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Minimum Ventilation Systems and their Effects on the Initial Stage of Turkey Production

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ABSTRACT

This study aimed at evaluating the live performance of turkeys during the initial stage of production (1-26 days of age) and to map the environmental variables inside turkey houses, such as temperature, relative humidity, CO_2 concentration, at two distinct minimum ventilation systems. House 1 (H1) was equipped with a negative-pressure ventilation system and House 2 (H2) was equipped with a positive-pressure ventilation system. This study was performed in commercial poultry houses, located in Francisco Beltrão, Paraná, Brazil, in June, 2008. A number of 14,000 turkeys toms at the same age, provided by the same local hatchery and were housed at a stocking density of 23 birds m^{-2}. Three 13 m^2 boxes with 300 turkeys each were placed inside the poultry houses. All treatments were assigned for the birds inside each of the three boxes. The poultry barns were virtually divided in eight equally distributed in areas where the environmental variables were recorded. The performance parameters measured were weight gain, feed conversion and mortality rate, recorded weekly. Analysis of variance and F-tests were performed to compare results within different environmental conditions, using MINITAB 14 statistical software. The ventilation systems did not significantly influence CO_2 concentrations ($p = 0.489$), whereas temperature ($p = 0.016$) and relative humidity ($p = 0.0001$) and feed conversion ($p = 0.001$) were significantly affected by ventilation system. Temperature and relative humidity in H2 (positive pressure ventilation system) was found to be less aversive than those in H1 (negative pressure system). Also, bids in H2 presented lower feed conversions than those in H1.

INTRODUCTION

During recent decades, fast-growing meat-type turkeys have shown significant improvements in growth performance, feed conversion and livability (Havenstein *et al.,* 2007), mainly as a result of progressive genetic selection. However, together with this improvement, there was a significant increase in heat production, with consequent problems in coping with extreme environmental conditions. For many years, research has mainly focused on the effects of environmental temperature and, to a lesser extent, of relative humidity (Yahav *et al.,* 1998) on the performance and thermoregulation of young and mature turkeys.

Good air quality in poultry houses requires cooling and/or heating systems capable of providing a balanced environment in terms of temperature and relative humidity. According to Senthilselvan *et al.* (1997), the incidence of respiratory disorders in humans that work in swine barns is a consequence of an unbalanced environment. Relative humidity and temperature may impact air quality by influencing the proliferation and survival of some pathogens, which may cause disease, animal welfare problems and performance impairment (Yalçin *et al.,* 1997; Wathes *et al.,* 1998).

Only recently there has been a shift of interest on the effects of ventilation rate (VR) on the thermoregulation and performance of turkeys. Yahav *et al.* (2009) studied the effects of different ventilation rates (VR) on the performance and thermoregulation of young turkeys exposed to constant environmental temperatures, and found that VR significantly affected live performance. The first few weeks post-hatch are crucial for subsequent growth and development of turkeys (Yahav *et al.,* 2011). Therefore, more studies are needed to help understanding how environmental factors affect the performance of domestic fowls, including turkeys.

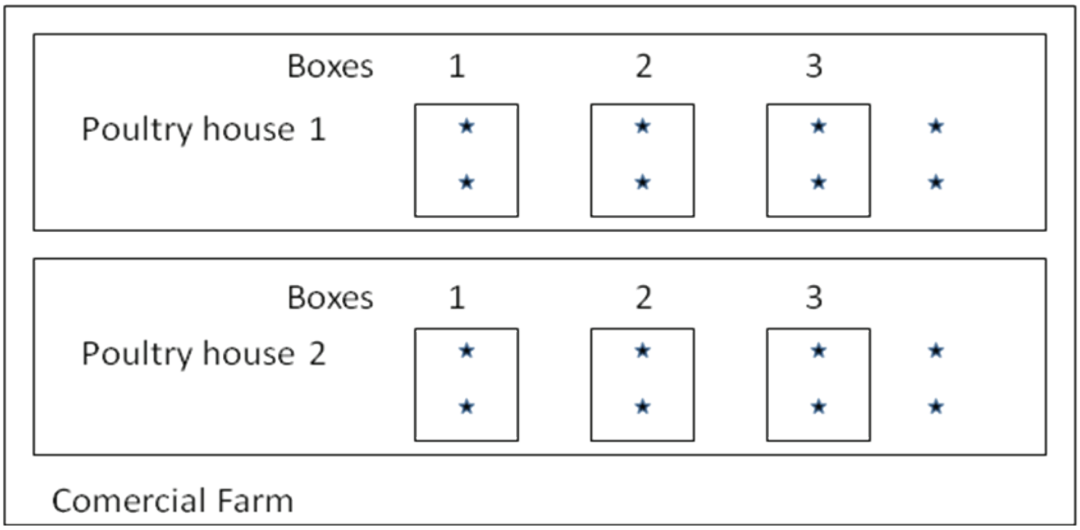

Figure 1 - Scheme of the top view of poultry houses 1 and 2, boxes and data logger positions.

