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Prediction of Productivity Traits of Growing-Finishing Pigs in Varying Ambient Temperature

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Research Article

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Keywords: Finishing pigs, Average body weight, Average daily weight gain, Feed conversion ratio, Average feed intake, Thermal environment, Regression analysis.

ABSTRACT

Objective: Recent decades have seen a rapid increase in global pig production system and consumption patterns. Since an optimum temperature level has a significant effect on pig performances, this study was undertaken to determine the effect of varying temperature on the productivity traits of growing and finishing pigs with regression analysis.

Methods: This experiment was conducted at the Sunchon National University in South Korea. A total of 40 three-way crossbred pigs were used, having average body weight 25.27 ± 0.47 kg. They were allocated into four treatments and provided temperature levels for growing phase were T1=16°C, T2=21°C, T3=26°C and T4=31°C. Finishing pigs were accommodated with T1=12°C, T2=18°C, T3=25°C and T4=32°C. The Average Daily Weight Gain (ADWG), Average Daily Feed Intake (ADFI) and Feed Conversion Ratio (FCR) were measured.

Results: Data analysed at the end of the experimental period revealed, in the growing phase, FCR was enhanced in the T2, T3 and T4 treatment groups ($p<0.05$). Furthermore, late finishing pigs in T1 treatment showed the highest FCR ($p<0.05$).

Conclusion: Regression analysis showed that improvement in FCR, ADWG and ADFI could be obtained by providing optimum temperature. Taken together, results of this study indicate that the performance of pigs could be enhanced with proper thermal environmental conditions.

INTRODUCTION

Livestock are important for global food supply since they provide 17% of kilocalorie consumption and 33% of global protein consumption [1]. However, since climate variability is a major threat to livestock production, researchers at the local level are required to be engaged in order to mitigate the problems through introducing sustainable strategies. Soerensen and Pedersen [2,3] reported that pig production is affected due to elevated environmental temperature through its potential effects on heat stress, as pigs need to acclimatize by making certain physiological adjustments.

Optimum temperature level positively impacts the growth of pigs due to its direct influence on productivity. Animal physiology, behavior and metabolic activities are known to change when they are exposed to high ambient temperatures [4]. These changes are utilized for maintaining the internal body temperature, which in turn are detrimental to the overall performances [5]. Prolonged elevated temperatures result in reduced voluntary feed intake in order to reduce the heat production associated with digestion and metabolism of nutrients, which in turn decreases their weight gain (ADG) [6]. Heat stress, which considerably damages tips of the intestinal villi, results in shorter villus height and crypt depth in the jejunum [7]. Since majority of nutrients are absorbed in the jejunum, the efficiency of nutrients absorption is thereby degraded due to heat stress. Le bellego et al. [8], mentioned that the separation of energy intake between protein and lipid deposition is modified by high temperature values.

Furthermore, alterations in the cell membrane and cellular proliferation due to heat stress may influence the transmission of nutrients through the cell membrane [9]. Myer and Bucklin [10] reported that the optimum temperature range for finishing pigs is between 10-23.9°C. Variations in carbohydrate and lipid metabolism were observed when growing pigs were kept at a higher temperature (32°C) for two weeks [11]. The adverse effects in animal performances were caused not only by the lower consumption pattern, but also by the enzymatic variations in the blood and in the muscle tissues [12].

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The current study, therefore, aimed to predict the productivity traits of growing-finishing pigs according to the varying ambient temperature.

MATERIALS AND METHODS

Animals and Experimental Design

This study was conducted at the livestock experiment station of the Sunchon National University, South Korea. All experiments were conducted according to guidelines established by the Animal Care and Use Committee at the Department of Animal Science, Sunchon National University. The experiment commenced on 1st August, 2017 and ended on 30th October, 2017. The piglets for the experiment were the three-way crossbreed, Landrace × Yorkshire × Duroc. A total of 40 pigs were enrolled in the study, having average body weight (BW) 25.27 ± 0.47 kg; 10 pigs were allotted to four incubators (1.5 × 1.2 m) assigned to 4 treatment groups: T1, T2, T3 and T4. The temperature level was changed according to their growth phase and growing phase was 35 days and 28 days were given for the both early and late finishing phase. Feed conversion ratio (FCR), Average Daily Weight Gain (ADWG), and Average Daily Feed Intake (ADFI) were measured for growing pigs, early finishing pigs and late finishing pigs.

