# Effects of ambient temperature on growth performance, blood parameter, and fat deposition of geese from 14 to 28 days of age

Z. L. Liu,[*,1] Z. P. Chen,[*,1] J. J. Xue,[*] X. F. Huang,[*] Y. Chen,[*] B. W. Wang,[†] Q. G. Wang,[*,‡] and C. Wang[*,‡,2]

[*]*Poultry Science Institute, Chongqing Academy of Animal Sciences, Rongchang, Chongqing 402460, China;* [†]*Department of Food Science and Engineering, Qingdao Agricultural University, Qingdao, 266109, China; and* [‡]*Scientific Observation and Experiment Station of Livestock Equipment Engineering in Southwest, Ministry of Agriculture, Chongqing, 402460, China*

**ABSTRACT** An experiment was conducted to investigate the effects of ambient temperature on the growth performance, blood parameter, and fat deposition in geese from 14 to 28 d of age in order to establish their optimal temperature requirements. A total of 150 14-day-old geese were allocated randomly to 5 environmentally controlled chambers with ambient temperature set at 18, 21, 24, 27, and 30°C from 14 to 28 d of age, respectively. As ambient temperature increased from 18 to 30°C, the feed intake decreased linearly ($P < 0.05$) and was accompanied by linearly or quadratically ($P < 0.05$) decreasing 28-day-old body weight, weight gain, and feed/gain. The upper critical level of ambient temperature from 14 to 28 d of age for 28-day-old body weight and weight gain were 25.83 and 26.17°C, respectively. There were no differences in plasma biochemical parameters or plasma hormones between geese fed at ambient temperature regimen at 18, 21, 24, 27, and 30°C. The abdominal fat weight and abdominal fat rate decreased linearly ($P \leq 0.05$) with higher ambient temperature, but the ambient temperature had no effect on subcutaneous fat thickness or intermuscular fat width. It was concluded that the upper critical temperature of the ambient temperature for geese from 14 to 28 d of age was 26.17°C and high ambient temperature could lead to growth depression.

**Key words:** ambient temperature, goose, growth performance, blood parameter, fat deposition

2022 Poultry Science 101:101758
https://doi.org/10.1016/j.psj.2022.101758

## INTRODUCTION

Moderate ambient temperature in the house is the prerequisite for commercial poultry to maintain health and performance. In the modern large-scaled and high-efficient poultry production system, high or low temperature is one of the major stressors that poultry face. High or low ambient temperature can cause major economic losses to the poultry industry by reducing growth rate and hatchability and by increasing mortality (Balog et al., 2003; Niu et al., 2009; Olfati et al., 2018). Broilers subjected to high ambient temperature are characterized by altered physiology, behavior and performance. Specifically, high ambient temperature reduced feed intake and body weight gain, increased feed to gain ratio and mortality, decreased body antioxidant capacity, nutrient absorption and intestinal immunity, impaired intestinal morphology, and deteriorated carcass quality in broilers (Sahin and Kucuk, 2003; Quinteiro-Filho et al., 2010; Zhang et al., 2012; Yi et al., 2016; Sahin et al., 2017; Zaboli et al., 2017; He et al., 2018; Ma et al. 2018; Song et al., 2018). Similarly, high ambient temperature decreased body weight and weight gain, increased feed/gain (**F/G**), and reduced breast and leg meat yield of growing White Pekin ducks (Sun et al., 2019; Xie et al., 2019). Low ambient temperatures remain a threat to growth performance and intestinal health, particularly for young poultry. Low ambient temperatures increased feed intake, but decreased the production potential of broiler chickens (Olfati et al., 2018; Zhou et al., 2021), laying hens (Sahin et al., 2001), and Japanese quails (Shit et al., 2012). Furthermore, cold stress caused by low ambient temperature can increase energy requirements, disrupt physiological homeostasis, alter immune response and behavior, lead to ascites syndrome and higher mortality, and increase production costs in broiler chicken, impair egg production, and feed



Received November 18, 2021.
Accepted January 18, 2022.

