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Impacto do sistema de climatização no desempenho zootécnico e no conforto térmico em aves jovens

Impact of acclimatization system on zootechnical performance and thermal comfort in young broiler chickens

Impacto del sistema de aclimatación en el rendimiento zootécnico y el confort térmico en pollos de engorde jóvenes

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Resumo

Controlar a temperatura ambiente dos galpões é freqüentemente difícil para os criadores; no entanto, é muito importante que o alojamento proporcione um ambiente térmico confortável para os pintinhos. Portanto, o objetivo deste trabalho foi comparar aspectos ambientais de dois sistemas de criação em frangos de corte de 1 a 21 dias, bem como a produtividade do lote durante o ciclo de produção (1-42 dias). O delineamento experimental foi em blocos casualizados, com dois tipos de galpão: um com sistema de pressão positiva e outro com sistema de pressão negativa. Os pesos médios aos 7, 14, e 21 dias foram medidos, assim como o peso final do abate e a conversão alimentar. Encontramos uma temperatura interna mais alta no sistema de pressão negativa em 7, 14, e 21 dias, mantendo as aves dentro da temperatura considerada ideal para o conforto térmico em suas idades. Em relação à umidade relativa, apenas aos 14 dias houve diferença entre os sistemas, nos quais o sistema de pressão negativa mantinha melhor umidade que o sistema de pressão positiva. Ambos os sistemas mantiveram a temperatura dentro da faixa recomendada para a idade dos pintinhos; no entanto, houve diferenças entre os sistemas nos dias 7 e 21. A umidade da cama mostrou diferença apenas aos 14 dias de idade; no entanto, ambos os sistemas estavam dentro da faixa ideal. As concentrações de amônia nos galpões de aves: não mostraram diferenças entre os dois tipos de tratamento. Também não houve diferenças significativas entre: os sistemas de aclimatação para temperatura da água potável e consumo de água. O peso médio dos pintos de 7 dias diferiu entre os sistemas de aclimatação, com pesos mais altos no sistema de pressão negativa do que no sistema de pressão positiva. Verificamos maior peso médio de abate e menor conversão alimentar em aves de corte criados no sistema de pressão negativa. Concluímos que: o sistema de pressão negativa melhorou o desempenho produtivo de galinhas e melhorou o conforto térmico.

Palavras-chave: Ambiente; Temperature; Estresse por frio; Conversão alimentar; Produção de aves.

Abstract

Regulating room temperature of poultry houses is frequently difficult for breeders; nevertheless, it is very important that housing provides a comfortable thermal environment for chicks. Therefore, the objective of this work was to compare environmental aspects of two rearing systems in broiler chicks aged 1 to 21 days, as well as batch productivity throughout the production cycle (1-42 days). The experimental design was randomized blocks, with two types of shed: one with a positive pressure system and one with negative pressure system. The average weights at 7, 14, and 21 days were measured, as was final slaughter weight and feed conversion. We found a higher internal temperature in the negative pressure system at 7, 14, and 21 days, and maintaining the birds within the temperature considered ideal for thermal comfort at their ages. Regarding relative humidity, only at 14 days was there a difference between the systems, in which the negative pressure system maintained better humidity than did the positive pressure system. Both systems maintained litter temperature within the recommended range for the chicks' ages; however, there were differences between the systems on days 7 and 21. Litter moisture showed a difference only at 14 days of age; however, both systems were within the optimal range. Ammonia concentrations in the poultry houses showed no differences between the two types of treatment. There was also no significant difference between the acclimatization systems for drinking water temperature and water consumption. The average weight of the 7-day-old chicks differed between the acclimatization systems, with higher weights in the negative pressure system than in the positive pressure system. We measured higher average slaughter weight and lower feed conversion in broiler chicks raised in the negative pressure system. We conclude that the negative pressure system enhanced the productive performance of chickens and improved thermal comfort.

Keywords: Ambience; Temperature; Cold stress; Feed conversion; Poultry production.