Animal Diets and Management

Pigs were given ad libitum access to feeds formulated according to the NRC requirements for swine (NRC 2012). Pigs had unlimited access to water through the nipple drinker system. The two metabolizable energy levels were 3,265 kcal/kg and 3,265 kcal/kg, and the two crude protein levels were 18% and 17% **(Table 1)**.

Table 1. Feed ingredients and chemical composition of the experimental diets (%).

Ingredients (%)	Growing	Finishing
Yellow Corn	51.36	55
Rice bran	7	8
Rapeseed oil meal	1.72	3
DDGS	6	6
Soybean meal	21.8	18.16
Limestone	0.84	1
Calcium phosphate	0.1	0.2
Salt	0.3	0.3
Vitamin. premix1)	0.45	0.2
Animal fat	6.78	4.76
Molasses	2.5	2.5
Amino acid additive	1.15	0.88
Sum	100	100
Chemical composition		
ME (kcal/kg)	3,265.00	3,265.00
Crude Protein (%)	18	17
Ca (%)	0.8	0.8
Available. P (%)	0.34	0.34
Lysine (%)	1.2	1.1
Methionine (%)	0.37	

[1)]Vitamin pre-mix provided following nutrients per kg of premix: vitamin A 6,000 IU; vitamin D3 800 IU; vitamin E 20 IU; vitamin K3 2 mg; thiamin 2 mg; riboflavin 4 mg; vitamin B6 2 mg; vitamin B12 1 mg; pantothenic acid 11 mg; niacin 10 mg; biotin 0.02 mg; Cu (copper sulfate) 21 mg; Fe (ferrous sulfate) 100 mg; Zn (zinc sulfate) 60 mg; Mn (manganese sulfate) 90 mg; I (calcium iodate) 1.0 mg; Co (cobalt nitrate) 0.3 mg; Se (sodium selenite) 0.3 mg

Measurement Parameters

The established temperature levels (°C) for pigs with respect to their growth phase and temperature, recorded at 8:00 am, 2:00 pm, 6:00 pm and 10:00 pm **(Table 2)**. Proper wind speed was maintained according to the recommendation of the Rural Development Administration (2016).

Table 2. Setting temperature levels (°C) according to the growth phase.

Variables	Temperature level of treatments (°C)			
Growth phase	T1	T2	T3	T4
Growing pigs	16	21	26	31
Finishing pigs	12	18	25	32

Growth Performance

Body weight, average daily feed intake, feed conversion ratio and average daily weight gain were measured in growers and

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finishing pigs. Body weight and feed intake were measured every two weeks, from start to the end of the experiment. Feed intake was measured every two weeks, by measuring the feed weight immediately before body weight measurement. Feed conversion ratio (FCR) was calculated by dividing the feed intake by average daily gain. Average daily weight gain (ADWG) was calculated by dividing the weight difference of starting and finishing weight by the experimental period.

Statistical Analysis

Growth performance of pigs

Statistical analysis of the data obtained by this study was analyzed using the SAS Statistical Package Program (SASⓐ9.4 Package/PC). The significance of the mean value of the treatment interval was tested by Duncan's multiple test method.

Relationship and regression equation between temperature of pig house and growth performance of pigs

Before analyzing the data, the outlier was added and subtracted from the 5-fold standard deviation to be analyzed and removed from the data. Assess the validity of the statistic, we conducted simulations under the null hypothesis, by setting all the regression co-efficient simultaneously equal to zero.

Regression analysis was performed using a per regression (step wise regression) in the SAS/REG method of SASⓐ9.4 Package/PC.

Model 1: $Y=a (X^2)+Bx+c$

Model 2: $Y=bX+c$

Where Y is the observed value of the dependent variable, a and b are the regression co-efficient for X (Temperature) and c is the intercept.

RESULTS AND DISCUSSION

Growth Performances of Growing Pigs

The growth performance of growing pigs was different according to their thermal environment **(Table 3).** The pig house temperatures were set at 16, 21, 26, and 31°C. The mean measured temperatures were 18.91, 21.43, 26.65, and 30.67°C, respectively. The experimental period for growers was 35 days.

Table 3. Effect of temperature inside the pig house, on the growth performances of growing pigs.