[1]These authors should be considered joint first author.
[2]Corresponding author: wangccq@foxmail.com

efficiency in laying hens (Deeb et al., 2002; Balog et al., 2003). Therefore, it is vital to keep the ambient temperature stable and appropriate during the life cycle of poultry. It has been documented that the optimal performance temperature for growing broilers is ranged from 18 to 24°C (Saleh et al., 2021). In ducks, the upper critical temperature of the ambient temperature for starter Pekin ducks and growing ducks were 31.3 and 27°C, respectively (Sun et al., 2019; Xie et al., 2019).

With the development of animal husbandry in China, commercial goose production has changed from conventional free-range and open water outdoors to confinement in housing and, hence, control of ambient temperature has become more critical than before. In goose production, multiple-phase feeding strategy is generally adopted when considering the long raising period for geese. Undoubtedly, goslings are more sensitive to low temperature than adult geese, but the optimum temperature requirements for each rearing stage have not been provided until now. Therefore, the objective of the current experiment was to investigate the effects of ambient temperature on growth performance, blood parameter, and fat deposition and evaluate the optimum ambient temperature of geese from 14 to 28 d of age. An understanding of the effect and importance of ambient temperature can help to optimize temperature recommendations for commercially housed geese.

## MATERIALS AND METHODS

### Experimental Design and Bird Husbandry

The present research was approved by the Animal Care and Welfare Committee of the Chongqing Academy of Animal Science (**CAAS**), China. All geese used in this study were obtained from the goose-breeding center of CAAS.

A total of 150 14-d-old White Sichuan geese were randomly allotted to 5 environmentally controlled chambers (9 $m^2$/chamber) with ambient temperature set at 18, 21, 24, 27, and 30°C from 14 to 28 d of age, respectively, and the relative humidity of all chambers was set at 60% during this period. In each chamber, 30 birds were divided randomly to 6 raised wire-floor pens (0.72 $m^2$/pen) of 5 birds. All pens had similar initial body weights at the start of the experiment. The temperature-humidity data loggers (GSP-8, Elitech, Xuzhou, China) were installed in the center of each chamber and the height was at 1 m above floor level. Ambient temperatures were measured at 3 h intervals, resulting in 8 measurements per pen per day. And the average temperature in each environmentally controlled chamber was 18.36, 21.62, 23.89, 26.34, and 30.51°C, respectively. The distribution of lighting and ventilation was the same in all chambers and pen locations within the individual chamber were similar for all the chambers to avoid the influence of pen location on ventilation, and lighting program was 16L: 8D. During this period, water was provided by drip-nipple water, and the diets (Table 1) based on corn-soybean meal-wheat bran were formulated according to breed requirement containing 11.50 MJ metabolizable energy/kg and 170 g crude protein/kg and were fed in pellet form. The geese had free access to water and feed.

**Table 1.** Composition and calculated nutrient levels of diet (as-fed basis).

| Ingredients | % | Calculated nutrient levels | % |
|---|---|---|---|
| Corn | 53.00 | Metabolizable energy (MJ/kg) | 11.50 |
| Soybean meal | 24.00 | Crude protein | 17.00 |
| Wheat bran | 18.80 | Crude fiber | 4.45 |
| Limestone | 1.20 | Calcium | 0.90 |
| Hydrophosphate | 1.90 | Total phosphorus | 0.75 |
| L-Lysine•HCl | 0.10 | Lysine | 1.00 |
| DL-Methionine | 0.30 | Methionine | 0.45 |
| Salt | 0.30 | Threonine | 0.65 |
| Choline chloride | 0.10 | Tryptophan | 0.20 |
| Mineral and vitamin premix[1] | 0.30 | Arginine | 1.15 |
| Total | 100.00 | | |

