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REGULAR ARTICLES

Behavioral responses of turkeys subjected to different climatic conditions

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Abstract

I was evaluated the effect of seven different combinations of temperature, air velocity, and relative air humidity on the frequency and duration of eating, drinking, resting, cannibalism, dust bathing, scratching, ground pecking, shivering, and stretching behaviors of turkeys at three different ages. The combinations tested of temperature, relative air humidity, and air velocity were, respectively: 1 (22 °C, 50%, 1 m/s); 2 (26.2 °C, 73.2%, 0.45 m/s); 3 (26.6 °C, 71.2%, 1 m/s); 4 (28.9 °C, 72%, 1.4 m/s); 5 (31.1 °C, 85%, 0.45 m/s); 6 (34.1 °C, 82.1%, 1 m/s); and 7 (34.4 °C, 82.1%, 1.4 m/s) for three ages of birds (61, 96, and 131 days of age). Seven birds were housed per pen, at a density of 3 males/m^2, totaling 147 birds in the entire experiment. Each combination was applied for 5 days. The data were analyzed considering the number of times the bird performed the behavior and the time it performed (in seconds). Each pen was considered a repetition. A comparison of the medians was used to compare the treatments by each age. The results showed that young birds were more likely to suffer from the combination of low temperature and high air velocity, reducing their frequency of normal behaviors. Increased humidity at a low temperature raised the frequency of scratching, shivering, and cannibalism behaviors leading to poorer bird welfare. It is recommended that the temperature, relative air humidity, and air velocity combination of 26.6 °C; 71.2%; and 1 m/s, respectively, for young birds, and 22 °C; 50%; and 1 m/s, respectively, for older birds should be used.

Keywords Poultry farming · Caloric stress · Ethology · Thermal sensation

Hypothesis
- It is possible to define which temperature, velocity, and relative air humidity combinations are better for each of turkeys' ages
- Turkeys are sensitive to climatic environmental changes
- Animal welfare is associated with environmental comfort in turkeys

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Introduction

There is a great need for improvements in understanding the factors that influence the welfare of turkeys, not only due to the increase in public demand for guaranteed sustainable production systems that fosters management practices and consider wellbeing but also because this information is necessary to reduce the losses due to the low performance of the birds (Marchewka et al. 2013).

It is known that susceptibility to stress is one of the major problems in modern poultry farming, and some management practices end up causing chronic stress in birds that are housed under high density environments (Cheng et al. 2002). The stress caused by the intensification of production can lead to physiological changes (Wein et al. 2017) and behavioral changes (O'Connor et al. 2011).

Stress occurs when the animals' environment causes changes in body homeostasis, causing the organism to produce physiological responses aiming to reestablish this homeostasis (Mumma et al. 2006). When under heat stress, for example, birds seek to maintain their homeostasis through behavioral changes such as decreased locomotor activity, holding their wings away from their body, and increased respiration (Mack et al. 2011).

Considering social behavior, it is suggestive that the frequency and intensity of aggressive interactions, total social cohesion, and the extent of social vices can be used to assess well-being. In a previous study, it was found that feathered peccary (non-aggressive, aggressive without feather removal, and feather removal) was one of the main problems related to welfare in commercial turkey production (Marchewka et al. 2015). Aggressiveness and cannibalism within batches are consequences of the inadequate management of animals and factors such as low thermal comfort, illuminance, genetics, group size, and nutrition may influence the abnormal behavior of the animals (Gustafson et al. 2007).

The temperature and humidity are some of the physical factors that most influence bird performance, especially in feed efficiency and weight gain (Khan et al. 2011). The elevation of temperature and environmental humidity raise the body temperature of the birds, resulting in a reduction in food intake, growth rate, feed efficiency, and bird quality, accompanied by an increase in the mortality rate (Kucuk et al. 2003; Khan et al. 2011). Thus, the objective of this study was to evaluate the impact of the thermal environment (temperature, velocity, and relative air humidity) on the frequency and duration of the following typical commercial bird behaviors: eating, drinking, resting, cannibalism, scratching, ground pecking, shivering, and stretching.

Materials and methods

This study was carried out in the climatic chamber of the Laboratory of Thermal Comfort of the Faculty of Agricultural Engineering at UNICAMP. The climatic chamber used was built in masonry, with double walls and ceilings, and filled with expanded polyurethane for thermal insulation. It has dimensions of 5 m in length, 4 m in width, and 3 m in height, with a white tile interior and black rubber floor.

The control of temperature and relative humidity was electronic; the internal environment could be cooled to 5 °C and heat up to a temperature of 40 °C. The cooling of the environment was performed using an evaporator installed inside the climatic chamber (Serraf Model). The heating was performed using resistors installed behind the evaporator fans.

Temperature (T) and relative humidity (RH) control was computerized and pre-set by a specific software to program the desired T and RH levels. The air velocity control was performed manually, after a preliminary evaluation of the airflow into the chamber by the fans installed in it.

A total of seven combinations of ambient temperature (T), relative humidity (RH), and air velocity (Av), respectively, were evaluated: 1 (22 °C, 50%, 1 m/s); 2 (26.2 °C, 73.2%, 0.45 m/s); 3 (26.6 °C, 71.2%, 1 m/s); 4 (28.9 °C, 72%, 1.4 m/s); 5 (31.1 ° C, 85%, 0.45 m/s); 6 (34.1 °C, 82.1%, 1 m/s); and 7 (34.4 °C, 82.1%, 1.4 m/s) and birds aging 61, 96, and 131 days were used. Birds from a commercial integrator from Uberlândia (MG) were housed in pens at a density of 3 males/m^2 (final density of 37,5 kg/m^2), with each pen carrying 7 birds, each combination held three experimental units. A total of 147 birds were used during the whole experimental period. Each combination was applied for 5 days.