Variables	T1	T2	T3	T4	SEM	p-value
Setting temp. (°C)	16	21	26	31	-	-
Actual temp. (°C)	18.91[d]	21.43[c]	26.65[b]	30.67[a]	0.16	<0.0001
Initial weight (kg)	25.76	26.31	25.22	23.78	1.11	0.4767
Final weight (kg)	58.83[a]	58.17[a]	53.69[b]	49.72[b]	1.49	0.0004
Weight gain (kg)	33.07[a]	31.86[a]	28.47[b]	25.94[c]	0.72	<0.0001
Feed intake (kg)	62.85[bc]	68.95[a]	64.36[ab]	58.57[c]	1.67	0.0015
FCR (1) (Feed/Gain)	1.90[b]	2.16[a]	2.26[a]	2.26[a]	0.05	<0.0001
ADWG2) (kg)	0.94[a]	0.91[a]	0.81[b]	0.74[c]	0.02	<0.0001
ADFI3) (kg)	1.80[bc]	1.97[a]	1.84[ab]	1.67[c]	0.05	0.0013

[a,b,c,d] Values with different superscripts in the same row differ significantly ($p<0.05$).
1)FCR=Feed conversion ratio; 2)ADWG=Average daily weight gain; 3)ADFI=Average daily feed intake

Relationship between temperature and performances of growing pigs with regression curve analysis

The correlation between the pig house inside temperature and growth performance of growing pigs. ADG was determined with parameters of -0.0174X+1.278 for temperature. ADFI was evaluated with a parameter of $-0.00534X^2+0.250X-0.999$ for temperature and $0.00528X^2+0.289 \times -1.659$ parameters for temperature were used for FCR analysis **(Table 4).**

Table 4. Correlation between temperature and growth performance of growing pigs.

Items	Parameter			
	a	b	c	R^2
Average daily weight gain	*	-0.0174	1.278	0.69
Average daily feed intake	-0.00534	0.25	-0.999	0.5145
Feed conversion ration	-0.00528	0.289	-1.659	0.4689

Model of pig productivity=a × (Temperature)^2+b × (Temperature)+c
*No parameter

Reduction of ADG was occurred when temperature is increased. ADG is higher when animals exposed to lower temperature

(Figure 1). Temperature range between 21°C to 24°C pigs had higher ADFI value **(Figure 2).** Furthermore low temperature showed reduced FCR value and again decreased when temperature is increased **(Figure 3).**

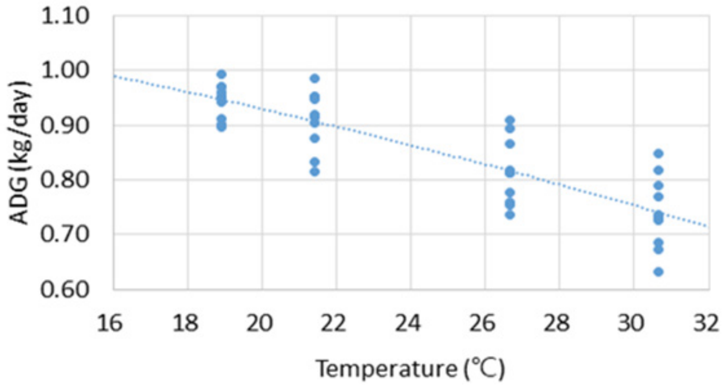

Figure 1. Estimated ADG curves for growing pigs according to the temperature.

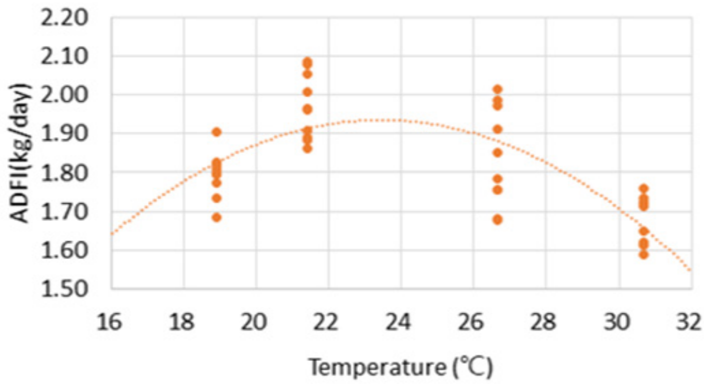

Figure 2. Estimated ADFI curves for growing pigs according to the temperature.