[1]Premix provided the following per kg of diet: Cu ($CuSO_4$•$5H_2O$) 8 mg; Fe ($FeSO_4$•$H_2O$) 96 mg; Zn ($ZnSO_4$•$H_2O$) 80 mg; Mn ($MnSO_4$•$H_2O$) 100 mg; Se ($Na_2SeO_3$) 0.3 mg; I (KI) 0.4 mg; Vitamin A 6000 IU; Vitamin $D_3$ 1,500 IU; Vitamin E 10 IU; Vitamin $K_3$ 2.4 mg; Vitamin $B_1$ 1.5 mg; Vitamin $B_2$ 5 mg; Vitamin $B_6$ 3 mg; Vitamin $B_{12}$ 0.02 mg; Pantothenic acid 10 mg; Nicotinic acid 50 mg; Folic acid 0.5 mg; Biotin 0.15 mg.

### Sample Collection and Analytical Determination

***Growth Performance*** At 21:00 pm on 27 d, all the geese were fasted (water available) for 12 h and the BW of each replicate was recorded at 9:00 am on 28 d, and the weight of the remaining feed of each replicate was recorded. The weight gain, feed intake, and F/G were calculated for the period of 14 d (n = 6, per treatment was represented by 6 replicates, with 5 birds per replicate).

***Blood Parameter*** After recording the BW and remaining feed weight, blood samples were collected from 3 geese randomly selected from each replicate (n = 6, per treatment was represented by 6 replicates, with 3 birds per replicate). About 5 mL of blood was drawn from the wing vein, and plasma was separated through refrigerated centrifuge (5424R, Eppendorf, Germany) at 3,500 rpm for 15 min at 4°C and then stored at −80°C for plasma biochemical parameters and plasma hormones determination. Total protein (**TP**), albumin (**ALB**), globulin (**GLO**), glucose (**GLU**), alanine amino transferase (**ALT**), aspartate amino transferase (**AST**), alkaline phosphatase (**ALP**), and lactate dehydrogenase (**LDH**) in the plasma were determined by the colorimetric method with the automatic biochemical analyzer (AU680, Beckman Coulter., Tokyo, Japan) with corresponding commercial kits (Nanjing Jiancheng Bioengineering Institute, Nanjing, China) following the manufacturer's guides. Plasma concentrations of adrenocorticotropic hormone (**ACTH**), corticosterone (**CORT**), cortisol (**COR**), triiodothyronine (**$T_3$**), and thyroxine (**$T_4$**) were determined by competition method using corresponding commercial goose analytical ELISA kits (Nanjing Jiancheng Bioengineering Institute), monitoring the change of absorbance at 450 nm with the microplate reader (SpectraMAX Plus384, Molecular Devices, San Francisco, CA) according to the manufacturer's recommendations.

***Fat Deposition*** After 12 h feed deprivation, 8 geese were selected according to the average body weight of corresponding treatment (n = 8, per treatment was represented by 8 replicates, with 1 bird per replicate), exsanguinated by cutting the jugular vein and eviscerated manually. The abdominal fats (comprising fat tissues surrounding the proventriculus and gizzard lying against the inside abdominal wall and around the cloaca) were removed manually from carcasses and weighed and the percentages relative to live body weight at processing were calculated. Meanwhile, a vernier caliper was used to measure the subcutaneous fat thickness after skin incision at the dorsal midline in front of the caudal vertebrae and intermuscular fat width at the end of the sternum xiphoid.

***Statistical Analysis*** Data were analyzed by one-way ANOVA procedure of SAS software (SAS Institute Inc., 2003), with pen used as the experimental unit for analysis. When temperature treatment was significant, means were compared using Duncan's multiple comparison procedure of SAS software (SAS Institute Inc., 2003). The linear and quadratic polynomial contrasts were performed to determine the effects of ambient temperature on performance and a probability level of $P \leq 0.05$ was considered to be statistically significant.