Before the beginning of the experimental period, the birds were subjected to T, RH, and Av thermoneutral conditions (22 °C, 50% and 0.5 m/s, respectively) for a period of 2 days, with the aim to minimize the stress of transporting the camera and changing between one climatic condition and another. Food and water were supplied ad libitum. In order to measure the T, RH, and Av, a Pacer® portable hygrothermometer was used. The measurements were taken in the center of the climatic chamber at 08:00 daily.

To monitor behavior of turkeys, video cameras with 2.45-mm lenses were installed inside the climatic chamber to observe the behavior of the birds without human interference. The methodology of data collection of animal behavior is proposed by (Marchant et al. 2001). Ten continuous minutes were monitored daily for each pen (each age), at two distinct times of the day, totaling 20 min daily per animal, and each bird was considered a repetition. The following behaviors were evaluated in commercial poultry: eating, drinking, resting, cannibalism, dust bathing, scratching, tickling, shivering, and stretching, according to the methodology proposed by Pereira et al. (2007).

The data generated were analyzed as total frequencies for observed behaviors and total time, regarding the duration (in seconds) of displayed behaviors. The data was analyzed through the medians ± 95% confidence interval since the data

did not present a normal distribution. In addition, the analysis of the means would not represent the actual observed behavior of the birds since the absence of a behavior was counted as zero. Medians were analyzed by the Kruskal-Wallis test ($P < 0.05$), when significance was observed the medians were compared by Dwass, Steel, Critchlow-Fligner Method, through statistical software SAS (University Edition 2.7 9.4 M5) (SAS, 1996) through the procedure PROC NPAR1WAY. The analyses were performed by separating the ages.

Results

Table 1 shows the values of the medians ± 95% confidence interval for the percentage of time the bird performed the evaluated behaviors. It was observed that the birds of 61 days of age did not perform behavior of eating when under combination 1, 4, and 5 being the lowest medians observed, differing from the combinations 2 and 3 where the birds presented higher frequency of this behavior.

Birds under combination 1 did not perform drinking behavior, which differed from combinations 6 and 7, and the drinking behavior for combinations 3, 4, and 5 differed from that of combination 6. There was an increase on the duration for resting behavior of the birds under combination 1, in relation to those under combinations 2 and 3. The higher median for cannibalism behavior was observed under combination 2, differing from combination 1. The birds under combination 1 have higher median for scratching behavior than the ones under combination 6. For the rest of the variables there were not observed effects of the treatments at 61 days of age. The

Table 1 Medians ±95% (confidence interval) of the number of times that the bird displayed the evaluated behaviors