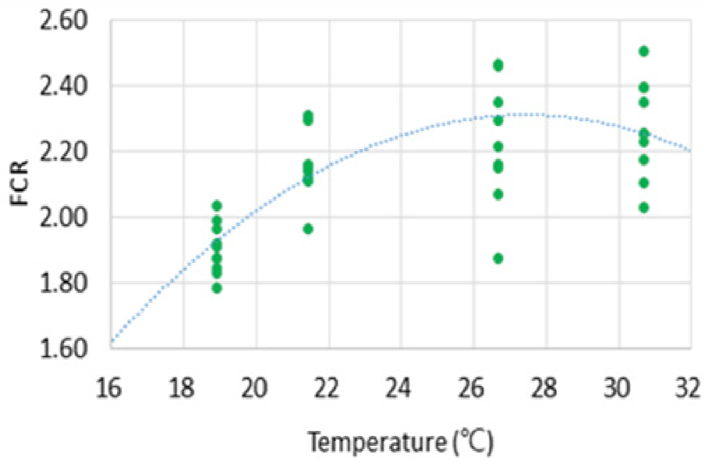

Figure 3. Estimated FCR curves for growing pigs according to the temperature.

The weight gain was highest in the T1 and T2 treatments, and lowest in T4 treatment ($p<0.05$). Feed intake was higher for pigs growing at 21.43°C as compared to pigs at 30.67°C ($p<0.05$). The FCR was significantly higher for pigs in the T2, T3 and T4 treatments, as compared with T1 treatment. ADWG was increased in T1 and T2 treatments and was lowest in T4 treatment ($p<0.05$). Pigs kept at 21.43°C showed higher ADFI than those at 30.67°C ($p<0.05$).

Our results indicate that feed intake was lower in T4 treatment compared with other treatments. Manno et al. [13] and Kiefer et al. [14], in a study with growing pigs, observed that pigs exposed to elevated temperatures greater than the upper critical temperature (27°C) minimize their food consumption and metabolic rate in order to decrease body temperature, which eventually leads to performance depletion. Initial heat affects the pigs to decline their voluntary feed intake in order to prevent the heat increment [15]. In T3 and T4 treatments, the final body weight is significantly lower than T1 and T2 treatments. The BW enhancement associated with feeding behaviors at elevated temperatures can reduce the ingestion time per day. It is reported

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that the time duration of each meal and the rate of feed intake decrease, which results in lower meal size and decreased feed intake [16]. As reviewed by Le Dividich et al. [17], between 20°C and 30°C, declining ADFI values ranged from a minimum of 40 to a maximum of 80 gd^{-1} per 1°C. According to Hazen and Mangold [18], temperature increment of 1°C (from 18°C to 32°C) influences for 7 g reduction in ADG in pigs weighing between 20-100 kg. This variability can be interpreted by numerous factors, including the pig's BW, breed, degree of fatness, nutritional composition of diets, and temperature ranges.

The thermo neutral zone (TNZ) is the normal body temperature which does not adversely affect the animal's activity [19]. Heitman et al. [20] and Holmes and Close et al. [21] reported that some factors like feed consumption level, size and wind velocity determine the thermal neutral zone. An upper critical temperature (UCT) and lower critical temperature (LCT) are considerable parameters in the pig industry. As BW increases, the UCT level decreases while the LCT level increases. Pigs exposed to the elevated UCT and reduced LCT experience extreme harmful effects.

The FCR value is significantly reduced in T1 treatment when compared with T2, T3 and T4 treatments. In the current study, the feed efficiency was better when animals were exposed to comfortable environmental temperatures. Nevertheless, when growing pigs exposed to higher temperatures showed better feed efficiency than those who are fed ad libitum or paired feeding under the thermal comfort zone [13]. Renaudeau et al. [22] observed lower feed conversion in the growing phase when pigs were exposed to heat stress.

Growth Performance of Finishing Pigs

The growth performances of early and late finishing pigs were vary according to the various temperature **(Table 5).**

Table 5. Effect of inside temperature of pig house on growth performance of early finishing pigs and late finishing pigs for a period of 28 days.

