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Total heat loss in broilers fed with different lipid sources

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Abstract To meet the growing demand for poultry products, many producers have decided to increase the density of animals per square meter. This, coupled with global warming, creates a severe problem for the poultry industry, as it is common to observe birds moving away from the thermal comfort zone. Therefore, the objective of this study was to evaluate the effect of three lipid sources and three levels of inclusion in broiler diets on sensible heat loss. Three hundred twenty-four female broilers from the Ross 308 line were housed in cages in an open house and distributed into nine different treatments. The body surface temperature was observed with an infrared thermography camera. Heat loss was analyzed by radiation, and convection was calculated by equations at weeks three, four, and six of broiler life, considering the importance of measuring and analyzing the following variables: wind speed, bird weight, bird area, ambient temperature, and relative humidity, among others. The treatments had no significant effect on Qt; however, the inclusion of palm oil, chicken oil at 3%, and sacha inchi oil at 9% can be an alternative in broiler chicken feed since they tend to reduce Qt at day 42 of life.

Keywords: fats, metabolic heat, oils, poultry, thermoregulation

1. Introduction

The poultry industry of recent years has been well-known for seeking great efficiency, produced by the system, and a high-quality product with increasingly competitive prices in the market. Therefore, poultry production systems promote high-density housing, management, health, genetics, and nutrition advances. However, a higher number of birds per square meter affects their thermal comfort, negatively impacting the environmental level and the zootechnical patterns (Cassuce 2011). In Colombia, poultry farming is concentrated in areas with high temperatures and humidity; Santander 24 °C and 70%, Cundinamarca 21 °C and 80%, Valle del Cauca 24 °C and 79%, and Antioquia 23 °C and 64%, respectively (ICA 2021). The average temperature and humidity to reach ideal production patterns and adequate heat transfer must be 19 to 25 °C, with a maximum average humidity of 75%. It does not seem like a good scenario considering that the temperature and humidity in the sheds are higher than the external environment conditions (Estrada et al 2007)

According to Lisboa and Luis (2012), when birds move to hydrate, eat, explore cold areas, and spread their wings, they create heat variations that increase their breathing rate. In line with Cooper (1971) cited by Quishpe (2006) and De Basilio et al (2003), they stated that birds' manipulation creates a rise in their body temperature and heart rate, forcing them to leave their comfort zone. Furthermore, considering poor air quality and a high ammonia concentration bed (NH_3) becomes stressing environmental factors leading to sore pulmonary system and immunological stress, resulting in greater sensible heat loss. The ability of birds to reduce heat decreases as environmental temperature and relative humidity increase above the thermal-neutral zone (air temperature of 24 °C and relative humidity of 70%) (Curto et al 2007). In agreement with Furtado et al (2003), the thermoneutrality zone is related to an ideal thermal environment, where birds can find perfect conditions to express their most productive characteristics when they are in thermal comfort. Metabolic heat is produced inside the body and distributed in the different body regions using blood circulation, promoting peripheral vasodilation and heat loss by surface conduction (Fiala et al 1999). This sensible heat loss also occurs throughout radiation, convection, and finally, remaining heat throughout evaporation (Ferreira et al 2011).

De Basilio (2006) states that one of the effects of heat stress on birds, leading to significant losses, is the decrease in food consumption, as birds attempt to reduce their internal heat production by decreasing food consumption. Both digestion and nutrient absorption generate energy, which is released through heat, named "caloric gain" (Nascimento and Silva 2010). Carbohydrates are replaced by sources of high energy concentration, such as oils and fats, aiming to reduce the effects of caloric gain in birds since they produce

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less heat, given that part of the fatty acids can be stored directly in the adipose tissue of the bird, decreasing the concentration of proteins, which also contributes to reducing the bird's metabolic heat loss (De Basilio 2006; Ferreira *et al* 2011; Kennedy 2017; Martínez 2008; Rabello 2008; Moraes 2013). Adding lipid sources to the bird's diet will promote thermoregulation and daily weight gain due to an increase in the digestibility of fat in the intestine since these have greater metabolizable energy than diets without fat but with the same energy concentration.