Age	Variable	N	Com1		Com2		Com3		Com4		Com5		Com6		Com7	
61	Eating	7	0.0 ± 0.0	C*	4.0 ± 2.0	AB	4.0 ± 2.9	A	0.0 ± 0.8	C	0.0 ± 0.9	C	0.0 ± 0.4	C	1.0 ± 1.3	BC
61	Drinking	7	0.0 ± 0.0	C	0.0 ± 1.1	ABC	0.0 ± 0.6	BC	1.0 ± 0.5	BC	0.0 ± 0.8	BC	2.5 ± 1.4	A	2.0 ± 0.8	AB
61	Resting	7	2.0 ± 0.8	A	1.0 ± 0.3	C	1.0 ± 0.4	BC	2.0 ± 0.6	ABC	1.0 ± 0.5	ABC	2.0 ± 0.5	ABC	2.0 ± 0.8	AB
61	Cannibalism	7	0.0 ± 0.3	B	0.0 ± 1.8	A	1.0 ± 1.1	AB	0.0 ± 1.0	AB	0.0 ± 0.5	AB	0.0 ± 0.6	AB	0.0 ± 0.5	AB
61	Dust bathing [ns]	7	0.0 ± 1.4		0.0 ± 0.0		0.0 ± 0.0		0.0 ± 0.0		0.0 ± 0.9		0.0 ± 0.0		0.0 ± 0.0	
61	Scratching	7	2.0 ± 2.9	A	3.0 ± 1.2	AB	3.0 ± 2.7	AB	1.5 ± 1.1	AB	2.5 ± 1.1	AB	0.0 ± 0.5	B	1.0 ± 0.7	AB
61	Pecking litter [ns]	7	0.0 ± 0.0		0.50 ± 0.6		1.0 ± 0.9		1.0 ± 1.0		1.0 ± 1.3		2.0 ± 1.4		1.0 ± 0.7	
61	Shivering	7	0.0 ± 0.0	B	0.0 ± 0.4	A	0.0 ± 0.2	AB	0.0 ± 0.2	AB	0.0 ± 0.0	B	0.0 ± 0.0	B	0.0 ± 0.0	B
61	Stretching [ns]	7	0.0 ± 0.0		0.0 ± 0.3		0.0 ± 0.6		0.0 ± 0.5		1.0 ± 0.4		0.0 ± 0.2		0.0 ± 0.3	
96	Eating	7	1.0 ± 0.8	B	7.0 ± 4.6	A	1.0 ± 1.5	B	0.0 ± 2.2	B	1.0 ± 1.1	B	0.0 ± 0.8	B	1.0 ± 2.7	B
96	Drinking [ns]	7	1.0 ± 0.5		0.0 ± 0.9		0.0 ± 0.4		0.0 ± 0.2		0.0 ± 0.5		0.0 ± 0.9		1.0 ± 0.8	
96	Resting	7	2.0 ± 0.7	A	0.5 ± 0.5	B	1.0 ± 0.4	B	1.0 ± 0.5	AB	1.0 ± 0.4	AB	1.0 ± 0.7	AB	1.50 ± 0.8	AB
96	Cannibalism	7	0.0 ± 0.3	B	3.0 ± 2.5	A	0.0 ± 0.5	B	0.0 ± 0.5	B	0.0 ± 0.8	B	0.0 ± 0.7	B	0.0 ± 0.4	B
96	Dust bathing [ns]	7	0.0 ± 0.0		0.0 ± 0.0		0.0 ± 0.0		0.0 ± 0.0		0.0 ± 0.2		0.0 ± 0.3		0.0 ± 0.0	
96	Scratching	7	2.0 ± 1.3	AB	3.0 ± 4.7	A	2.0 ± 1.3	AB	2.0 ± 1.4	AB	1.0 ± 0.8	AB	0.0 ± 0.4	B	1.0 ± 3.0	AB
96	Pecking litter [ns]	7	2.5 ± 1.0		1.5 ± 0.7		1.5 ± 1.9		0.0 ± 0.7		0.0 ± 1.0		0.0 ± 1.2		2.0 ± 1.2	
96	Shivering [ns]	7	0.0 ± 0.2		0.0 ± 0.3		0.0 ± 0.4		0.0 ± 0.2		0.0 ± 0.0		0.0 ± 0.2		0.0 ± 0.3	
96	Stretching [ns]	7	0.0 ± 0.3		0.0 ± 0.4		0.0 ± 0.4		0.0 ± 0.3		0.0 ± 0.3		0.0 ± 0.2		0.0 ± 0.0	
131	Eating	7	1.0 ± 3.1	AB	4.5 ± 4.4	A	2.0 ± 2.3	AB	2.0 ± 1.5	AB	0.0 ± 0.8	B	0.0 ± 0.2	B	0.5 ± 2.2	AB
131	Drinking [ns]	7	0.0 ± 0.5		0.0 ± 1.1		0.5 ± 1.1		0.0 ± 1.0		0.0 ± 0.6		0.0 ± 0.4		0.0 ± 0.9	
131	Resting [ns]	7	1.0 ± 0.6		0.0 ± 0.4		0.5 ± 0.4		1.5 ± 0.6		1.0 ± 0.3		1.0 ± 0.7		1.0 ± 0.6	
131	Cannibalism [ns]	7	0.0 ± 1.2		1.0 ± 3.7		0.0 ± 1.5		0.0 ± 1.5		0.0 ± 0.5		0.0 ± 0.5		1.0 ± 1.9	
131	Dust bathing	7	0.0 ± 0.5	A	0.0 ± 0.0	B	0.0 ± 0.0	B	0.0 ± 0.0	B	0.0 ± 0.0	B	0.0 ± 0.0	B	0.0 ± 0.0	B
131	Scratching	7	0.0 ± 0.4	B	5.0 ± 2.0	A	2.0 ± 1.3	AB	2.0 ± 1.0	B	0.5 ± 1.0	B	0.0 ± 1.1	B	1.0 ± 1.1	B
131	Pecking litter [ns]	7	0.0 ± 0.8		0.0 ± 0.2		0.0 ± 0.5		0.0 ± 0.0		0.0 ± 0.5		0.0 ± 0.7		0.0 ± 1.0	
131	Shivering [ns]	7	0.0 ± 0.2		0.0 ± 1.3		0.5 ± 2.3		0.0 ± 0.2		0.0 ± 0.8		0.0 ± 0.9		0.0 ± 0.3	
131	Stretching [ns]	7	0.0 ± 0.3		0.0 ± 0.4		0.0 ± 0.2		0.0 ± 0.2		0.0 ± 0.0		0.0 ± 0.2		0.0 ± 0.3	

*Distinct uppercase letters in the same row differ significantly by Friedman's test. [ns] Non-significant. Comb1 22 °C, 50%, 1 m/s; Comb2 26.2 °C, 73.2%, 0.45 m/s; Comb3 26.6 °C, 71.2%, 1 m/s; Comb4 28.9 °C, 72%, 1.4 m/s; Comb5 31.1 °C, 85%, 0.45 m/s; Comb6 34.1 °C, 82.1%, 1 m/s; and Comb7 34.4 °C, 82.1%, 1.4 m/s

highest median for shivering behavior was obtained under combinations 1, 5, 6, and 7 in relation to combination 2.

At the age of 96 days, birds under combination 2 presented higher median for eating behavior, differing from all the other treatments. Birds under combination 1 presented higher median for resting behavior, differing from combinations 2 and 3. For cannibalism behavior, it was observed that birds submitted to combination 2 have higher median than the birds under the other treatments. Birds under combination 2 presented higher median than birds under combination 6 for scratching behavior. For the other behaviors, no statistical differences were observed.