Variables	Treatments					
	T1	T2	T3	T4	SEM	p-value
Early F.						
Setting temp. (°C)	12	18	25	32		
Actual temp. (°C)	17.77^{d}	21.13^{c}	28.77^{b}	31.10^{a}	0.13	<0.0001
Initial weight (kg)	58.83^{a}	58.17^{a}	53.69^{b}	49.72^{b}	1.49	0.0004
Final weight (kg)	87.15^{a}	84.40^{a}	79.60^{b}	73.85^{c}	1.52	<0.0001
Weight gain (kg)	28.32^{a}	26.23a^{b}	25.91^{ab}	24.13^{b}	0.96	0.0389
Feed intake (kg)	74.40^{ab}	80.01^{a}	67.85^{b}	58.16^{c}	2.77	<0.0001
FCR1 (Feed/Gain)	2.63^{b}	3.05^{a}	2.62^{b}	2.41^{b}	0.11	0.0032
ADWG2 (kg)	1.01^{a}	0.94a^{b}	0.93^{ab}	0.86^{b}	0.03	0.0363
ADFI3 (kg)	2.66^{ab}	2.86^{a}	2.43^{b}	2.08^{c}	0.1	<0.0001
Late F.						
Setting temp. (°C)	12	18	25	32		
Actual temp. (°C)	16.90^{d}	20.90^{c}	28.20^{b}	31.60^{a}	0.13	<0.0001
Initial weight (kg)	87.15^{a}	84.40^{a}	79.60^{b}	73.85^{c}	1.52	<0.0001
Final weight (kg)	108.30^{a}	104.75^{a}	103.35^{ab}	95.60^{b}	2.56	0.0176
Weight gain (kg)	21.15	20.35	23.75	21.75	1.62	0.5627
Feed intake (kg)	90.40^{a}	75.42^{b}	80.61^{b}	70.14^{b}	4.63	0.0393
FCR1) (Feed/Gain)	4.27^{a}	3.71^{b}	3.39^{b}	3.33^{b}	0.13	<0.0001
ADWG2) (kg)	0.75	0.73	0.85	0.78	0.06	0.5453
ADFI3) (kg)	3.23^{a}	2.69^{b}	2.88^{ab}	2.51^{b}	0.17	0.0395

^{a,b,c,d} Values with different superscripts in the same row differ significantly ($p<0.05$). 1)FCR=Feed conversion ratio; 2)ADWG=Average daily weight gain; 3)ADFI=Average daily feed intake.

Relationship between temperature and performances of early finishing pigs with regression curve analysis

The correlation between the temperature of pig house and growth performance of early finishing pigs were evaluated by using equations **(Table 6).** ADWG was analyzed with parameters of -0.00892 × +1.154 for temperature.-0.0101X^2+0.449 × -2.139 parameter was used for the evaluation of ADFI and FCR was determined by using parameter of -0.0118X^2+0.557 × -3.484 for temperature.

Table 6. Correlation between the pig house inside temperature and growth performance of early finishing pigs.

Item	Parameter			
	a	b	c	R^2
Average daily weight gain	*	-0.00892	1.154	0.3677
Average daily feed intake	-0.0101	0.449	-2.139	0.7087
Feed conversion ration	-0.0118	0.557	-3.484	0.4538

Model of pig productivity=a × $(\text{Temperature})^2$+b × (Temperature)+c *No parameters

The regression analysis also confirmed the above variations of ADG **(Figure 4)**, ADFI **(Figure 5)** and FCR **(Figure 6).**

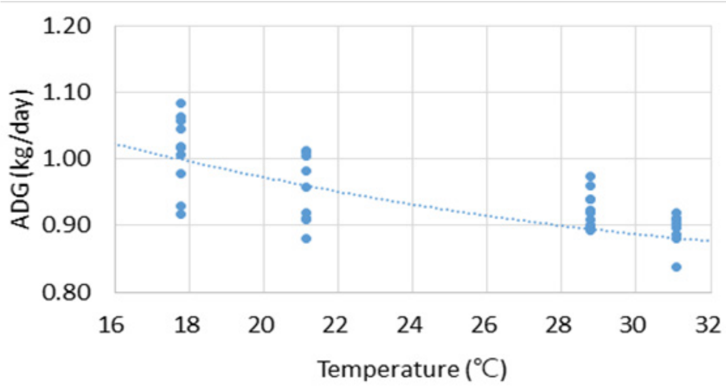

Figure 4. Estimated ADG curves for early finishing pigs according to the temperature.