In line with Ghazalah et al (2008) and Lisboa & Luis (2012), including up to 5% of lipid sources in the diet contributes to reducing caloric stress in broilers found in environments with air temperatures from 29 to 36 °C; this level of inclusion in their diet decreases heat production because proteins produce more heat than carbohydrates and lipids, having transformation yields from metabolizable energy to clean energy of 80 and 95% respectively, concluding on a direct impact on consumption. On the other hand, Quishpe (2006) states that chickens drink twice as much water as the amount of feed consumed based on the weight in environments close to thermoneutrality conditions. However, this water/food measure is affected by the environmental temperature increase and the diet caloric increase. Finally, this research aimed to evaluate the effect of three lipid sources: palm oil (*Elaeis guineensis*), chicken oil, Sacha inchi oil (*Plukentia volubilis*), and three levels of inclusion in the broilers' diet on total heat loss.

2. Materials and Methods

This study was carried out at the San Pablo Agricultural Station, located at Vereda Tablacito, Río Negro municipality, 52 km from Medellín, on Santa Elena Road, department of Antioquia, Colombia, located at 2100 meters above sea level (m.s.n.m.), with the coordinates 6°07'51.3"N and 75°27'19.1"W. Its temperature ranges between 12 and 18 °C and the average annual rainfall is 2280 mm. The average relative humidity is 75.5%.

A total of 324 broilers (females) from the Ross 308 line of a commercial incubator in the region were used. The birds were supplied with water and *ad libitum* food. The shed is built with an east-west orientation and has the following dimensions: width 10.12 meters (m), length 12 (m), right foot height 2.5 (m), and it works with natural airing and curtain management. The birds were housed in four horizontal lots of sixteen cages each; the dimensions of the cages were (0.7 m long x 0.75 m wide x 0.6 m high), for a total of 54 cages (Figure 1). Upon the arrival of the birds, they were supplied with heating from gas breeders, the first week of life from 5:00 pm to 9:00 am. The second week from 7:00 p.m. to 6:00 a.m., the airing was handled with curtains to keep the average temperature for the species.

A B

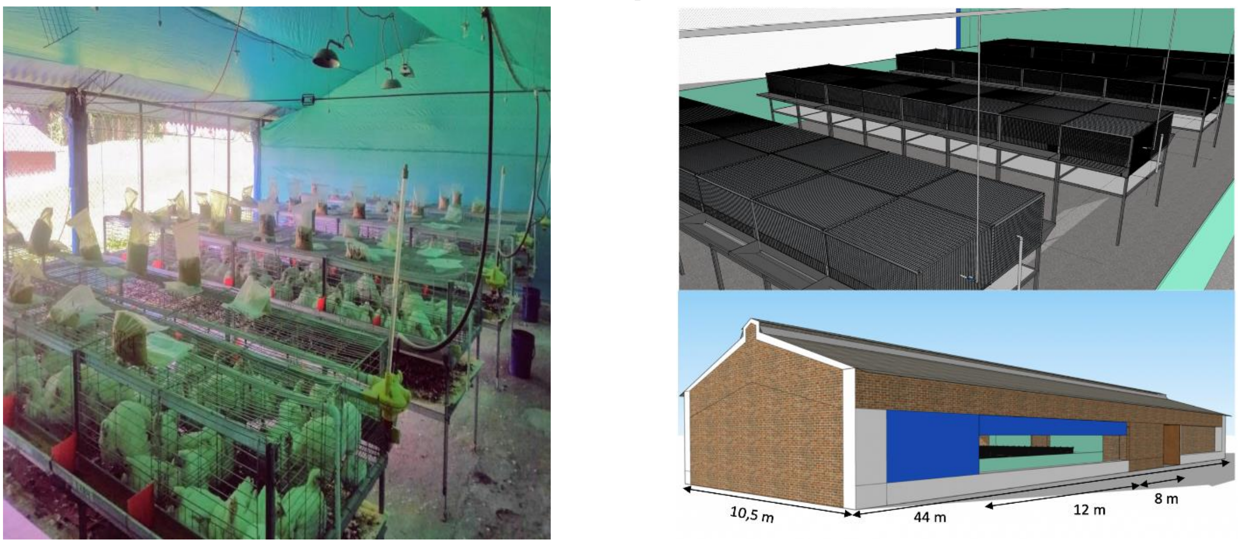


Figure 1 Images of the experimental shed: Birds distribution and treatments (A), Internal and external design of the shed (B).