The upper critical temperature was estimated by broken-line regression (Huynh et al., 2005). The upper critical temperature was designated as the inflection point temperature above which the goose response started to change. The broken-line model was provided as follows: y = l + u (x-r); Where y = goose response (28-day-old body weight or weight gain), x = ambient temperature (°C), r = breakpoint between two lines which was defined as the optimal ambient temperature, u = the slope of the curve, l = maximum or minimum response if x < r and y = l + u (x- r) if x ≥ r.

## RESULTS AND DISCUSSION

### Growth Performance

The effects of ambient temperature on growth performance of geese are presented in Table 2. All the birds show no mortality during the experimental period. The feed intake linearly decreased ($P < 0.05$) with higher ambient temperature. Furthermore, 28-day-old body weight, weight gain, and F/G linearly or quadratically decreased ($P < 0.05$) with higher ambient temperature. Our results were partly supported in broilers (Sohail et al., 2012; Zhang et al., 2015; de Souza et al., 2016; Yi et al., 2016; Sahin et al., 2017; He et al., 2018; Ma et al., 2018; Song et al., 2018) and ducks (Sun et al., 2019; Xie et al., 2019), that high ambient temperature depress feed intake, body weight, and weight gain. When ambient temperature is higher than the thermoneutral temperature, it can lead to higher body temperature and thus heat burden. Then birds decrease feed intake to diminish metabolic heat production and maintain homeothermy, resulting in lower body weight gain (Temim et al., 1999; Song et al., 2013; Sahin et al., 2017; Song et al., 2018). Therefore, high temperature via reducing feed intake impairs growth performance in geese. In the present study, increased ambient temperature decreased F/G of geese, and geese raised at 18°C had higher F/G compared with those raised at 24 and 27°C, indicating that lower temperature had negative effects on F/G, which was consistent with the previous studies on broilers (Yang et al., 2014; Zhou et al., 2021).

However, there was no difference in 28-day-old body weight or weight gain between geese fed at the ambient temperature regimen at 18, 21, 24, and 27°C ($P > 0.05$, Table 1), which indicated that there existed a temperature plateau and the upper critical temperature for goose growth and the growth response would be reduced when the temperature went beyond the upper critical temperature. Therefore, based on the growth performance at 28 d of age, the upper critical temperature of ambient temperature of geese from 14 to 28 d of age was estimated by broken-line regression. According to broken-line regression, the upper critical level of ambient temperature from 14 to 28 d of age for 28-day-old body weight and weight gain were 25.83 and 26.17°C, respectively (Figures 1 and 2). Therefore, the upper critical temperature of the ambient temperature for geese from 14 to 28 d of age was 26.17°C. Recently, Sun et al. (2019) reported that the upper critical level of ambient temperature of male growing White Pekin ducks during the growing period for body weight, weight gain, and F/G were 27.4, 27.4, and 26°C, respectively. It is clear that different physiological and productive parameters of poultry have different critical temperatures. Those threshold temperatures vary depending on genotype, body weight, physiological stage, and living on different seasons and latitudes (Shi et al., 2008).

### Blood Parameter

The effects of ambient temperature on plasma biochemical parameters of geese are presented in Table 3. There were no significant differences in plasma concentration of TP, ALB, GLO, GLU, ALT, AST, ALP, or LDH in geese from 14 to 28 d of age ($P > 0.05$). The effects of ambient temperature on plasma hormone of geese are presented in Table 4. And no significant differences were observed among the 5 groups for plasma concentrations of ACTH, CORT, COR, $T_3$, or $T_4$ in geese ($P > 0.05$). Therefore, ambient temperature did not affect plasma biochemical parameters or hormone concentration in geese from 14 to 28 d of age in this study. There might be an adaptation in the blood parameter for geese under high temperature of 30°C for 14 d. Sahin et al. (2017) found that high temperature (34 ± 2°C for 8 h/d) did not affect serum concentrations of TP,