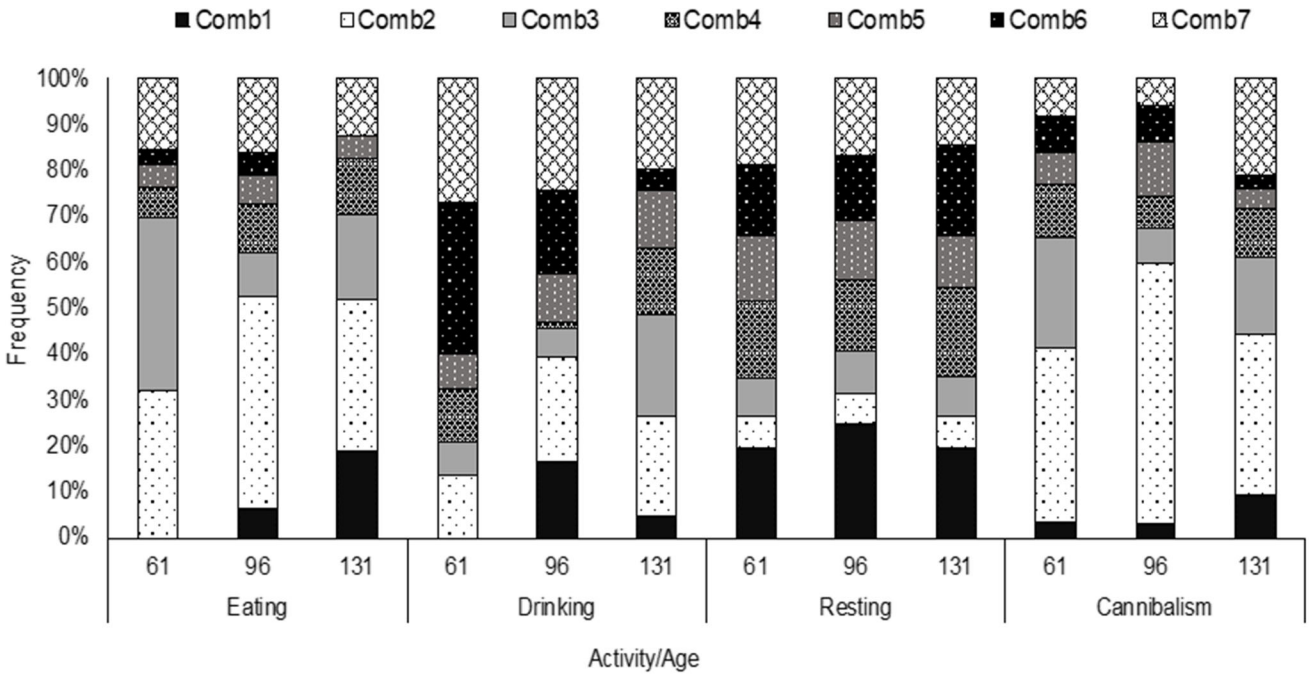
For the birds at the age of 131 days, it was observed a higher median for combination 2 in comparison to combinations 5 and 6 for eating behavior. Birds under combination 1 presented higher median than all other treatments for dust bathing behavior. Birds under combination 2 have higher median for scratching behavior than the ones under combinations 1, 4, 5, 6, and 7. For the other behaviors, no statistical differences were observed.

Figures 1 and 2 show the total percentage of times that the bird exhibited each behavior, separated by ages. Birds under combination 2 show higher frequencies of eating, cannibalism and shivering behaviors, regardless the age. Under combination 1, there are lower frequencies of eating and drinking behavior, with higher frequency of dust bathing for birds with 61 and 131 days old, as well as rest and bed ground pecking behaviors. It was under combination 3 that the birds presented most of the evaluated behaviors, except for dust bathing.

In Table 2 it is presented the medians with ± 95% confidence interval for the period in seconds of the behaviors displayed. At 61 days of age birds under combination 1 have higher median for drinking than under combination 2. Under combination 2, birds have lower median for resting when compared to combinations 1, 5, 6, and 7. It was also observed significant difference between the medians of combinations 3 and 5, being higher for combination 5. Birds under combination 1 have higher median for scratching behavior than the birds under combinations 6 and 7. For ground pecking, combination 1 have higher median than combination 2. For the other behaviors, no statistical differences were observed.