The variables dry bulb temperature (dbt) and relative humidity (RH) were determined with the help of a thermo-hygrometer branded: (LWH®, HTC-1) with an accuracy of ± 1.0 °C, ± 5%, relative humidity. To capture the thermographic images of the birds, an infrared thermography camera (FLIR® E50) was used, following the methodology used by Nääs et al (2010), about placing the camera one meter away from the target and taking samples in groups, front, and side position to be evaluated with the specific camera software. To measure the surface temperature of the birds, an infrared thermometer (YARUIFANSEN®, DT-380) was used with an accuracy of ± 2 °C. The body temperature was determined with the help of a flexible tip digital thermometer branded: (BEGUT®) with an accuracy of ± 1 °C rectally. The wind speed was measured with the help of an ultrasonic anemometer (GILL®, WindSonic 75) with an accuracy of ± 2%. The birds and food weight were obtained with the help of a digital scale (TRÚMAX®, FENIX) with an accuracy of ± 1.0 gram (g).

The animals were fed for 42 days with a diet based on corn and soybeans to provide the necessary nutrients in each of the physiological and productive stages, following the recommendations of the genetic line and/or the National Research Council (NRC 1994). The treatments were organized according to the base diet, the different lipid sources, and the three levels of inclusion (Figure 1).

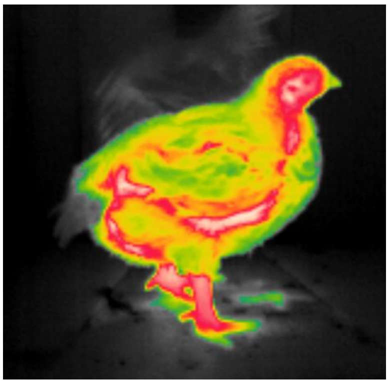


Figure 2 Infrared thermography of a 28-day-broiler.

The birds were distributed in 54 cages with 6 birds in each. The effect of three lipid sources (palm oil, chicken oil, and sacha inchi oil) was evaluated with three inclusion levels (3%, 6%, and 9%), having a total of nine treatments completely distributed at random. In each cage, and at the same time, five experimental data were taken. On the 21, 28, and 42 days of birds' life in the following schedules: (6:00 am, 12:00 pm, and 3:00 pm).

Once data was collected, the sensible heat loss or total heat (Qt) was calculated, which is equivalent to the sum of the heat loss by radiation (Qr) and convection (Qcc). (Qt) measures the amount of heat the bird loses to the environment. Qt was calculated using Eq. (1) of Yahav et al (2004), (Qr) was calculated using the Eq. (2) of Monteith and Unsworth (2013), where (e) is the emissivity of the complexion, (σ), it is Stefan Boltzman's constant in: $\frac{W}{m^2 \cdot k^4}$, (A) is the surface area of the bird in m^2 calculated with the software (ImageJ®), (Ts) is the surface temperature of the bird, which was obtained with the help of the thermal imaging camera (FLIR® E50), and (Ta) is the environmental temperature. (Qcc) was calculated using Eq. (3) of Holman (2010), where (h) represents the heat transfer coefficient by convection, and it was calculated using Eq. (4) from Mount (1979), (d) is the diameter of the bird, (Nu, Gr and Pr) are dimensionless numbers necessary for the calculation of heat flow by natural convection taking the bird's body as a sphere and disregarding its legs, is calculated through the Eq. (5, 6 and 7) proposed by Nascimento (2015). Finally, the air properties at atmospheric pressure; fluid thermal conductivity (K) in, air kinematic viscosity in $(\frac{W}{m}.°Cv)$, air density in $\frac{m^2}{s}$ (p) $\frac{Kg}{m^3}$ and the specific heat of the air in $\left(\frac{KJ}{Kg}.°C\right)$ were taken from (Baêta y Souza 2010). The software (Image J) was used to calculate the surface area of the birds.