**Table 2.** Effects of ambient temperature on growth performance of geese from 14 to 28 d of age.[1]

| Temperature | 14-day-old body weight (g/bird) | 28-day-old body weight (g/bird) | Weight gain (g/bird/day) | Feed intake (g/bird/day) | Feed/gain (g/g) |
|---|---|---|---|---|---|
| 18°C | 469.05 | 1363.83[a] | 63.91[a] | 143.67[a] | 2.25[a] |
| 21°C | 472.47 | 1,354.47[a] | 63.00[a] | 136.44[b] | 2.17[ab] |
| 24°C | 468.82 | 1,362.97[a] | 63.87[a] | 133.89[b] | 2.10[b] |
| 27°C | 460.30 | 1,345.40[a] | 63.22[a] | 130.66[b] | 2.07[b] |
| 30°C | 464.83 | 1,221.60[b] | 54.05[b] | 114.88[c] | 2.14[ab] |
| SEM | 7.82 | 24.21 | 1.65 | 2.43 | 0.04 |
| Probability | | | | | |
| Temperature | 0.838 | 0.001 | 0.001 | <0.001 | 0.035 |
| Linear | 0.413 | 0.001 | 0.001 | <0.001 | 0.016 |
| Quadratic | 0.929 | 0.009 | 0.007 | 0.062 | 0.033 |

[a, b, c]In the same column, values with different small letter superscripts mean significant difference ($P < 0.05$), while with common or no letter superscripts mean no significant difference ($P > 0.05$).
[1]Data are means of 6 replicates, with 5 birds per replicate.

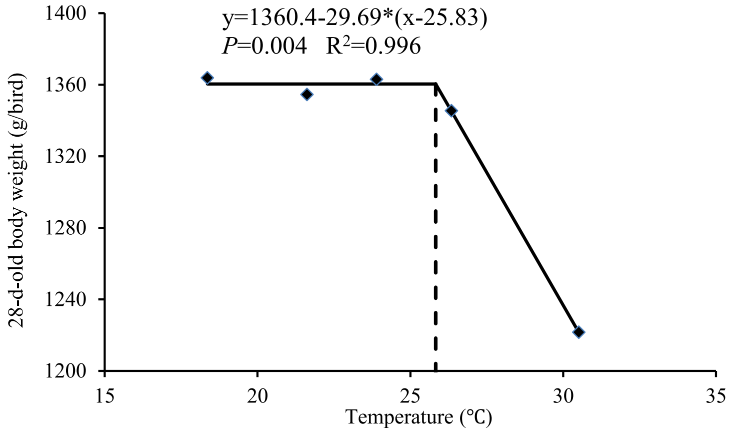


**Figure 1.** Body weight response to ambient temperature of geese at 28 d of age.

ALB, GLO, or AST, but increased serum GLU, cholesterol, ALT and LDH concentrations in broilers, indicating that high temperature increased serum enzymes concentration in broilers. Bueno et al. (2017) demonstrated that high temperature at 36°C for 1 hour from 16 to 42 d of age increased serum AST concentration, whereas had no effect on GLU, uric acid, ALT, triglycerides, or very low density lipoproteins concentration in broilers. Zhou et al. (2021) showed that low temperature (16°C) for 72 h increased blood AST and GLU levels of the broilers. Quinteiro-Filho et al. (2012) reported that 31°C high temperature stress increased CORT serum level, impaired performance parameters, induced intestinal inflammation and reduced macrophage