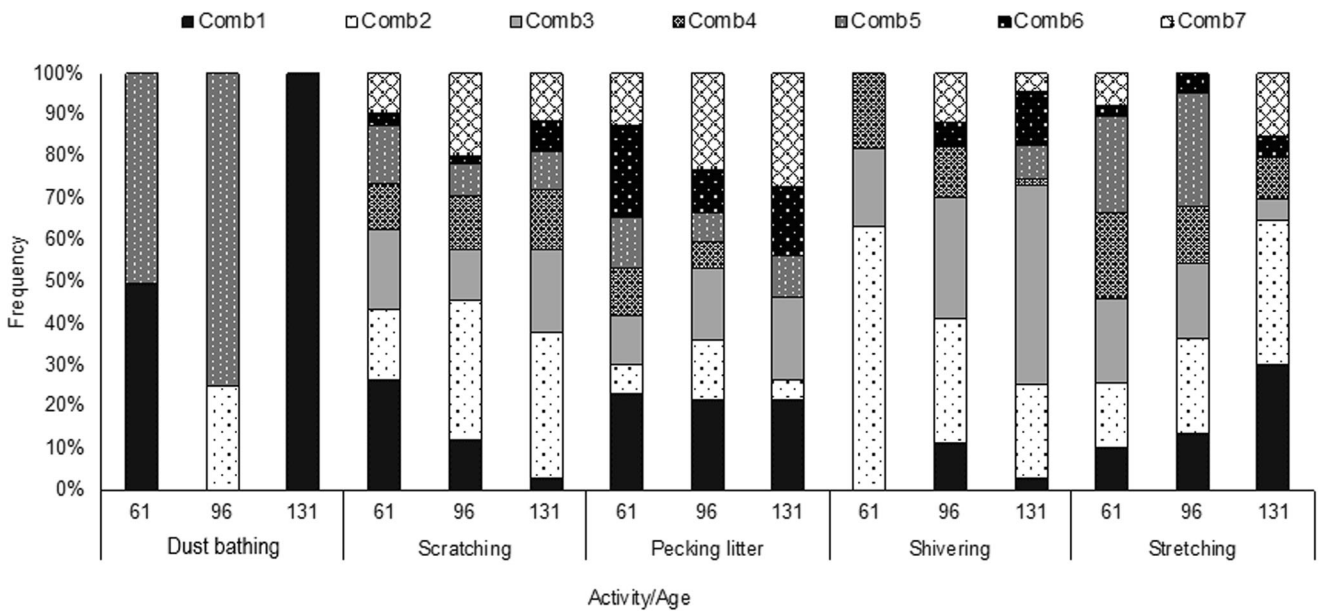
At the age of 96 days, it was observed an increase in the median of combination 1, when compared with combinations 3, 4, and 5, for drinking behavior. Birds under combination 2, 3, and 7 have lower medians than the birds under combinations 5 and 6, for resting behavior. For cannibalism and dust bathing behaviors, the medians under combination 2 are higher than for combinations 1, 3, 4, 5, 6, and 7. For scratching behavior, combination 6 have higher median than combination 2. For the other behaviors, no statistical differences were observed.

At the age of 131 days, birds under combinations 2 and 3 have lower medians than combinations 1 and 6, for resting behavior. Combination 1 have higher median than combination 2 for scratching behavior. For the other behaviors, no statistical differences were observed among the combinations tested.



Treatments: Comb1: 22 °C, 50%, 1 m/s; Comb2: 26.2 °C, 73.2%, 0.45 m/s; Comb3: 26.6 °C, 71.2%, 1 m/s; Comb4: 28.9 °C, 72%, 1.4 m/s; Comb5: 31.1 °C, 85%, 0.45 m/s; Comb6: 34.1 °C, 82.1%, 1 m/s; Comb7: 34.4 °C, 82.1%, 1.4 m/s.

Fig. 1 Total frequency of the displayed behaviors of eating, drinking, resting, and cannibalism, expressed in percentage



Treatments: Comb1: 22 °C, 50 %, 1 m/s; Comb2: 26.2 °C, 73.2 %, 0.45 m/s; Comb3: 26.6 °C, 71.2 %, 1 m/s; Comb4: 28.9 °C, 72 %, 1.4 m/s; Comb5: 31.1 °C 85 %, 0.45 m/s; Comb6: 34.1 °C, 82.1 %, 1 m/s; and Comb7: 34.4 °C, 82.1 %, 1.4 m/s.

Fig. 2 Total frequency of the displayed behaviors of dust bathing, scratching, pecking litter, shivering, and stretching, expressed in percentage

Figures 3 and 4 show total percentage of time of each behavior displayed, by age and for each combination. Birds at the age of 61 days did not present the behaviors of eating and drinking when submitted to combination 1. Birds under combination 2 spend more time dust bathing at the ages of 61 and 96 days; however, for the age of 131 days, this behavior was exclusively observed in birds under combination 1. Cannibalism was more frequent for older birds when submitted to combination 2. Birds under combination 3 have displayed more shivering behavior than all other combination. For the other behaviors, no statistical differences were observed.

Discussion

Behaviors such as running freely, ground pecking, scratching, flapping wings, grooming plumage, resting, and sleeping without being disturbed are signs of comfort and well-being for modern farmed birds (Bergmann et al. 2017). It can be observed that broilers raised in the free-range system spend approximately 60% of their time outdoors walking, scratching, dust bathing in sand, and pecking at the soil (Dawkins et al. 2003). Dawkins et al. (2003) reported that in conditions of thermal discomfort (high T and RH) the birds decrease the behaviors representative of well-being.

For turkeys, an increase in temperature and humidity leads to an increase in internal temperature, which is more pronounced in males than in females (Vermette et al. 2017). Consequently, we observed that older birds had a higher food intake when they were under combination 2 (T 26.2 °C, RH 79.2%, and Av 0.45 m/s) (Fig. 1), but with the increase in temperature and humidity in combinations 5, 6, and 7, food intake reduced.

For the younger, 61-day-old turkeys, combination 1 was detrimental because it inhibited food and water consumption as a result of the low temperature associated with high air velocity, which led to stress for the birds. It is known that in the initial phase of thermal stress, the postganglionic neurons and the medullary tissue of the adrenal glands release catecholamines, which are responsible for triggering the rapid release of glucose to maintain body homeostasis if the bird cannot (Puron et al. 1994; Khan et al. 2011).