$$Qt = Qr + Qcc \quad (1)$$

$$Qr = e \cdot \sigma \cdot A \cdot (Ts^4 - Ta^4) \quad (2)$$

$$Qcc = A \cdot h \cdot (Ts - Ta) \quad (3)$$

$$h = \frac{Nu \cdot K}{(d/100)} \quad (4)$$

$$Nu = 2 + \left\{ \frac{\left(0{,}589 \cdot (Gr \cdot Pr)^{\left(\frac{1}{4}\right)}\right)}{\left(1 + \left(\frac{0{,}469}{Pr}\right)^{\left(\frac{9}{16}\right)}\right)^{\frac{4}{9}}} \right\} \quad (5)$$

$$Gr = \frac{\left(\left(\frac{1}{Ta}\right) \cdot 9{,}8 \cdot \left(\frac{d}{100}\right)^3 \cdot (Ts - Ta)\right)}{(v \cdot 10^{-6})^2} \quad (6)$$

$$d = \sqrt{\left(\frac{(A \cdot 4)}{3{,}1415}\right)} \quad (7)$$

$$Pr = \frac{\left((p \cdot 1000) \cdot Cp \cdot (v \cdot 10^{-6})\right)}{K} \quad (8)$$

The experimental design used was a random drawing (Split-split-plot). The measures were compared using the Tukey test ($P < 0.05$) with the help of statistical software (SAS Inst. Inc., Cary, North Carolina) All the results were subjected to variance analysis (ANOVA).

Table 1 Experimental diets.

Treatment	Basal diet (db)		Concentration (%)
		Source of fat	
1	Commercial diet	Palm oil	3
2	Commercial diet	Palm oil	6
3	Commercial diet	Palm oil	9
4	Commercial diet	Chicken oil	3
5	Commercial diet	Chicken oil	6
6	Commercial diet	Chicken oil	9
7	Commercial diet	Sacha inchi oil	3
8	Commercial diet	Sacha inchi oil	6
9	Commercial diet	Sacha inchi oil	9

3. Results and Discussion

Figure 3 shows the temperature distribution and the relative humidity inside the house at (6:00 am, 12:00 pm, 3:00 pm.) during the days of data collection (on days 21, 28, and 42), obtaining temperature isotherms and relative humidity with the help of the software (Surfer®). In general, it was found that, along the experimental stage, the temperature distribution and relative humidity in the house were consistent and without differences higher than ± 1 °C and ± 5%, which allowed to determine that the microclimatic environmental conditions in which the birds were raised during the production cycle were homogeneous throughout the experience.