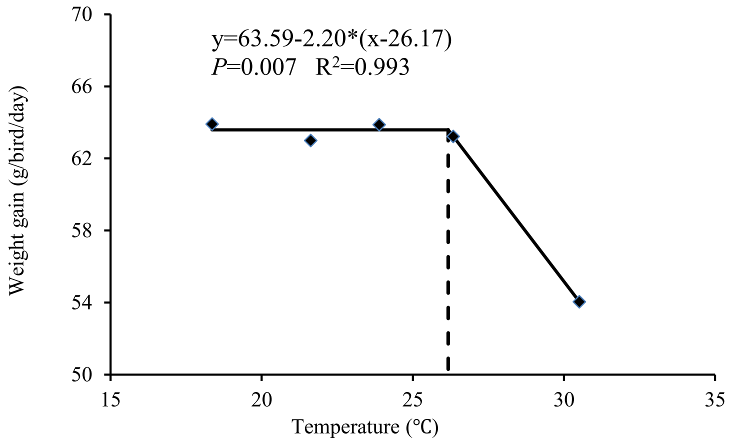


**Figure 2.** Weight gain response to ambient temperature of geese.

**Table 3.** Effects of ambient temperature on plasma biochemical parameters of geese from 14 to 28 d of age.[1]

| Temperature | TP (g/L) | ALB (g/L) | GLO (g/L) | ALT (U/L) | AST (U/L) | ALP (U/L) | LDH (U/L) | GLU (mmol/L) |
|---|---|---|---|---|---|---|---|---|
| 18°C | 30.43 | 13.31 | 17.28 | 15.53 | 19.53 | 869.64 | 513.25 | 8.37 |
| 21°C | 33.66 | 14.69 | 18.79 | 16.75 | 16.97 | 902.94 | 484.78 | 9.58 |
| 24°C | 36.97 | 15.99 | 21.03 | 19.50 | 20.64 | 987.17 | 513.11 | 9.83 |
| 27°C | 33.67 | 14.70 | 19.01 | 17.83 | 17.94 | 973.61 | 503.78 | 9.00 |
| 30°C | 33.91 | 14.76 | 19.21 | 14.08 | 15.97 | 1,025.50 | 344.28 | 9.35 |
| SEM | 2.38 | 0.94 | 1.44 | 1.93 | 1.90 | 109.42 | 52.29 | 0.53 |
| Probability | | | | | | | | |
| Temperature | 0.452 | 0.415 | 0.500 | 0.352 | 0.431 | 0.848 | 0.140 | 0.352 |
| Linear | 0.362 | 0.337 | 0.379 | 0.770 | 0.316 | 0.280 | 0.065 | 0.412 |
| Quadratic | 0.169 | 0.148 | 0.213 | 0.058 | 0.471 | 0.883 | 0.138 | 0.171 |

Abbreviations: ALT, alanine aminotransferase; AST, aspartate aminotransferase; ALP, alkaline phosphatase; ALB, albumin; GLU, glucose; GLO, globulin; LDH, lactate dehydrogenase; TP, total protein.

[1]Data are means of 6 replicates, with 3 birds per replicate.

**Table 4.** Effects of ambient temperature on plasma hormones of geese from 14 to 28 d of age.[1]

| Temperature | ACTH (pg/mL) | COR (pg/mL) | CORT (ng/mL) | $T_3$(nmol/L) | $T_4$ (nmol/L) |
|---|---|---|---|---|---|
| 18°C | 46.33 | 5,005.42 | 88.14 | 4.25 | 133.11 |
| 21°C | 49.49 | 5,513.60 | 94.42 | 4.56 | 132.86 |
| 24°C | 40.53 | 5,108.80 | 81.40 | 4.17 | 134.91 |
| 27°C | 41.65 | 4,855.65 | 79.34 | 4.12 | 135.12 |
| 30°C | 53.32 | 6,209.51 | 99.93 | 4.62 | 159.26 |
| SEM | 4.02 | 531.13 | 9.09 | 0.48 | 13.62 |
| Probability | | | | | |
| Temperature | 0.167 | 0.401 | 0.475 | 0.920 | 0.604 |
| Linear | 0.633 | 0.307 | 0.770 | 0.843 | 0.217 |
| Quadratic | 0.084 | 0.363 | 0.256 | 0.692 | 0.366 |

Abbreviations: ACTH, adrenocorticotrophic hormone; COR, cortisol; CORT, corticosterone; $T_3$, triiodothyronine; $T_4$, thyroxine.