Resumen

Regular la temperatura ambiente de los gallineros es con frecuencia difícil para los criadores; Sin embargo, es muy importante que la vivienda proporcione un ambiente térmico confortable para los pollitos. Por lo tanto, el objetivo de este trabajo fue comparar los aspectos ambientales de dos sistemas de cría en pollos de engorde de 1 a 21 días, así como la productividad del lote durante todo el ciclo de producción (1-42 días). El diseño experimental fue bloques al azar, con dos tipos de cobertizo: uno con un sistema de presión positiva y otro con un sistema de presión negativa. Se midieron los pesos promedio a los 7, 14 y 21 días, al igual que el peso final del sacrificio y la conversión alimenticia. Encontramos una temperatura interna más alta en el sistema de presión negativa a los 7, 14 y 21 días, y mantener a las aves dentro de la temperatura considerada ideal para el confort térmico a sus edades. Con respecto a la humedad relativa, solo a los 14 días hubo una diferencia entre los sistemas, en los que el sistema de presión negativa mantuvo una mejor humedad que el sistema de presión positiva. Ambos sistemas mantuvieron la temperatura de la cama dentro del rango recomendado para las edades de los pollitos; sin embargo, hubo diferencias entre los sistemas en los días 7 y 21. La humedad de la camada mostró una diferencia solo a los 14 días de edad; sin embargo, ambos sistemas estaban dentro del rango óptimo. Las concentraciones de amoníaco en los gallineros no mostraron diferencias entre los dos tipos de tratamiento. Tampoco hubo diferencias significativas entre los sistemas de aclimatación para la temperatura del agua potable y el consumo de agua. El peso promedio de los pollitos de 7 días difería entre los sistemas de aclimatación, con pesos más altos en el sistema de presión negativa que en el sistema de presión positiva. Medimos un mayor peso promedio de sacrificio y una menor conversión de alimento en pollos de engorde criados en el sistema de presión negativa. Concluimos que el sistema de presión negativa mejoró el rendimiento productivo de los pollos y mejoró el confort térmico.

Palabras clave: Ambiente; Temperature; Estrés por frío; Conversión alimenticia; Producción avícola.

1. Introduction

Broilers are homeothermic, meaning that their internal body temperature tends to remain independent of environmental temperature fluctuations. Nevertheless, ambient temperatures outside of the thermoneutral zone can cause severe performance problems, especially in the initial phase of life, when their thermoregulatory systems are not yet well developed (Arjona et al., 1988; Macari et al., 2004). These problems include reduced feed conversion and weight gain. Broilers are extremely sensitive to low temperatures in the early phase. An efficient heating system must provide adequate temperature in this phase to avoid damaging the birds and their production (Arjona et al., 1988; Macari et al., 2004; Azad et al., 2010). Until the 5th day of life, chicks cannot regulate their body temperature; their thermoregulatory systems do not become fully developed until 14 days of life (Furlan and Macari, 2002; Olanrewaju et al., 2010). In addition to warming in the initial phase, during warmer periods of the year, it is necessary to ventilate poultry houses to avoid overheating and maintain the temperature of the birds as close to the ideal comfort range as possible.

In the south and southeast regions of Brazil, weather and temperature fluctuations are common; controlling the internal environment is therefore significantly more important, considering that the thermal environment is the primary stressor in poultry; this stress results from the interaction between temperature, humidity, radiant heat and air velocity (Lin et al., 2006). Birds that are uncomfortable during this phase have lower initial weights, major feed conversion and consequently lower slaughter weights (Teixeira et al., 2009). According to

Macari et al. (2004), the comfort range for birds in the first week of life varies from 34 °C to 32 °C; in the second week, it varies from 32 °C to 28 °C; and in the third week, it varies from 28 °C to 26 °C. Larger oscillations may occur if the thermal control system is not adequate; litter quality is also an important factor that affects batch performance. For these reasons, characterizing litter moisture and temperature is important because excess moisture in the litter at the early stages can indicate heating or equipment failures.

For the poultry industry, studies of the environment, harmful gases and effects of temperature and humidity on broiler development are increasingly important. Because of temperature changes in the external environment, it is necessary to increase control of the internal environment, because such changes may compromise bird development (Bhadauria, 2017). Irreversible economic losses may result from sudden changes in temperature and humidity, as well as from improper adjustment of these variables. This is because the birds have a rapid life cycle and are extremely sensitive to climate changes. Ventilation systems stabilize the environment, providing better thermal comfort. Artificial ventilation is achieved using special equipment such intake and exhaust fans, both of which necessary whenever natural ventilation conditions do not provide adequate air movement and/or temperature reduction. There are two ways to artificially promote air movement: 1) negative pressure or exhaust systems and 2) positive pressure or pressurization systems. The pressure must be adequate for the system to function successfully; the negative pressure system creates a vacuum effect that forces air to circulate from outside to inside; in the positive pressure system, the air is forced from the inside out (Abreu and Abreu, 2000; PPM, 2015). The objective of this study was to determine whether positive or negative pressure ventilation systems would affect the thermal conditions and productive efficiency of young broiler chicks.