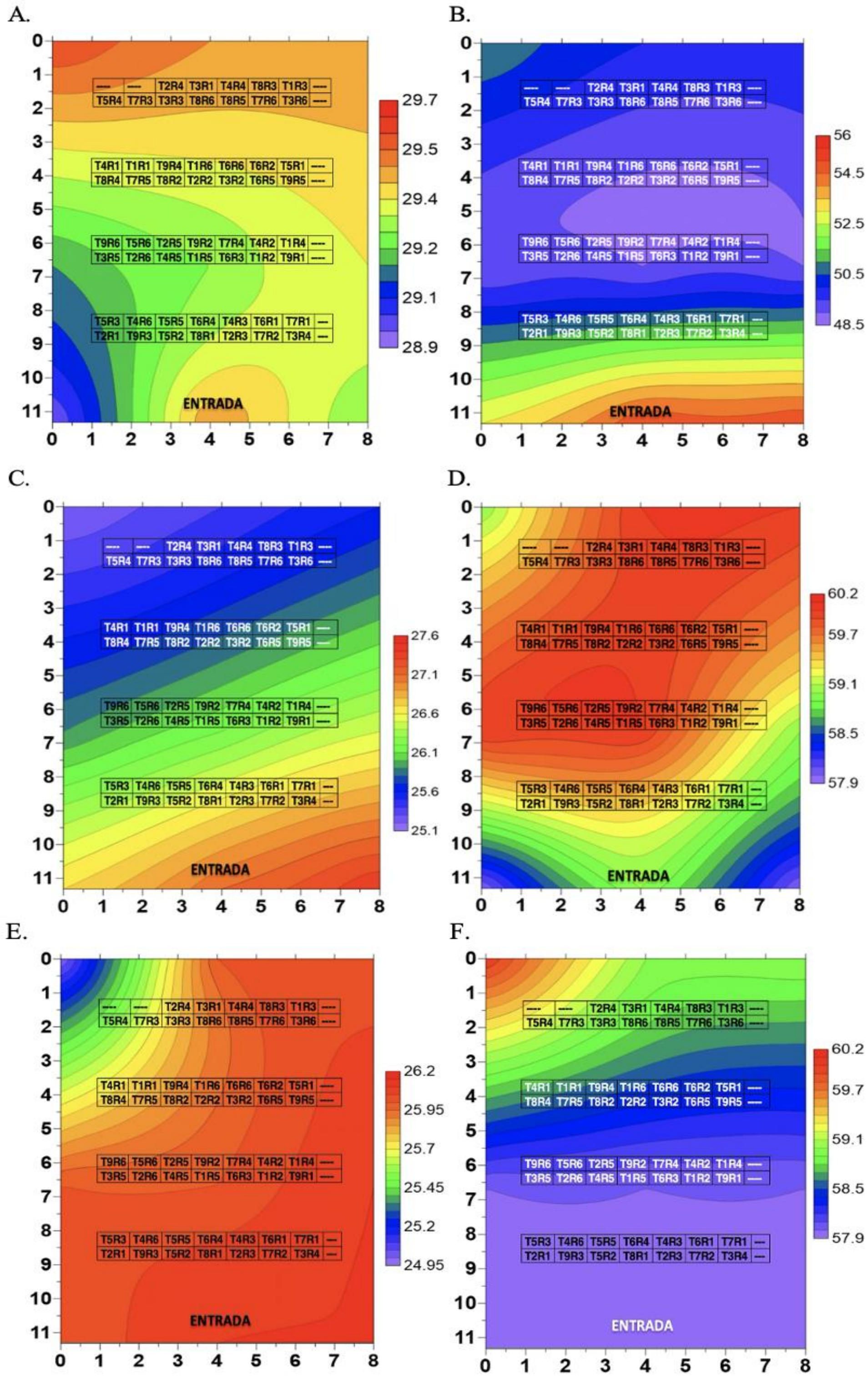


Figure 3 Isothermal temperature (°C) and humidity (%) of the shed: Temperature in week 3 (A), humidity in week 3 (B), Temperature in week 4 (C), humidity in week 4 (D), Temperature in week 6 (E), humidity in week 6 (F).

Figure 4 shows the behavior of the nine treatments regarding the total heat loss at different times of the day (6:00 am, 12:00 pm, 3:00 pm) on day 42, to determine if any of the treatments show greater heat loss in a saturated environment and at the exact moment in life in which the chick tends to experience thermal stress (days before slaughter), higher losses are observed at 6 a.m., compared to the other times during the day when total heat losses were lower. According to Malheiros et al (2000), the reason why the total heat loss in birds was significantly different in each of the times evaluated is probably due to an increase in the thermal conductivity of the skin when the air temperature increases from 20 to 40 °C. This implies an increase in peripheral blood flow, which could determine the surface temperature change during exposure to different environmental temperatures. On day 42, sacha inchi oil recorded the highest total heat loss. Birds fed with palm oil dissipate less heat than other lipid sources.

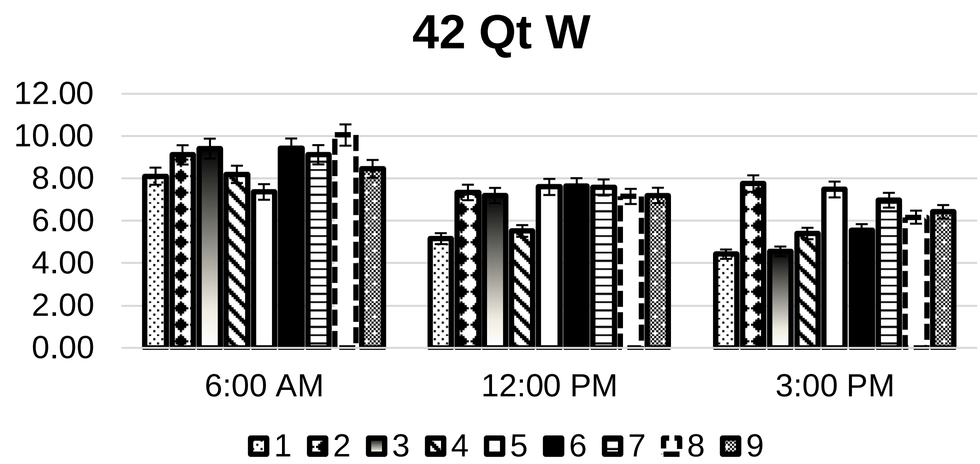
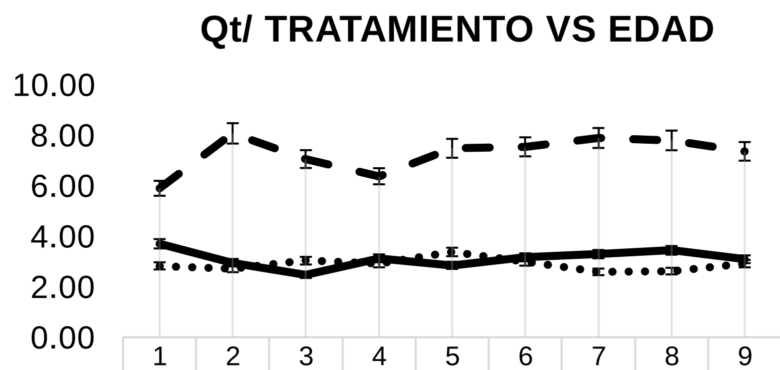