Monitoring environmental variables, such as environmental temperature, relative humidity and gas concentrations, is essential for effectively controlling the physical environment inside barns where animals are reared. Animal heat and moisture production rates provide substantial information for the design and operation of mechanical ventilation systems (Gates *et al.,* 2005). Although there is limited literature available on heat and moisture production by turkeys, it is known that environmental variables inside poultry houses can be controlled by air exchange, which depends on the type of ventilation system used, as well as on its operation schedule (Goovaerts, 1997).

According Yahav *et al.* (2011), the VR range (expressed as air velocity, AV) that allowed optimal body weight gain widened as environmental temperature declined from 35 to 25°C, and the authors concluded that 30°C, combined with AV between 1.5 and 2.5 ms^{-1}, provided the optimal conditions for young turkeys.

Both brooding and finishing phases in turkey production require adequate ventilation systems in order to provide the fresh air required to maintain a good air quality, as well as to promote efficient operation of the cooling and heating systems. The ventilation system is one of the main factors that contribute for the establishment of an adequate environment inside poultry houses (Barber *et al.,* 1991; Wang *et al.,* 1999). Minimum ventilation can be provided both by positive and negative pressure systems, when the air is blown into the house or exhausted from the house, respectively. Both negative and positive pressure systems allow the removal of heat and excessive moisture, reduce dust and odors, controlling the build-up of harmful gases, such as ammonia and carbon dioxide, as well as supply oxygen for respiration (Bucklin *et al.,* 2009).

Therefore, studying the efficacy of ventilation systems is essential to improve productivity and promote good animal welfare. This study aimed at evaluating two types of ventilation systems and their effects on the environment inside turkey houses and on turkey performance during the brooding phase.

MATERIAL AND METHODS

Birds and husbandry

A total of 900 turkey toms obtained from the same hatchery were randomly distributed into three 13-m² pens with 300 birds each, placed in two commercial turkey houses that housed 14,000 one-day-old Nicholas turkey toms at a stocking density of 23 birds m^{-2}. The 900 experimental birds were housed at one day of age, and were reared until 26 days old. Birds had access to water and feed ad libtum three times a day: 7:00h, 12:00h and 17:00h.

This study was carried out in two 50.0 x 12.0 x 2.7-m identical commercial turkey houses, located in one farm in Francisco Beltrão, PR, Brazil. Turkey house 1 (NP) was equipped with a negative-pressure ventilation system, whereas turkey house 2 (PP) was equipped with a positive-pressure ventilation system.

Two 120 m³ min-1 fans were installed at the ceiling of each poultry house. The brooding system consisted of three wood furnaces inside each house. Figure 1 illustrates the location of the 13-m² pens (replicates) inside Turkey Houses 1 and 2, as well as the position of the data loggers.

All the fans inside the barns were programmed to operate identically, moving air at a rate of approximately 0.9 m³ s^{-1} per 10,000 birds each, as recommended by Nixey & Grey (1989) for 0.5 kg birds during the brooding phase. Table 1 shows the operation of fans inside the houses during the four experimental weeks.

Table 1 – Minimum ventilation operation program.

Weeks	Bird weight (kg)	Air flow rate* (m³/s)	Air flow rates* (m³/s)	Number of fans	Turned ON/OFF
1	0.14	0.3528	21.168	2	30s ON/297s OFF
2	0.33	0.8316	49.896	2	30s ON/114s OFF
3 and 4	0.6	1.5112	90.672	2	60s ON/100s OFF

*Circulated air for 14.000 birds.