2. Materials and Methods

A research is done to obtain new knowledge to society as stated by Pereira et al. (2018). In that research it was done a quantitive study using measures, numbers, statistics, maths formulas, maths models, calculations and tables to sumarize obtained results.

2.1. Farms and trial period

We used two commercial aviaries belonging to the same farm in west Santa Catarina, located in Planalto Alegre, Santa Catarina, Brazil. The broods from the two poultry houses were always housed on the same day and subsequently slaughtered at the same age (42 days). We used male Cobb 500® birds, hatched from 38-week-old hens. The aviaries were 12 m x 100 m, with 50 cm concrete walls and 25.4-mm mesh screen, to prevent other animals from entering the facilities (Supplementary Material 1). The farm was fenced according to biosecurity precepts, meeting all the requirements for certification of poultry farms in the state of Santa Catarina.

In both units, there were heating machines as well as nipple drinkers and endless screw feeders. The unit with the positive pressure system was equipped with 18 fans and an internal misting system with spray nozzles. The unit with the negative pressure system was equipped with six exhaust fans, with internal and external misting apparatuses equipped with spray nozzles. The birds were housed according to the density recommended by company and according to animal welfare principles: 10.33 birds/m² for the positive pressure (conventional) unit and 10.66 birds/m² for the negative pressure unit.

All poultry houses were equipped with fans (0.5 cv WEG motor). The poultry houses have a total of six hoods (Butterfly infinity 50” model, 1 CV motor, 12 m3/s flow), with a ceramic cooling-type air inlet (Supplementary Material 1).

Three replicates of the experiment were performed for tabulation and data analysis. The experimental period lasted 6 months (30 weeks), allowing a production equivalent of three broods of broiler chicks, with an average interval of 14 days between broods. Data were collected at 7, 14 and 21 days of age.

After the experiment was completed at 21 days, the broilers remained in the same poultry and under the same conditions (temperature, ventilation and humidity) until they were slaughtered at 42 days of age. All handling between days 22 and 42 of the experiment was carried out by chicken farmers; feed was based on commercial feed specific for growth phase (day 22 to 34 of life) and termination (day 35 to 42 of life).

2.2. Zootechnical performance

We weighed the birds on days 7, 14 and 21 at six points in the housing units (Supplementary Material 2), randomly selected, contained first by a circle using a fiber sheet (Eucatex, Brazil). It is important to note that weighing always started on the right and ended on the left in the aviary direction. For the 7-day weight, we weighed 50 birds at each point (a total 300 birds per unit). At 14 days, we weighed 35 birds per point (a total 210 birds per unit); and at 21 days, we weighed only 25 birds per point (a total 150 birds per unit).

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The average weight at 42 days was obtained after the birds were slaughtered in the company's slaughterhouse. The company provided feed intake data that made it possible to calculate feed conversion of each brood. Slaughter weight and feed conversion were not the focus of our study; nevertheless, we included these as complementary data to help reinforce our conclusions.

2.3. Temperature, relative humidity, humidity index (THI) and wind speed

For temperature and relative humidity measurements of the internal and external environments, we used a Testo data logger (model 174/10) programmed to record every 30 minutes throughout the productive period. Six equally divided appliances were installed in each aviary, two of which were located inside and two located outside, south and north of the facility. The data loggers were installed on the first day of bird life (the day the chicks arrived on the farm), exactly one hour before housing, and they were removed on the day of bird loading for slaughter after the third brood.

The internal temperatures of the units were chosen based on the management recommendations table adopted by the company that coordinated the poultry units. The thermal comfort range was defined as initial temperature of 35–32 °C in the first week. Humidity was controlled using panels that set the minimum level of 50% and maximum of 70%. The THI was used to determine the thermal comfort, defined according the equation described by Thom (1958):

$$(THI = Ta + (0.36 \times Tdp) + 41.5),$$

where THI is the temperature and humidity index (non-dimensional), Ta = air temperature (ºC), and Tdp = dew point temperature (ºC). T determine dewpoint, we employed the following simplified formula:

$$To = T - (14.55 + 0.114 \times T) \times [1 - (0.01 \times RH)] - \{(2.5 + 0.007 \times T) \times [1 - (0.01 \times RH)]\}3 - (15.9 + 0.117 \times T) \times [1 - (0.01 \times RH)\ ]14,$$ where T = air temperature in °C and RH = relative humidity in %.