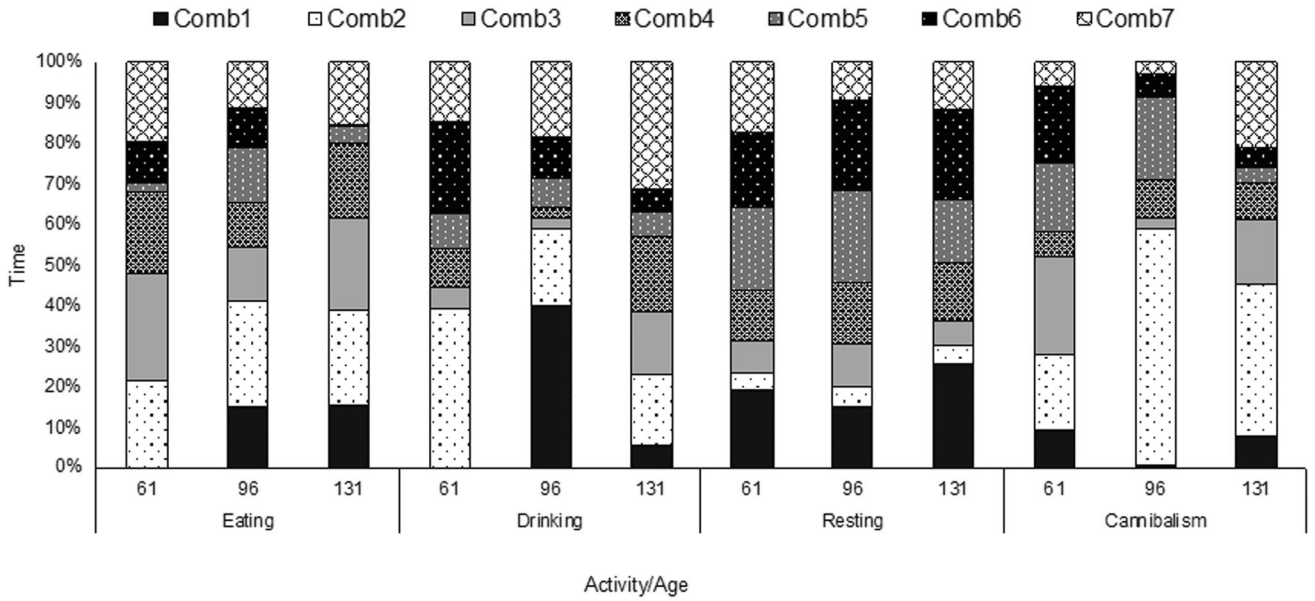
Therefore, it is important to point out that for young birds, the combined use of low temperature and an air velocity of 1 m/s or higher is not recommended, as it will inhibit the consumption of food and water. It is known that the combination of high-velocity, low-temperature air can induce cooling of the bird's body, which requires more energy for temperature maintenance, thus impairing performance and development, and compromising animal welfare. For birds aged 96 days, the combination 1 increased resting frequency possibly resulted from discomfort due to the association between T and Av.

In an experiment to test the effect of the association between temperature and air velocity, Yahav et al. (2008) tested the performance of young turkeys exposed at temperatures of 25, 30, and 35 °C, with air velocities of 0.8, 1.5, 2.0, and 2.5 m/s. The authors observed that birds exposed to 35 °C showed better food intake with an air velocity of 2.0 m/s and a lower body temperature than under higher temperatures. At 30 °C,

Table 2 Median ± 95% (confidence interval) of the time that the bird displayed the evaluated behaviors, expressed in percentage (%)