Data recording and analysis

The following environmental variables were monitored: environmental temperature (T), relative humidity (RH), and CO_2 concentration. These variables were collected within eight virtual spaces, equally distributed in each house. Temperature and relative humidity were recorded by eight HOBO® data loggers, while CO_2 concentration was manually collected using an Indoor Air Quality Meter (model 8732, IAQ-CALC TM). All measurements were performed within each of the eight virtual spaces (Figure 1) at 40 cm from the floor. The HOBO® data loggers were programmed to record data every 30 minutes and the CO_2 concentrations were measured three times daily: 7:00h, 12:00h and 17:00h, according to the methodology suggested by Miragliotta *et al.* (2005). An extra data logger was installed outside of the houses, protected from sun radiation and rain, to record external environmental data.

Performance parameters, including average live weight, weight gain, feed conversion ratio, and mortality rate, were determined for each bird housed

Table 2 – Carbon dioxide concentration (CO_2, ppm), temperature (T, °C) and relative humidity (RH, %), collected at 8:00h, 12:00h and 17:00h, averaged per data collection date (June 7 - 26), according to ventilation system.

Ventilation system	Recording time	Variables	Date: Jun 7	Jun 14	Jun 15 - 21	Jun 22- 26
NP	8:00h	CO2	1833.5 ± 2.33	2918.3 ± 3.13	2939.1 ± 3.08	3663.4 ± 2.90
		T	22.6 ± 0.95	27.5 ± 0.99	27.4 ± 0.89	28.4 ± 1.01
		RH	63.3 ± 1.12	74.4 ± 1.09	75.5 ± 1.22	75.1 ± 1.32
	12:00h	CO_2	1520.1 ± 2.85	1730.2 ± 2.33	2473.8 ± 2.03	1557.4 ± 2.42
		T	29.2 ± 0.88	29.2 ± 0.91	27.6 ± 1.00	26.5 ± 0.99
		RH	51.2 ± 1.12	61.7 ± 1.54	66.5 ± 1.22	65.9 ± 1.22
	17:00h	CO_2	1704.9 ± 2.39	2272 ± 2.55	3233.5 ± 2.89	2257.3 ± 2.76
		T	29 ± 1.33	29.1 ± 0.33	27.5 ± 0.93	25.6 ± 1.03
		RH	51.1 ± 1.13	67.3 ± 0.83	72.9 ± 1.33	66 ± 1.33
PP	8:00h	CO_2	1747.7 ± 1.88	3228.2 ± 2.33	2925.1 ± 2.77	3751.4 ± 3.03
		T	23.5 ± 0.76	27.2 ± 0.93	28.3 ± 1.00	28.6 ± 1.11
		RH	54.9 ± 1.33	71.7 ± 1.78	70.7 ± 1.87	68.6 ± 1.39
	12:00h	CO_2	1406.4 ± 2.03	1717.2 ± 2.10	2185.9 ± 1.99	1900.4 ± 2.00
		T	29.9 ± 0.66	30.7 ± 1.33	28.2 ± 1.22	27.1 ± 1.42
		RH	47.2 ± 1.93	59.4 ± 2.02	61.2 ± 2.00	62.8 ± 2.00
	17:00h	CO_2	1827.1 ± 2.83	2609.8 ± 3.33	3142.8 ± 3.09	2466.4 ± 2.44
		T	29.4 ± 0.77	30.1 ± 1.33	28.8 ± 1.44	26 ± 1.19
		RH	48.8 ± 1.80	61.9 ± 2.00	68.8 ± 2.09	62 ± 2.33

in each pen. The feed remaining in the feeders after the birds were allowed to eat was weighed in order to determine feed intake in order to calculate feed conversion ratio. Feed and body weight were measured using a digital scale.

A completely randomized experimental design with three replicates (pens) per treatment (ventilation system) was applied. Environmental data were submitted to analysis of variance and the F-test was performed to compare means at 95% confidence level, using the statistical software Minitab, version 14.0 (Ryan *et al*., 1985).

RESULTS AND DISCUSSION

Table 2 shows the environmental data collected during 26 experimental days in both poultry houses (H1 and H2), whereas Table 3 shows the results of the analysis of variance of the environmental data. As shown in Table 3, ventilation systems did not significantly influence CO_2 concentrations. However, ventilation system affected temperature and relative humidity inside the turkey houses. Also, bird age (designated by date of data collection) and time of data collection significantly influenced all variables evaluated.

The results shown in Table 3 agree with those reported by Xin *et al.* (1998), who found that environmental temperature and relative humidity may vary according to the ventilation system used in male turkey houses. Seo *et al.* (2006) found that maintaining adequate and uniform environments inside large broiler houses may be difficult. According to Andonov *et al.* (2003) and to Mutaf *et al.* (2004), ventilation efficacy is related to the design of the ventilation system, which was observed in experiments with pigs. Wang & Zhang (1999) also reported that environmental temperature and air velocity are related to the type of ventilation system adopted. Moreover, ventilation efficacy is primarily affected by the type of ventilation system applied, followed by the effects of the fan operation program (Zhang *et al.,* 2001).

