cycling of fans during gusty conditions [15].

RESULTS AND DISCUSSION

Trial 1, using the sail switch, demonstrated the potential for augmenting forced ventilation with natural ventilation. Results, in general, indicate that controlling the fans with this device for the final weeks of rearing resulted in an average reduction of 44% of fan run-time. Based on the potential to run continuously for twenty-four hours, fans in Trial 1 ran 56% of the time.

Figure 6 is a continuous picture of ambient temperatures, interior temperatures, and fan run-time for a single summer day during the final weeks of rearing. On the day recorded, the broilers were 7 wks of age and had an average weight of 4.9 lb. Temperature was plotted using the left "Y" axis and fan run-time was plotted using the right "Y" axis. Both temperatures are typically cyclical, with the interior temperature almost always a few degrees higher than ambient during the later weeks of broiler rearing. Fan run-time is the series of straight lines plotted from point to point. The points represent the percentage out of the last 15 minutes the fans operated. (An explanation which also applies to the remaining figures.)

Early in the day recorded, the ambient temperature fell to 71°F and then rose to a high of 94°F. Close examination of Figure 6 provides an idea of temperatures and wind conditions at various times throughout the day. The fans ran approximately one-third of the time from midnight to 4:00 A.M., but lack of wind caused substantial fan run-time from 4:00 to approximately 7:00 A.M. From mid-morning until early afternoon, windy conditions prevented fan operation much of the time. Lack of wind during mid-afternoon caused fans to
FIGURE 6. Ambient temperatures, interior temperatures, and fan run-time for a single summer day (Trial 1 with sail switch) with 7-wk old broilers. Average wind speed was 2.6 mph and fans ran 40.1% of the time.

Figure 6 shows that there were three distinct periods during the day when the wind velocity was low enough to require the use of fans. In general, the interior temperature was maintained within a few degrees of ambient throughout the day.

For Trial 1, the broilers reached a final weight of 5.5 lb in eight weeks with a feed conversion (weight of feed consumed divided by weight gain) of 2.24. During this test, ambient temperature ranged from 65°F to 95°F, and inside temperature was maintained within 2 to 3°F of ambient. During this trial, the inside temperature never increased enough to cause the high temperature override, arbitrarily set at 98°F, to run the fans automatically.

Trial 2 was used to test the wind speed and direction device with the computer logic. Results indicated that controlling the fans with this system for the final weeks of rearing resulted in a reduction of 51% of fan run-time. Based on the potential to run continuously for twenty-four hours, fans in Trial 2 operated 49% of the time. These results cannot be compared directly with Trial 1 because this flock was reared the following summer.

Figure 7 shows a day with broilers at 4.5 wks of age. Average wind speed for the day recorded was 3.6 mph, and the fans ran 24.8% of the time. Figure 8 resulted from data recorded the day before the broilers were processed. Average wind speed recorded for this day was 2.4 mph, and the fans ran 17.6% of the time. Ambient temperature was quite high this day, and the fans ran very little during the hottest hours of the day. Figure 9 is somewhat unique in that it illustrates one of the hottest days experienced during these tests. Ambient temperature rose to a high of 103°F. The broilers were over 5 wks of age and the average...
FIGURE 7. Ambient temperatures, interior temperatures, and fan run-time for a single summer day (Trial 2 with propeller device) with 4.5-wk old broilers. Average wind speed was 3.6 mph and fans ran 24.8% of the time.

FIGURE 8. Ambient temperatures, interior temperatures, and fan run-time for a single summer day (Trial 2 with propeller device) with 6-wk old, market-weight broilers. Average wind speed was 2.4 mph and fans ran 17.6% of the time.
wind speed was only 2.3 mph. However, on this day fans operated only 59.4% of the time. During the middle of the afternoon, the high temperature override caused the fans to run, although the condition of wind speed and direction may have been sufficient to turn fans off.