Age	Variable	N	Com1		Com2		Com3		Com4		Com5		Com6		Com7	
61	Eating [ns]	7	0.0 ± 0.0		29.5 ± 27.6		26.0 ± 42.6		0.0 ± 58.9		0.0 ± 10.5		0.0 ± 24.3		18.0 ± 36.2	
61	Drinking*	7	0.0 ± 0.0	B	12.5 ± 71.7	A	0.0 ± 10.8	AB	11.0 ± 12.6	AB	0.0 ± 30.6	AB	25.5 ± 37.7	AB	26.5 ± 14.3	AB
61	Resting	7	303.0 ± 119.2	AB	7.0 ± 73.1	C	169.0 ± 81.4	BC	207.5 ± 82.5	ABC	303.5 ± 98.4	A	277.0 ± 97.5	AB	257.5 ± 83.6	AB
61	Cannibalism [ns]	7	0.0 ± 7.5		0.0 ± 8.3		5.0 ± 8.3		0.0 ± 3.1		0.0 ± 7.7		0.0 ± 9.5		0.0 ± 2.6	
61	Dust bathing	7	0.0 ± 3.1	B	0.0 ± 18.5	A	0.0 ± 0.0	B	0.0 ± 0.0		0.0 ± 3.0	B	0.0 ± 0.0	B	0.0 ± 0.0	B
61	Scratching	7	54.0 ± 73.0	A	18.0 ± 32.3	AB	13.0 ± 20.6	AB	16.0 ± 30.1	AB	10.0 ± 29.7	AB	0.0 ± 2.7	B	8.5 ± 11.1	B
61	Pecking litter	7	33.5 ± 49.6	A	1.5 ± 7.2	B	6.0 ± 12.6	AB	2.5 ± 18.1	AB	2.5 ± 31.9	AB	23.0 ± 30.0	AB	15.0 ± 6.4	AB
61	Shivering [ns]	7	0.0 ± 0.0		0.0 ± 0.4		0.0 ± 0.5		0.0 ± 0.2		0.0 ± 0.0		0.0 ± 0.0		0.0 ± 0.0	
61	Stretching [ns]	7	0.0 ± 0.4		0.0 ± 0.5		0.0 ± 10.1		0.0 ± 0.8		1.50 ± 0.9		0.0 ± 0.6		0.0 ± 0.4	
96	Eating [ns]	7	11.0 ± 37.3		58.0 ± 44.8		9.0 ± 56.2		0.0 ± 42.0		54.5 ± 22.3		0.0 ± 34.7		20.5 ± 21.7	
96	Drinking	7	6.5 ± 17.4	A	0.0 ± 10.0	AB	0.0 ± 2.5	B	0.0 ± 3.6	B	0.0 ± 4.2	B	0.0 ± 6.3	AB	4.0 ± 8.2	AB
96	Resting	7	241.0 ± 90.4	AB	13.0 ± 67.7	B	122.5 ± 122.4	B	250.0 ± 95.2	AB	444.0 ± 92.0	A	515.5 ± 114.3	A	125.0 ± 83.8	B
96	Cannibalism	7	0.0 ± 0.5	B	16.0 ± 16.0	A	0.0 ± 1.1	B	0.0 ± 6.1	B	0.0 ± 8.6	B	0.0 ± 3.2	B	0.0 ± 1.2	B
96	Dust bathing	7	0.0 ± 0.0	B	6.5 ± 16.9	A	0.0 ± 0.0	B	0.0 ± 0.0	B	0.0 ± 0.3	B	0.0 ± 1.4	B	0.0 ± 0.0	B
96	Scratching	7	39.5 ± 38.4	AB	14.0 ± 53.2	A	25.0 ± 53.9	AB	58.5 ± 47.0	AB	6.5 ± 25.2	AB	0.0 ± 0.8	B	7.5 ± 13.3	AB
96	Pecking litter [ns]	7	35.5 ± 16.7		1.0 ± 9.6		4.5 ± 13.3		0.0 ± 13.4		0.0 ± 19.5		0.0 ± 28.1		42.5 ± 14.6	
96	Shivering [ns]	7	0.0 ± 0.2		0.0 ± 0.5		0.0 ± 2.3		0.0 ± 1.4		0.0 ± 0.0		0.0 ± 0.2		0.0 ± 0.8	
96	Stretching [ns]	7	0.0 ± 0.5		0.0 ± 0.7		0.0 ± 0.9		0.0 ± 0.7		0.0 ± 0.6		0.0 ± 0.2		0.0 ± 0.0	
131	Eating [ns]	7	7.5 ± 53.9		43.5 ± 67.8		19.0 ± 66.8		43.5 ± 43.7		0.0 ± 19.6		0.0 ± 3.2		2.0 ± 47.3	
131	Drinking [ns]	7	0.0 ± 9.4		0.0 ± 14.6		3.0 ± 11.0		0.0 ± 23.6		0.0 ± 5.1		0.0 ± 7.1		0.0 ± 35.2	
131	Resting	7	340.0 ± 93.0	A	0.0 ± 91.6	B	12.0 ± 84.9	B	229.5 ± 89.5	AB	180.5 ± 121.0	AB	300.0 ± 114.2	A	69.5 ± 110.5	AB
131	Cannibalism [ns]	7	0.0 ± 4.1		3.5 ± 13.8		0.0 ± 6.0		0.0 ± 4.9		0.0 ± 2.1		0.0 ± 2.8		3.5 ± 5.4	
131	Dust bathing [ns]	7	0.0 ± 21.3		0.0 ± 0.0		0.0 ± 0.0		0.0 ± 0.0		0.0 ± 0.0		0.0 ± 0.0		0.0 ± 0.0	
131	Scratching	7	0.0 ± 1.9	B	52.5 ± 33.6	A	17.5 ± 23.6	AB	11.0 ± 48.6	AB	10.0 ± 13.9	AB	0.0 ± 18.1	AB	31.5 ± 22.3	AB
131	Pecking litter [ns]	7	0.0 ± 16.3		0.0 ± 1.1		0.0 ± 5.3		0.0 ± 0.0		0.0 ± 6.3		0.0 ± 8.4		0.0 ± 14.7	
131	Shivering [ns]	7	0.0 ± 0.3		0.0 ± 11		2.5 ± 15.7		0.0 ± 1.2		0.0 ± 8.5		0.0 ± 8.9		0.0 ± 9.7	
131	Stretching [ns]	7	0.0 ± 0.9		0.0 ± 1.1		0.0 ± 0.3		0.0 ± 0.3		0.0 ± 0.0		0.0 ± 0.5		0.0 ± 0.7	

*Distinct uppercase letters in the same row differ significantly among themselves. [ns] Non-significant. Comb1 22 °C, 50%, 1 m/s; Comb2 26.2 °C, 73.2%, 0.45 m/s; Comb3 26.6 °C, 71.2%, 1 m/s; Comb4 28.9 °C, 72%, 1.4 m/s; Comb5 31.1 °C, 85%, 0.45 m/s; Comb6 34.1 °C, 82.1%, 1 m/s; and Comb7 34.4 °C, 82.1%, 1.4 m/s