Figure 4 Total heat loss from the nine treatments during day 42 at different times of the day

In another way, greater total heat loss is observed in the morning hours, which matches with Cooper and Washburn (1998) conclusion, showing that birds benefited from the total heat loss in the morning due to the high value of ΔT and the increase of latent heat loss in the afternoon when the environmental temperature increased. Even though the statistical analysis concludes that no significant differences were found among the types of oil used, Figure 5 shows the heat loss behavior by: radiation, convection, and total heat loss for the ages of 21, 28, and 42 in the nine treatments.

As Nascimento et al (2014) reported, there were moments when the qr value did not increase with age, as shown in (Figure 5). In Figure 5, although there is no statistically significant difference ($P > 0.05$), the total heat loss in broilers at day 42 tends to decrease with the inclusion of 9% sacha inchi oil compared to the other levels of inclusion with the same oil. This is considered an excellent contribution for nutritionists since there is no research evaluating the effect of this oil on total heat loss in broilers. In the same number, birds that consume a diet with 3% chicken oil tend to lose total heat than the ones that consume 3% palm oil.



	1	2	3	4	5	6	7	8	9
21 Qt W	2.83	2.71	3.03	2.91	3.38	2.98	2.59	2.62	2.91
28 Qt W	3.70	2.95	2.47	3.13	2.85	3.17	3.29	3.44	3.09
42 Qt W	5.90	8.07	7.06	6.37	7.48	7.54	7.89	7.79	7.36

Figure 5 Total heat loss/treatment at day 21, 28 and 42.

Table 2 shows a connection between the total heat loss (Qt) in watts (W), the bird's age, and the time of day. The total heat loss was affected by the bird's age, as highly significant differences (*P* < 0.0001) were found between them, except for the comparison between day 21 and day 28. Comparing the total heat loss between day 28 and day 42, a highly significant difference was found (*P* < 0.0001), as well as time, and similar results were reported by (Estrada et al 2007; Nascimento et al 2014)

As already stated by Nääs et al (2010), it was found that the total heat loss was influenced by the time of the day, having that the heat dissipation was significantly different at three o'clock, as well as the interaction between most times of the day and the bird's ages.

Table 2 Bird's Age and time of day Statistical effect on Qt (W).

Effect	Adjustment	*P*-value
Age¤	Tukey	0.4502
Age+	Tukey	<.0001
Age+	Tukey	<.0001
Time+	Tukey	<.0001
Time+	Tukey	<.0001
Time+	Tukey	<.0001

A = Age; T = Time of day; (+) = Significant differences (D.S); (¤) = No significant differences (D.S)

4. Conclusions

No significant differences exist (P > 0.05) in using the evaluated lipid sources and their inclusion level in the sensible heat loss diet. Including palm oil, 3% chicken oil, and 9% sacha inchi oil can be an alternative in broiler feed, as it tends to decrease the total heat loss at day 42 of life. Age, plumage, and the time of day are the key factors that significantly influence total heat loss. The total heat loss was influenced by the interaction between the level of inclusion and the age of the birds.

Ethical considerations

All processes within the experimental analysis were carried out according to the guidelines proposed by "The international guiding principles for biomedical research involving animal" (CIMOS and ICLAS 2012). The present project had the endorsement of the committee of ethics in animal experimentation of the Universidad Nacional de Colombia Sede Medellín CMED-006 as of March 17, 2016.

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Conflict of Interest

There is not any interest conflict.

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