The wind speed was measured at a height of 50 cm from the broiler litter, in a total of ten points inside the house, five on the right side and five on the left. For the fair measurement on days 1, 7, 14, and 21 of the birds' age, a high precision anemometer (Testo®) was used. The results of the ten points were presented average by collection date and poultry houses.

2.4 Temperature, moisture and ammonia content of floor covering

The floor covering was composed of pine wood chips, a litter used to raise nine lots of chickens (beginning of the experiment). To analyze moisture, we collected samples from each unit before entry of the birds (day 0), and at 7, 14 and 21 days of age. Samples were collected in "zig-zag" fashion, according to the model proposed by Singh et al. (2004) using a shovel and an individual container for each treatment. A sample of 5 kg of litter was collected from each unit. Samples were homogenized, and 100 grams (in duplicate) were removed to a specialized laboratory for analysis. The samples were weighed and dried for 48 hours in a forced ventilation oven at 105 ºC; They were then weighed again using the moisture determination methodology proposed by the Brazilian Ministry of Agriculture.

The surface temperature of the bedding (ºC) was measured using a 6-point infrared digital thermometer, always considering the right side of the units as the initial reference at 7, 14 and 21 days of age. The evaluation of the internal ammonia concentration of the poultry houses (in ppm) was performed using SENKO SP2nd meter. The measurements were performed twice daily (morning and afternoon) from the days 1 to 21.

2.5 Drinking water temperature

The drinking water temperature was evaluated daily from days 1 to 21, twice daily (morning and afternoon) at six points within each house and during each period, totaling 12 daily water temperature measurements. A stick thermometer (Thermoterm) in an insulated glass container was used to adjust avoid temperature differences between the environment and water.

2.6 Statistical analysis

The experiment employed a randomized block design, with two treatments (positive and negative pressure units) and three production broods (blocks). Broods were evaluated weekly from housing (day 1) until day 21, and post-slaughter parameters and for average weight and feed conversion. The mathematical model used was $Yij = \mu + Gi + Lj + eij$, where

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μ is a general average common to all observations, Gi is the effect of unit i (I = 1, 2), Lj is the effect of block j (j = 1, 2, 3), and eij is the random error attributed to each observation Yij.

Descriptive data analysis and analysis of variance were performed using SAS software (version 9.2), comparing the units (positive and negative pressure) in terms of animal performance, ammonia concentration, room temperature, relative humidity, bedding moisture and temperature and humidity index (THI) using the Fisher-Snedecor test (5%). All data were verified for normality using the Shapiro-Wilk and Kolmogorov-Smirnov tests prior to variance analysis. P-values less than 0.05 were considered significant.

3. Results

3.1. Zootechnical performance

Zootechnical performance was determined based on data of average weight at different ages, average slaughter weight and feed conversion during the productive cycle (Table 1). There was a significant difference between the units with respect to bird weight day 7 (p <0.05), with birds in the negative pressure unit heavier than those in the positive pressure unit. There were no differences in body weights between units at 14 or 21 days (p>0.05; Table 1).

Table 1: Mean weights, final weight and mortality of broiler chickens in two production systems (positive pressure and negative pressure).

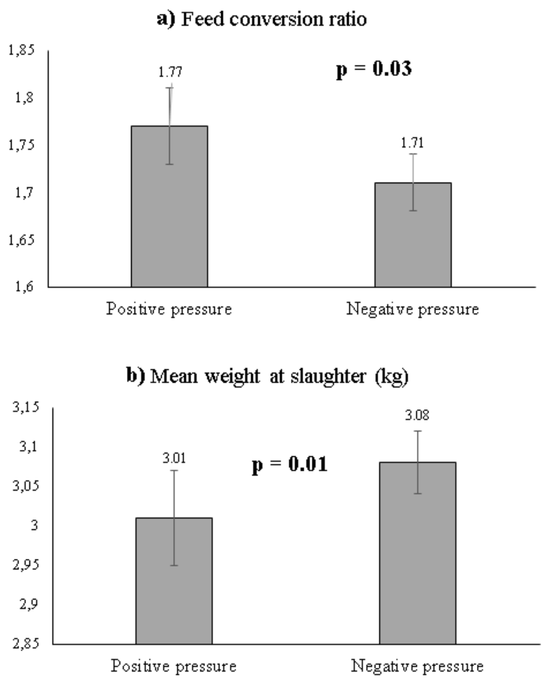
Variables	Positive pressure	Negative pressure	CV (%)	p-value
MW: day 7 (g)	184.58	194.87	16.46	0.03*
MW: day 14 (g)	441.13	490.41	12.07	0.71
MW: day 21(g)	843,53	921.29	18.08	0.59
FW (kg)	2.94	3.00	5.04	0.44
Mortality (%)	3.73	3.27	42.92	0.30

Note: Mean weight (MW) at 7, 14 and 21 days; final weight to 42 day (FW) and mortality in broiler chicks raised in positive and negative pressure units. Final weight considering 10 broods; * differences between units according to the Fisher-Snedecor test (p<0.05). Coefficient of variation (CV).
Source: Authors.