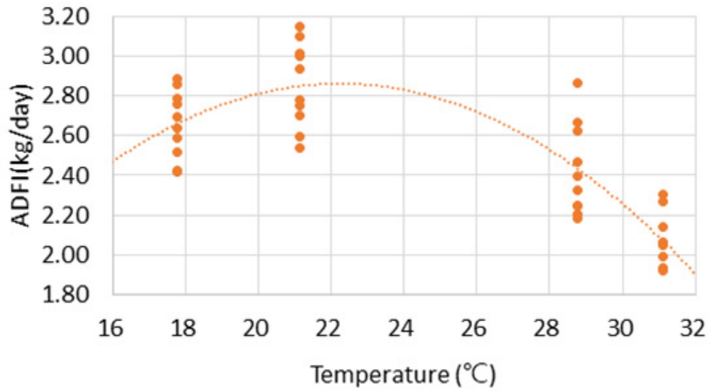

Figure 5. Estimated ADFI curves for early finishing pigs according to the temperature.

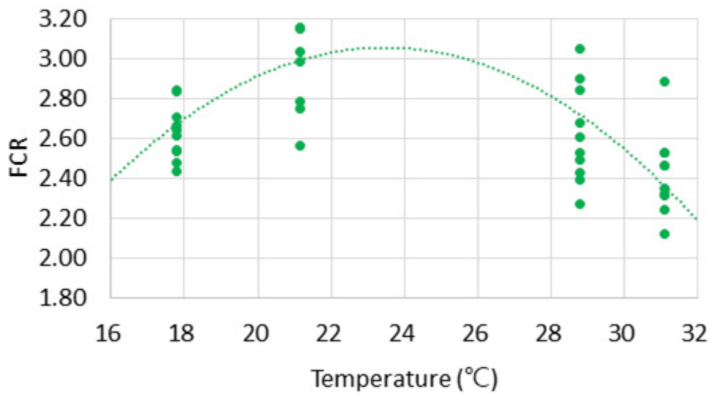

Figure 6. Estimated FCR curves for early finishing pigs according to the temperature.

Relationship between temperature and performances of late finishing pigs with regression curve analysis

The correlation between the pig house inside temperature and growth performance of late finishing pigs also evaluated by using equation **(Table 7).** ADWG for the temperature had no significant parameters. ADFI was evaluated with a parameter of -0.0351X+3.688 for temperature and FCR was determined with a parameter of -0.0455X+4.708 for temperature.

Table 7. Correlation between the pig house inside temperature and growth performance of late finishing pigs.

Item	Parameter			
	a	b	c	R^2
Average daily weight gain	*	*	*	*
Average daily feed intake	*	-0.0351	3.688	0.2931
Feed conversion ration	*	-0.0455	4.708	0.2968
Model of pig productivity=a × $(\text{Temperature})^2$+b × (Temperature)+c *Nothing parameter				

The resulted regression analysis also confirmed the resulted value of ADG **(Figure 7),** ADFI **(Figure 8)** and FCR **(Figure 9).**

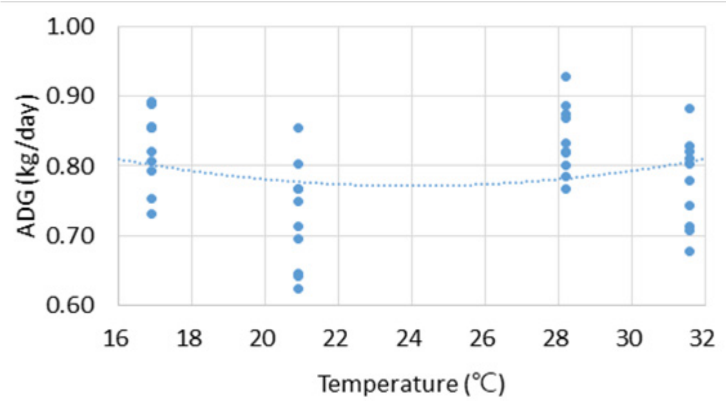

Figure 7. Estimated ADF curves for late finishing pigs according to the temperature.