Klooster *et al.* (1993) compared positive-pressure with negative-pressure ventilation systems and concluded that the exhausting (negative-pressure) ventilation system was 40% more efficient in terms of environmental dust removal than the positive-pressure ventilation system. Wang (2000) observed that the average dust removal rate increased 196% when air outlets were correctly positioned.

Carbon dioxide concentrations were significantly influenced by bird age and recording time (Table 3). The lowest CO_2 concentrations were obtained at 12:00h, which was the time of the day when the curtains were most frequently opened and therefore, air was usually renewed. During the initial phase of the experiment, CO_2 concentrations were lower, as young birds produce less manure and present lower respiration rates than older birds. This result is consistent with the findings of Xin *et al.* (1998), who studied heat and moisture production in Nicholas turkeys during the five-week brooding-growing period and also found strong correlation between CO_2 concentrations both with bird age and body mass. Since turkeys are sensitive to high CO_2 and ammonia concentrations, ventilation systems must be well designed and effective; otherwise, young turkeys may become drowsy, reduce their water and feed intake, and therefore may present higher mortality rates (Boni *et al.,* 2007).

Independently of treatment, average CO_2 concentrations were within the recommended limits of 3,000 ppm (Noll *et al.,* 2003) and 2,500 ppm (Frame *et al.,* 1999) for turkey production. According to Gerritzen *et al.* (2006), turkeys can sense CO_2 at concentrations

Table 3 – Analysis of variance of the environmental variables: CO_2 concentration (ppm), temperature (T, °C) and relative humidity (RH, %).

	CO_2 concentration (ppm)			Temperature (°C)			Relative humidity (%)		
Component	DF	F	p	DF	F	p	DF	F	p
Ventilation system	1	0.48	0.489	1	5.8	0.016	1	35.22	0.000
Age	2	87.43	0.000	2	5.75	0.003	2	188.43	0.000
Hour	2	68.53	0.000	2	29.2	0.000	2	68.34	0.000
CV (%)	13.1			5.2			7.1		

DF = Degrees of freedom; F = F-value; p = p-value; CV = Coefficient of Variance.

of 2.3% and may suffer seizures at concentrations of 26%, which demonstrates the importance of adequate operation of minimum ventilation. However, Seedorf *et al.* (1998) states that the ventilation rates commonly used in animal housing may not be sufficient for maintaining adequate air quality, depending on litter management practices.

Environmental temperature was lowest at 8:00h in both treatments when birds were between one and 14 days of age. This indicates that the brooding system was not capable of supplying sufficient heat to cover the low heat generation of young birds when the external temperatures were lowest (8:00h). On the other hand, during the last experimental days, the highest temperatures were measured at 8:00h due to the higher heat production by the birds, and because side curtains were usually closed at this time of the day. This change in temperature inside poultry houses was also observed by Miragliotta (2005), who studied different broiler stocking densities and different ventilation systems inside broiler houses. The author found major differences between environmental temperature and relative humidity during the distinct heating phases in the barns.

In the current study, temperature was 25°C or higher for most part of the time (Table 3). Temperatures below 25°C are considered adverse for young turkeys, as suggested by Yahav *et al.* (2009), who found young turkeys housed below 25°C directed a significantly higher proportion of energy for body temperature maintenance, *i.e.*, they felt cold, irrespective of air velocity.

The positive-pressure house presented the highest environmental temperatures, independently of age or time of data collection (Table 2). This result suggests that the positive pressure ventilation system allowed for a greater mixing of the outside air with the heated air, which tends to stay close to the ceiling. This effective air mixing may have reduced heat loss, contributing to maintain environmental temperatures higher levels inside the PP house. On the other hand, negative pressure ventilation systems initially exhaust the previously heated air inside the barn, which may have contributed to lower temperatures levels in the NP house, which was equipped with a negative pressure ventilation system.