3.2. Air temperature, relative humidity and THI

There were significant differences (p <0.05) in body weight at the end of the productive cycle (42 days; Figure 1), with higher slaughter weights and lower feed conversion (p <0.05) in birds in the negative pressure unit than in the positive pressure unit (Figure 1).

Figure 1: Feed conversion and average weight at slaughter of broiler chickens at 42 days of age in two acclimatization system (positive pressure and negative pressure).



Source: Authors.

3.3. Bedding temperature and moisture

Inside the aviaries, there were significant differences (p <0.05) between the units, with the negative pressure system showing higher temperatures at 7, 14, and 21 days. Inside the aviaries, there was a significant difference in relative humidity, (p <0.05) between the units at 14 days of age. In the negative pressure unit, the humidity was higher (p <0.05) than that of the positive pressure unit in inside the aviaries. The THI differed between the systems at 7, 14, and 21 days of age with greater THI in the negative pressure unit (p <0.05; Table 2). The temperature and relative humidity of the air was similar outside the aviaries at the evaluated time points (Table 2).

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Table 2: Inside and outside the aviaries the mean air temperature (ºC), relative humidity (RH) and thermal comfort index in the aviaries (THI) in the two production systems (positive pressure and negative pressure).

Age		Positive pressure	Negative pressure	CV (%)	p-value
Inside					
7 days	Temp (°C)	29.41	31.34	6.34	0.001*
	RH (%)	56.97	56.90	10.75	0.900
	THI	78.05	80.67	2.79	<0.001*
14 days	Temp (°C)	27.43	28.93	6.05	0.007*
	RH (%)	56.95	62.73	9.20	0.001*
	THI	75.47	78.03	2.88	<0.001*
21 days	Temp (°C)	27.43	27.74	7.35	0.012*
	RH (%)	70.84	71.38	13.71	0.850
	THI	75.37	77.21	2.32	0.018*
Outside					

*means between units differ significantly according to the Fisher-Snedecor test (p <0.05). THI: temperature-humidity index; RH (%) relative humidity; Temp: air temperature; CV: coefficient of variation. Source: Authors.

The bedding temperature differed between units at 7 and 21 days of age, being higher in the negative pressure unit. Despite the significant difference, the temperatures in both units were within the recommended range for age (28–32 ºC at 7 days and 25–27 ºC at 21 days) according with Abreu and Abreu (2011). At 14 days, there was no significant difference in litter poultry temperature between units. The litter moisture was significantly different at 14 days (p <0.05), being higher in the negative pressure unit; nevertheless, the values remained in the ideal range (less than 35%) in both units (Table 3).

Table 3. Temperature and relative humidity of bedding by unit RH: relative humidity. Temp ºC: bedding temperature at the moment of collection in two production systems (positive pressure and negative pressure).

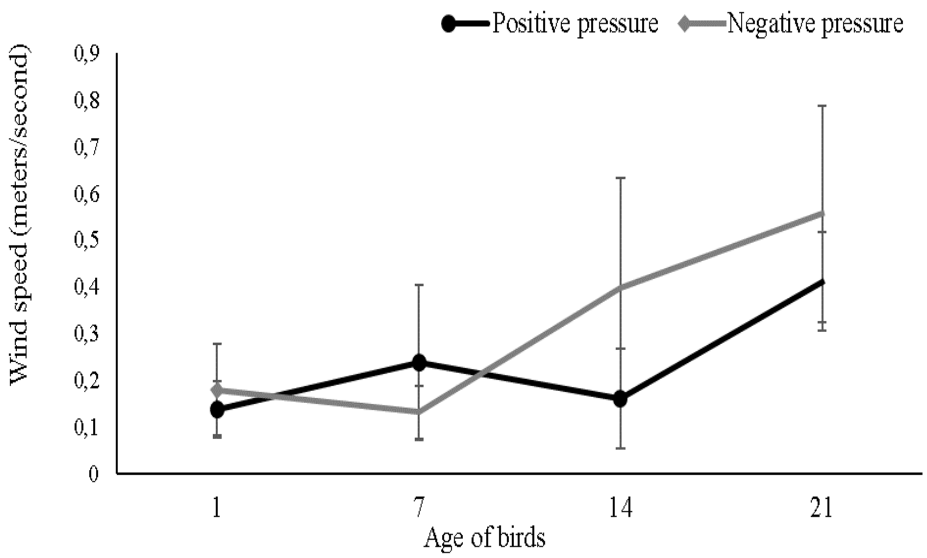
Age		21.46	20.95	1.73	0.620
7 days	Temp (°C)	28.07	29.14	2.93	<0.001*
	RH (%)	22.19	21.68	4.61	0.290
14 days	Temp (°C)	26.71	27.03	6.51	0.590
	RH (%)	24.04	26.22	5.37	0.004*
21 days	Temp (°C)	25.34	27.45	7.14	0.002*
	RH (%)	25.96	27.60	7.98	0.120