[1]Data are means of 6 replicates, with 3 birds per replicate.

activity in broiler chickens. Olfati et al. (2018) found that ambient temperature had no effect on serum concentration of CORT in broilers on 21 d, but high (33 ± 3°C) and low temperature (12 ± 1°C) increased serum CORT concentration on 42 d, indicted that chronic high and low temperature have negative effects on performance and immunity. The variability of the effects observed between many of the studies published may be easily explained by the use of birds of different age or genetic background, as well as due to variable intensity and duration of the high temperature treatments applied.

## Fat Deposition

The effects of ambient temperature on fat deposition of geese are presented in Table 5. The abdominal fat weight and abdominal fat rate decreased linearly ($P \leq 0.05$) with increase in ambient temperature. Otherwise, no significant differences were observed on subcutaneous fat thickness or intermuscular fat width at different ambient temperature ($P > 0.05$). Therefore, higher ambient temperature could decrease abdominal fat deposition in geese from 14 to 28 d of age. Early fast growth rate in poultry is accompanied by increased body fat deposition. In this study, higher ambient temperature may decrease feed intake and weight gain, resulting in depression of growth performance, and decreases abdominal fat deposition in geese. Lu et al. (2007) showed that Arbor Acres broiler chickens exposed to ambient temperature of 34°C had slightly decreased abdominal fat deposition and significantly decreased subcutaneous fat as well as intermuscular fat deposition compared to ambient temperature of 21°C.

**Table 5.** Effects of ambient temperature on fat deposition of geese from 14 to 28 d of age.[1]

| Temperature | Abdominal fat weight (g) | Abdominal fat rate (%) | Subcutaneous fat thickness (mm) | Intermuscular fat width (mm) |
|---|---|---|---|---|
| 18°C | 37.96[a] | 2.31 | 1.89 | 9.87 |
| 21°C | 34.36[ab] | 2.06 | 1.71 | 9.39 |
| 24°C | 35.24[ab] | 1.93 | 1.83 | 9.56 |
| 27°C | 28.22[b] | 1.79 | 1.78 | 10.31 |
| 30°C | 28.73[b] | 1.97 | 1.74 | 9.72 |
| SEM | 2.50 | 0.15 | 0.11 | 0.56 |
| Probability | | | | |
| Temperature | 0.036 | 0.178 | 0.772 | 0.807 |
| Linear | 0.004 | 0.050 | 0.509 | 0.728 |
| Quadratic | 0.973 | 0.144 | 0.751 | 0.862 |

[a,b]In the same column, values with different small letter superscripts mean significant difference (P<0.05), while with common or no letter superscripts mean no significant difference (P>0.05).

[1]Data are means of 8 replicates, with 1 bird per replicate.

On the other hand, Sahin et al. (2017) observed that high ambient temperature caused depressions in feed intake and weight gain as well as elevations in feed conversion and abdominal fat rate. The differences reported above could be related to the age of the bird, the model of high temperature (constant or cyclic), the method used to measure the fat index, and breed.

## CONCLUSIONS AND APPLICATIONS

High ambient temperature could have negative effects on the growth performance of geese from 14 to 28 d of age. According to the broken-line regression based on growth performance, the upper critical temperature of the ambient temperature for White Sichuan geese was 26.17°C.

## ACKNOWLEDGMENTS

Funding for this study was provided by General Project of Chongqing Natural Science Foundation (cstc2019jcyj-msxmX0077), China Agriculture Research System of MOF and MARA (CARS-42-22), the Key R & D Project in Agriculture and Animal Husbandry of Rongchang (cstc2020ngzx0007), and Cooperative Extension Project of Major Agricultural Technology in Chongqing (21315)

## DISCLOSURES

There are no conflicts of interest with any individual or organization.

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