The environmental temperatures inside both houses (NP and PP) were not maintained within the optimal temperature range recommended in the guidelines by Nicholas Turkeys, Lewisburg, WV, USA. Still, the measured temperatures were within the turkeys' thermalneutral zone: first week (25 to 32 °C); second week (24 to 31 °C); third week (23 to 30 °C) and fourth week (22 to 29 °C). Menegali *et al.* (2008) found that both positive and negative pressure ventilation systems provided adequate environmental conditions for turkey production in Brazil, because the environmental temperatures inside the barns did not exceed the upper critical temperature of the turkeys' thermal comfort, which could impair bird performance (Van der Hel *et al.,* 1992).

The highest relative humidity levels were obtained at 8:00h, independently of age, because curtain opening was less frequent and external environmental temperatures were lower at this time of measurement. Also, humidity rates increased during the last two experimental weeks, as older turkeys produce more moisture and require less heating. Accordingly, Yahav *et al.* (1998) reported that 10 to 19-week-old turkeys can cope better with relative humidity challenges than younger turkeys, which emphasizes the need of a better control of moisture level for younger birds, avoiding humidity fluctuations during rearing.

Miragliotta (2005) observed higher moisture levels at lower temperature spots inside poultry barns and attributed this finding to the lower capacity of the air to hold moisture when temperatures are low. Average environmental conditions are usually within 50% to 70% the thermal comfort range of the birds (Miragliotta, 2005; Menegali *et al.*, 2008). However, in the present study, relative humidity levels exceeded the upper limit of turkeys' thermal comfort zone during the mornings of the last experimental days in both treatments (NP and PP). Because PP presented the highest temperatures, it also had the lowest relative humidity levels.

Table 4 shows the effects of treatments on average body weight, feed conversion ratio and mortality rates. Birds submitted to treatment NP were heavier and presented worse feed conversion and lower mortality rate compared with those submitted to treatment PP.

Table 4 – Analysis of variance of performance parameters.

Variable	Final weight (g)	Feed conversion (g/g)	Mortality rate (%)
Poultry House 1	804 ns	1335*	2.64 ns
Poultry House 2	759	1297	4.58
CV	1.28	7.6	0.28

* Significant at 95% confidence level by the F-test.
ns: not significant at 95% confidence level

These results agree particularly with those obtained by Menegall *et al.* (2008), who performed a similar study with broiler chickens and determined worse feed conversion and lower mortality rate when birds were reared in housed equipped with negative-pressure ventilation systems. Seo *et al.* (2006) also reported that ventilation system may impact the environment of animal houses. On the other hand, Feedes *et al.* (2003) did not find any influence of ventilation rate or air velocity on broiler mortality, as well as Weaver & Meijerhof (1991) did not find any effect of ventilation on mortality rate.

Zuidhof *et al.* (1993) found higher incidence of respiratory disorders in turkeys and lower O_2 concentrations inside barns with reduced air change rates. Feed conversion and weight gain were also better when brids were reared in houses with higher air exchange rates. As previously reported, the rate of air change has more impact on turkey performance than turkey stocking density (Janni *et al.*, 1989; Feedes *et al.*, 2003).

According Yahav *et al.* (2011), under diurnally-cycling conditions, it must be considered that using appropriate ventilation rates may partially offset the negative effects of environmental temperature. Also, Cordeau & Barrington (2010) stated that air temperature stratification was an important source of heat loss (25%) and that it needs to be corrected using ventilation systems capable of mixing the inside air.

Feedes *et al.* (2003) compared two different air exchange rates and reported that the average maximum temperatures on day 20 of the rearing period of broilers were 30.5°C e 30.0°C for the treatments with high and low air exchange rates, respectively. According to those authors, broilers reared in environments with low air exchange rates consumed more water, which suggests that these birds were close to experiencing thermal stress. Lott (1991) found that broilers submitted to heat stress consume more water, trying to reduce their elevated body temperatures. Also, Howlider & Rose (1989) found that broilers reared in environments with low air exchange rates increased their feed intake when mean environmental temperature was 21°C.

These results emphasize the importance of adequate operation of minimum ventilation systems in poultry houses, since minimum ventilation operation, as well as system design, depend on specific climatic data where the facility is located (ASRHAE, 1997). Wheeler *et al.* (2000) also emphasized that, although the heat loss should be kept in a minimum rate inside an animal facility, minimum ventilation practices are required to maintain proper control of environmental variables, such as relative humidity and temperature, as well as to provide good air quality with satisfactory bird performance.

CONCLUSIONS

The positive pressure ventilation system (PP) provided less aversive temperature and relative humidity conditions, and promoted lower feed conversion during minimum ventilation operation. Ventilation systems did not significantly influence CO_2 concentrations.

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