*Differences between means significant according to the Fisher-Snedecor test (P <0.05).

Source: Authors.

In the evaluated periods, wind velocity inside the aviaries did not differ significantly between treatments (p >0.05; Figure 2).

Figure 2: Wind speed during the trial period. There was no (P>0.05) difference for this variable between treatments.



Source: Authors.

3.4 Ammonia concentration

Ammonia concentration in the aviaries did not differ between units (p >0.05), either in the morning or in the afternoon. At all ages, ammonia concentrations remained within the range considered ideal for broilers (<20 ppm) (Table 4).

Table 4. Mean ammonia concentrations (ppm) in the units at the moment of collection in two production systems (positive pressure and negative pressure) to broilers.

Age	Period	Positive pressure	Negative pressure	CV (%)	p-value
1–7 days	morning	11.33	10.00	31.47	0.511
	afternoon	3.83	5.33	52.32	0.310
14–21 days	Morning	16.33	14.84	71.39	0.820
	afternoon	5.83	4.16	66.02	0.407

Note: CV: coefficient of variation. Source: Authors.

3.5. Drinking water temperature and water consumption

There were no significant differences between units with respect to drinking water temperature or water consumption at any bird age ($p > 0.05$; Table 5).

Table 5. Temperature and water consumption for both production systems (positive pressure and negative pressure) by age of birds.

Age		Period	Positive pressure	Negative pressure	CV(%)	P-value
7 days	Temp. (°C)	Morning	28.48	27.68	5.91	0.677
		Afternoon	29.41	29.17	4.44	0.089
	Cons. (L)	Day	627.14	552.19	25.94	0.120
14 days	Temp (°C)	Morning	25.40	25.86	5.26	0.483
		Afternoon	26.10	26.04	2.97	0.774
	Cons. (L)	Day	1312.05	1294.86	25.94	0.870
21 days	Temp (°C)	Morning	25.58	25.22	3.99	0.604
		Afternoon	26.39	26.64	3.79	0.771
	Cons. (L)	Day	2209.29	2399.81	17.14	0.126

Note: Temp ºC: drinking water temperature at the moment of collection. Cons. (L) measured daily. $p > 0.05$ no significant difference according to the Fisher-Snedecor test. CV: coefficient of variation.

4. Discussion

At 7 days of age, birds raised in the negative pressure system had higher body weights (Table 1). This may be related to the climate control system that maintained the birds in better thermal conditions. Although both systems provided thermal conditions within the range usually considered comfortable for the first week of the birds, the better performance at this age may suggest the need to review these thermal comfort standards established by the industry. Carvalho et al. (2011) showed that negative pressure-type aviaries have better renewal rates and air quality (conditions that we did not find in the present study), but that may be related to better performance of birds at the beginning of the production cycle. By contrast, according to Cassuce et al. (2013), the temperature ranges for the first week of bird life should be 34–32 °C. There was a significant difference in temperature at all ages evaluated, with the negative pressure unit achieving the temperature closest to the thermal comfort range.