For Trial 2, the broilers reached a final weight of 4.25 lb in six weeks with a feed conversion of 1.91. During this test, the ambient temperature ranged from 65°F to 105°F, and inside temperature was maintained within 2 to 3°F of ambient. Although sufficient wind was present at times on specific very hot days, it became apparent that a small amount of fan run-time was caused by the high temperature override.

When dealing with environmental studies involving wind, there may be no such thing as a typical day. The days depicted in the figures above were not typical; they were chosen because the data recorded were accurate and complete. The power required to run fans varies with the temperature of the air being moved. However, the fans in the research house would have used 64 kWh of electricity for 24 h if run continuously. This situation was true for both trials. It should be noted that one device could control the fans for several houses.

**CONCLUSIONS AND APPLICATIONS**

1. Natural ventilation is unreliable and inconsistent. However, periodically, when wind is sufficient to remove metabolic heat, it is possible to operate safely on hot days without fans.
2. The systems developed could automatically turn fans off when sufficient wind was present to ventilate a curtain-sided broiler house. Use of these systems did not result in excessive inside temperature.
3. When managers use either of the systems described above, overall fan run-time during the final weeks of rearing could be reduced by approximately 50%, and on days with sufficient wind, fan run-time could be reduced by as much as 75%.
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4. The simple sail switch offered lower initial cost and simplicity, while the commercial wind speed and direction sensor offered precise control, accurate wind speed determination, and the added input of wind direction.

5. These tests did not reveal which system was capable of saving the most electric power.

6. A typical commercial broiler house is five to six times larger than our research house. Based on the energy saving capability of the tested equipment and the size differential (and percentage increase in bird number), the potential savings of electricity to the industry could be as much as 3/700 kWh per house for the last three weeks of rearing.

7. A typical broiler farm has four houses. And depending on usage and demand, electricity for a rural farm in the South will cost about 6e per kWh. Based on this estimate for reduction in electricity usage, the potential savings could be as much as $800 to $900 per flock (all birds in four houses) when reared during the heat of summer. It appears possible that either device could be paid for after rearing a single flock.

8. The research house was located just north of a similar second house that was somewhat of a barrier to the prevailing wind. This would suggest that the system used in this research would work well on broiler houses even though they may be arranged in groups.

REFERENCES AND NOTES


13. Twenty-one of the dual function (temperature and relative humidity) sensors were placed at a height of 16 in at approximately equal spacing of 14 ft on center and connected to a desk-top computer. An additional sensor was placed outside the broiler house in a small weather station to record ambient conditions. All sensors were read in sequence and the values were averaged (after each reading) to represent inside temperature or relative humidity. Fan run-time was determined by continuously sampling the condition (open or closed) of the main relay providing power to all the fans. Fan run-time was reported as the percentage of a 15-minute period that this relay was closed. Electricity use was recorded with a standard kWh meter.

14. Trade names in this article are used solely to provide specific information. Mention of trade names does not constitute a guarantee or warranty by USDA and does not signify that the product is approved to the exclusion of other comparable products.

15. Common circuitry appears in Figures 2 and 4. As the sail switch or propeller device detected sufficient wind, a one-minute time delay would activate before turning off the fans. This procedure insured a sustained wind and prevented needless quick cycles. When the wind subsided, a four-minute time delay went into effect before the fans could be restarted. Experience with large broilers in this house demonstrated that when fans failed on a windless, hot, summer day, the temperature could rise as much as 10°F within twenty minutes [16]. Therefore, it was arbitrarily decided that without wind, the house could remain for four minutes without fans. If during the four-minute delay period, a sufficient wind were sustained for one minute, the four-minute time delay circuit would reset. A one-minute wind of 2.0 mph or more could sweep excess heat and moisture from the house. If, after four minutes without wind, as either the pendulum hung motionless vertically, or the propeller indicated a wind below 2.0 mph, the fans were restarted. As a precaution with both systems, a high temperature thermostat was wired to the main fan relay and would run all fans if the inside temperature rose above an arbitrary setting of 98°F. For Trial 1, wind speed was determined periodically using a thermocouple anemometer. For Trial 2, wind speed was recorded continuously using the propeller device.