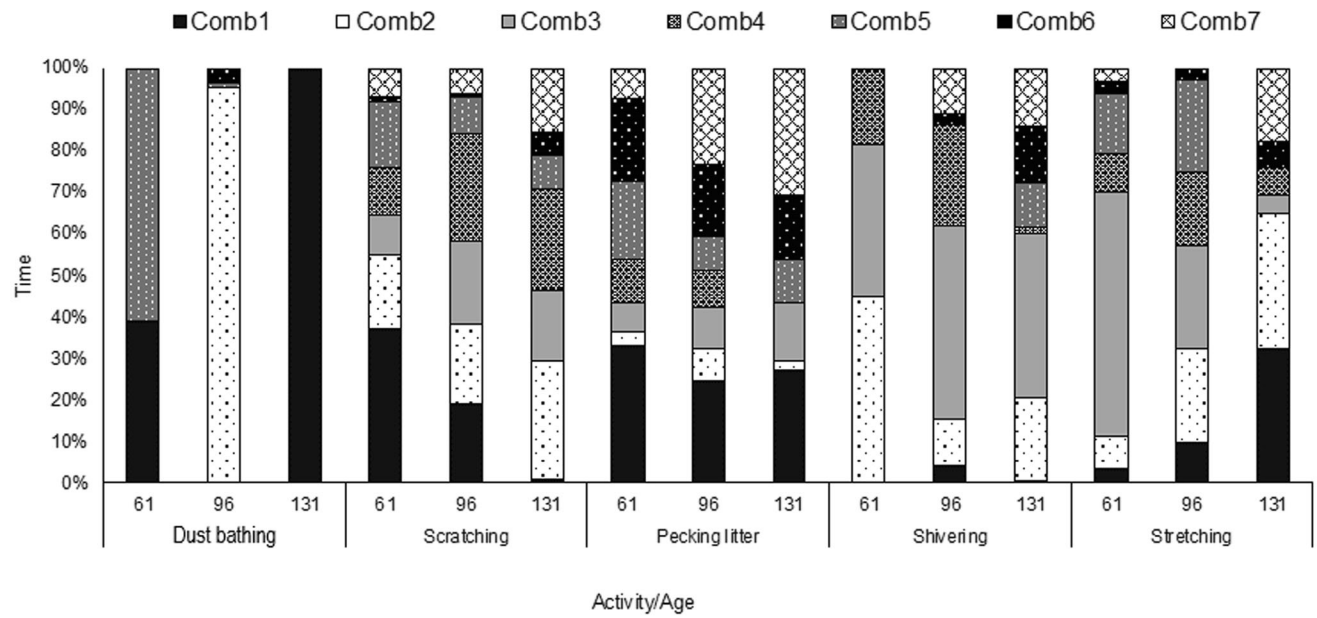
Treatments: Comb1: 22 °C, 50 %, 1 m/s; Comb2: 26.2 °C, 73.2 %, 0.45 m/s; Comb3: 26.6 °C, 71.2 %, 1 m/s; Comb4: 28.9 °C, 72 %, 1.4 m/s; Comb5: 31.1 °C 85 %, 0.45 m/s; Comb6: 34.1 °C, 82.1 %, 1 m/s; and Comb7: 34.4 °C, 82.1 %, 1.4 m/s.

Fig. 3 Total time of the displayed behaviors of eating, drinking, resting, and cannibalism, expressed in percentage

the birds' performance deteriorated with a speed of 0.8 m/s, but at 25 °C, the air velocity did not influence performance.

An important finding in the present study was the increase in cannibal behavior when the birds were subjected to combinations 2 and 5. It is believed that the increase in humidity associated with low air velocity in these combinations influenced this behavior more than the elevation in temperature. Another explanation might be the increase in the percentage of time the birds performed shivering and scratching behaviors, since an increase in these activities can damage the skin. In addition, the act of scratching or ground pecking may cause problems for feathers, and the increase in pecked feathers may be correlated with increased cannibalism (Mcadie and Keeling 2000; Cronin et al. 2018).

The older birds of 131 days of age subjected to combination 1 had a frequency of 100% for dust bathing behavior.



Treatments: Comb1: 22 °C, 50 %, 1 m/s; Comb2: 26.2 °C, 73.2 %, 0.45 m/s; Comb3: 26.6 °C, 71.2 %, 1 m/s; Comb4: 28.9 °C, 72 %, 1.4 m/s; Comb5: 31.1 °C 85 %, 0.45 m/s; Comb6: 34.1 °C, 82.1 %, 1 m/s; and Comb7: 34.4 °C, 82.1 %, 1.4 m/s.

Fig. 4 Total time of the displayed behaviors of dust bathing, scratching, pecking litter, shivering, and stretching, expressed in percentage

According to Sherwin and Kelland (1998), the main differences in the behavior of turkeys compared with other bird species are related to the absence of dust baths or soil scratches, which are commonly observed in broiler chickens or laying hens. Therefore, combination 1 for older birds may enable an unusual behavior.

Conclusion

In conclusion, young birds are more likely to suffer from the combination of low temperature and high air velocity and reduce their frequency of normal activities. Increasing humidity at low temperatures increases the frequency of scratching, shivering, and cannibalism behaviors leading to poorer bird welfare. For young birds, the T, RH, and Av combination of 26.6 °C, 71.2%, and 1 m/s, respectively, and the combination of 22 °C, 50%, and 1 m/s, respectively, for older birds is recommended.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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