In Brazil, climatic conditions, particularly in the south and southeast, require an adequate source of warming, because birds experiencing cold stress have blunted development, and this affects the uniformity of the flock and, consequently, final mean weight (Ipek and Sahan, 2006; Cony and Zocchi, 2004), as we observed in our study. When evaluating the final slaughter weight between the two treatments, we found that the chicks in the negative pressure unit achieved higher body weight. Similar results were reported by Andreazzi et al. (2018), who reported that negative pressure aviaries with a curtain and a solid wall produced greater slaughter weight in relation to the conventional aviary equipped with a positive pressure system. The same was observed in the study by Verdi (2009), in which the highest weights and the lowest food conversion were observed in the dark house system with curtain (negative pressure), when compared to the positive pressure system. Our results, as well as those of Andreazzi et al. (2018) and Verdi (2009) suggest that the technology applied in the new aviary models, in which the air conditioning systems are based on negative pressure, guarantees less chance of error in the environment, because they produce environments with greater control, as opposed to conventional poultry houses that use positive pressure. By contrast, Vigoderis et al. (2010) in the same climate region; reported that unventilated (positive pressure) units produced larger chickens than those raised in positive pressure units using fans that were used to remove gases and dust from within the facility. Nevertheless, because the study was conducted during winter, the ventilation of the indoor environment may have interfered with the internal temperature, consequently affecting thermal comfort and productive performance.

Lower feed conversion in the negative pressure unit was another positive result. According to Amaral et al. (2011), one of the main factors affecting food conversion is air temperature; and in the initial phase, the birds do not yet have well-developed thermoregulatory systems; therefore, it is necessary to provide sufficient heating sources to maintain body temperature so as not to lose performance. Another important factor in this phase is ventilation that is used to remove gases (mainly ammonia and carbon dioxide), dust and moisture; ventilation renews environmental oxygen and maintains ideal temperatures for birds inside the facility (Curi et al, 2014). Because our study was conducted between late spring and early fall (November to May), there was no difficulty in controlling the internal temperature of the aviary, and therefore the birds all remained in thermal comfort. These factors probably increased the production in the negative pressure unit.

Because of provided heating, relative humidity during the first weeks of life tends to be lower; however, the ideal level according to Abreu and Abreu (2011) should be higher than 60%. According to Cobb (2013), the higher the internal temperature of the sheds, the greater the possibility of not being able to maintain relative humidity within the recommended limits, because for every 1 °C increase in temperature, humidity decreases about 5%. This suggests that raising unit temperature excessively would reduce the relative humidity to levels below 50% (not recommended). The average relative humidity for age at 7 days in both units was below the ideal relative humidity, suggesting that the birds experienced a challenge during the first days of life. Low relative humidity of the air can generate respiratory, cardiac problems and dehydration of the mucous membranes. Cordeiro et al. (2010) reported values below 50% RH (recommended for the initial phase) in the first week of the birds' lives. The highest rate of organ development occurs in the first 7 days; therefore, harm is inflicted on animals kept outside the thermal comfort zone, because adverse temperatures and relative humidity are associated with poor feed conversion and performance (Cordeiro et al 2010). At 14 days, only the negative pressure unit was able to maintain the correct relative humidity corresponding to the age in the period, and at 21 days, both units maintained temperatures within the established standard range (Table 2).

Paula et al. (2014) evaluated the performance of broiler chickens up to 21 days and found that the relative humidity of the indoor air of the units ranged between 60% and 70%, similar to our findings. We believe that minimal ventilation assists in efficient air renewal by maintaining the temperature and relative humidity within optimal levels of thermal comfort, as occurred at 14 days in the negative pressure unit, the highest relative humidity. However, Naas et al. (2007) argues that open-type installations using ventilation and misting systems promote better housing conditions than do fully enclosed ones in temperate climates; we did not observe this phenomenon in the present study.

According to literature, the THI must be higher than 25; because maintaining air humidity is crucial for achieving thermal comfort conditions (Silva, 2007). The ideal THI values of the first week are 72.4 to 80; in the second week they are 68.4 to 76; and in the third week they are 64.8 to 72 (Abreu and Abreu, 2002, Silva, 2007). In our experiment, the THI remained with the recommended range in both units. In the negative pressure unit, the THI was within the hazardous zone for birds. This can be explained by the architectural features of the negative pressure system that must be well-sized to promote constant air renewal while maintaining temperature and humidity. When this does not occur, there is a tendency to increase internal temperature, associated with the failure of air renewal. Staub et al. (2016) studied birds in environments with high and low rainfall and found that the THI ranged from 76.04 in the first week to 74.82 in the second week, lower than the values observed in the present study.

In some points during our study, there was higher humidity and bedding temperature in the negative pressure unit. According to Carvalho et al. (2011), optimum bedding temperature for birds over 7 days is 27 °C to 35 ° C; humidity should be less than 35%. It is important to maintain a good quality bedding, as this may influence the appearance of locomotor problems in birds, leading to slaughterhouse rejections. In birds raised in excessively moist bedding, there may be increased incidence of dermatitis (Zikic et al., 2017). It is important to emphasize that the increase of humidity associated with pH generates higher ammonia concentration; this was not observed in our study. The litter poultry temperature remained within the range considered ideal for the first week of life, probably because temperature ammonia concentration remained within normal ranges.