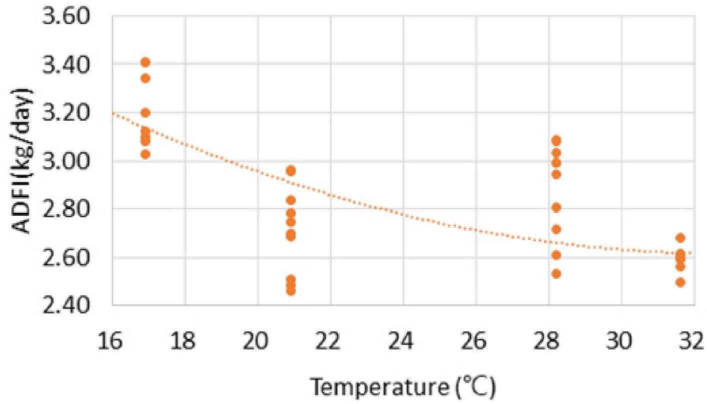

Figure 8. Estimated ADFI curves for late finishing pigs according to the temperature.

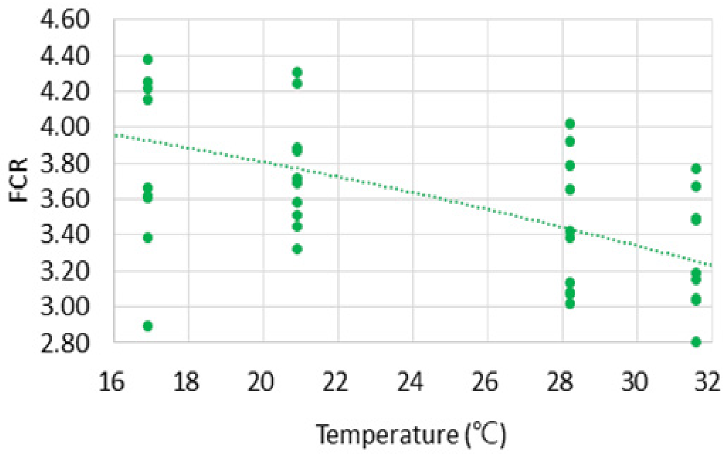

Figure 9. Estimated FCR curves for late finishing pigs according to the temperature.

In the present study, the early finishing pigs housed at T4 treatment had reduced BW, FI and ADWG ($p<0.05$) as compared to T1 treatment. However, the effect of temperature on ADWG was not significant in late finishing pigs at all treatment temperatures. White et al. [23] reported that pigs housed at 32.2°C had decreased AGD and ADFI as compared to pigs at 23.9°C. Early finishing pigs had the highest feed intake in T2 treatment, which reduced at T1 as well as T4 temperature conditions. Myer and Bucklin [10] stated that for finishing pigs weighing 54.5-118.2 kg, the optimum temperature range is 10°C-23.9°C. Temperatures higher than this range resulted in declined feed intake, reduction of meal frequency, and decreased meal size [24]. The feed intake probably decreases in order to maintain the heat production in the animal body [25]. In addition, physical activities and metabolic rates were also decreased [26].

In the current study, the final body weight of late finishing pigs in T4 treatment was significantly decreased compared to T1. During heat stress, animals show a low average daily gain, which is partially associated with insufficient nutrients intake. Feed intake and average daily gain have a curvilinear relationship during thermal load, and heavier pigs are more susceptible than lighter animals [22]. Furthermore, Rodrigues et al. [27] reported that thermo neutral or elevated temperature levels do not affect the feed conversion in finishing pigs. These results could be associated with declining feed intake in pigs and a reduced proportion of energy intake available for growth. According to the results obtained in the current study, late finishing pigs have higher FCR values in T1 than in T2, T3 and T4 treatments. On the other hand, Renaudeau et al. [28] reported enhanced FCR when pigs were exposed to mild heat stress, which could be due to feed restriction affecting the composition of body weight gain.

According to the results, feed intake in early finishing pigs was significant in T2, T3 and T4 treatments, and feed intake was not significant in late finishing pigs between T2, T3 and T4 treatments. This could be because pigs are unable to adjust to extreme situations, and later develop physiological changes due to unfavorable conditions. Furthermore, Sanz Fernandez et al. [11] reported that during the heat stress period, variations in growth performances may also rely on the heat load, as compared with pair-fed thermal neutral controls.

CONCLUSION

The present study provides evidence that exposure of pigs to high ambient temperature affects their poor performances in ADWG, ADFI and FCR during growing and finishing phases and optimum temperature level could enhance the performances in ADWG, ADFI and FCR in both growing and finishing pigs.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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