There was no significant difference between the units in terms drinking water temperature, an advantageous result for both systems. Drinking water is a means of dissipating heat from birds when consumed at temperatures below body temperature. The greater the difference, the better the effect and consumption (Fairchild and Ritz, 2006). The higher the ambient temperature, the higher the water consumption by the birds, and water supplied at a lower temperature can prevent performance losses due to overheating inside the unit. According to Manning et al. (2007), for each 1 °C increase in ambient temperature there is a 6% increase in water consumption at temperatures above 20 °C. In the present study, the drinking water temperature was above 20 ºC for both units; nevertheless, there was no difference in temperature and water consumption between 1 and 21 days of age. Low water consumption during the first days of a chick's life can compromise the growth and the functional capacity of the intestine. During the initial hours, it is important for the bird to consume adequate quantities of water and food for the sake of the development of intestinal villi (density and size) and enterocytes; if this does not occur, the result is malabsorption and poor overall digestion (Maiorka et al, 2002). Researchers claim that chicken performance improves when birds consume colder water during warmer periods (Damron, 2002). However, according to Penz and Figueiredo (2003), for the initial phase, it is recommended that the water be supplied warm, to avoid wasting energy from the birds if the water is cold. Therefore, in the initial phase, depending on the ambient temperature, it is recommended to use flushing, that is, to evacuate the lines so as to provide fresh water. According to Barbosa et al. (2014), chicks up to 7 days under heat stress can lose 12% of their body weight and older chickens can lose around 4.5%. In the 1990s, researchers stated that birds prefer water temperatures around 10 °C, and that temperatures above 24 °C tend to reduce consumption and consequently reduce weight gain (Beker and Teeter 1994). Therefore, it is important to control the temperature of drinking water.

5. Conclusion

The negative pressure system improves zootechnical performance in the first week of life in broiler chicks. This would give rise to higher body weights at slaughter and lower feed conversion in the negative pressure system. These positive effects on performance are probably a consequence of the negative pressure system providing superior thermal comfort. The trend is moving toward negative pressure systems because of their ability to promote better environmental conditions to produce quality birds.

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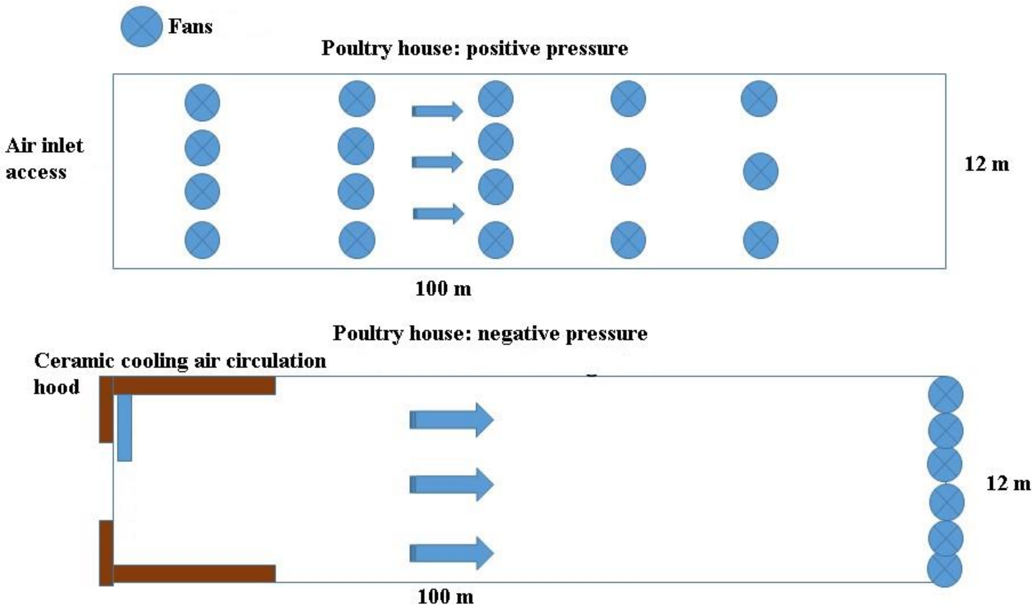
Supplementary material 1: Illustration of the two poultry houses used in our study: positive pressure (conventional) and negative pressure.



Supplementary material 2: Illustration of the points where the birds were weighed in the three periods, as well as the number of birds per moment.