Influence of environmental temperature, dietary energy level and sex on performance and carcass characteristics of pigs

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Abstract

Pigs are quite sensitive to high environmental temperatures and the thermoregulation mechanisms represent great expenses in energy for heating loss, reducing animal well-being and production performance, and altering carcass quality. The aim of this study was to assess the effects of sex and dietary energy level in growing-finishing pigs submitted to characteristic seasonal variation of temperature in sub-tropical humid climate, and to propose a mathematical model to predict growth performance and carcass characteristics. Twenty-eight crossbred growing-finishing pigs were randomly allotted to twelve treatments, in a 2x2x3 factorial trial (2 sex; 2 environmental conditions, and 3 energy levels). Heat stress condition (climatic chamber) showed temperatures of 31 ºC at 7:00 and 22ºC at 17:00 (maximum of 33 °C) and thermal comfort condition (stall) showed temperatures of 18 °C at 7:00 and 24 °C (maximum of 27 °C). Pigs were fed *ad libitum* with diets containing 12.2 (low), 13.6 (medium) and 15.0 (high) MJ ME/kg DM. Voluntary feed intake, daily weight gain, and final body weight were higher ($P<0.01$) at thermal comfort condition and were influenced by sex ($P<0.01$) in growing pigs. Feed to gain ratio decreased as the energy level increased ($P<0.01$), with values of 2.67, 2.59, and 2.32 (12.2, 13.6, and 15.0 MJ ME/kg DM, respectively). There was energy level and sex interaction only for daily weight gain. Regarding finishing pigs, environmental conditions also showed effects ($P<0.01$) on voluntary feed intake, daily weight gain, and final body weight. Performance of pigs was better at thermal comfort condition. Feed to gain ratio values were 3.55, 3.42, and 2.95 for low, medium, and high energy level, respectively. Interactions between energy level and sex were observed for voluntary feed intake, daily weight gain, and final body weight ($P<0.05$). Carcass yield and quality were affected by environmental condition and dietary energy level. Both hot and cold carcass weight increased as energy of ration increased. Cold carcass weight increased by 1.142 kg/MJ EM whereas backfat thickness was up to 252 mm/MJ EM. *Longissimus thoracis* muscle thickness was around 16 mm smaller in pigs under heat stress, but lean content was 2.68% higher in those animals. Regression equations were proposed to predict the performance values in the different situations studied.

Key words:
Heat stress.
Growth.
Carcass.
Dietary energy.
Swine.

Introduction

The relationship between growth potential of pigs and efficiency in lean meat gain of pigs is regulated by genetic and environmental components. These factors are influenced by variations in voluntary feed intake (VFI), body weight (BW) and body composition. Among these, breed, sex, age and body weight, as well as environmental temperature and humidity affect pig performance and carcass composition.[1,2,3,4,5] Tropical hot weather alters animal metabolic and endocrine mechanisms, reducing appetite and consequently VFI, limiting the animal production efficiency.[1,4] This condition can also affect production of fatty acids altering lipid accretion rate at intra and extra-muscular levels.[6,7] Pigs are quite sensitive to high environmental temperatures because of high metabolic rates; consequently, they have high endogenous heat production. Then, their bodies have expensive demand of energy for thermoregulation. Only after energy cost for maintenance is achieved, nutrients for growth are mobilized.[8] Thus, in tropical areas, besides the care with the environment to keep these animals within 13-21 ºC during the growing-finishing period[9,10,11], it is necessary a special attention with feed management to prevent heat stress and to guarantee adequate performance and meat quality[10,12,13]. BW depends on the amount and location of nutrients being deposited in the tissues. Growth potential results from the interaction among the protein, lipids, water and minerals deposition. Lean pigs are highly efficient to utilize energy for protein deposition while fattening animals towards better this energy utilization to fat deposition. Concerning sex, it is known that castrated males have increased VFI and faster growth rate than females.[14] In spite of showing thicker backfat and smaller eye-of-loin area, they are not different from females related to lean meat because they have muscle *longissimus dorsi* with larger volume. [6] Works done to evaluate VFI, BW and carcass composition in tropical areas [1,4], have good application for environmental conditions where those experiments were carried out.

This study aimed to determine and to evaluate the effects of sex and dietary energy level (EL) in growing pigs, submitted to characteristic seasonal variation of sub-tropical humid climate of the southeast region of Brazil (21º 59' Lat. S., 47º 26' Long. W), and to propose a mathematical model to predict growth performance and carcass characteristics.

Material and Method

Twenty eight crossbred pigs (Landrace x Large White), castrated males and females were housed in suspended metabolic cages, averaging 73 days old and 24.6 ± 0.3 kg BW. Cages had area of 1.7 m^2, iron fence, metallic grill floor, and automatic hod and nipple drinkers. Pigs were randomly allotted to twelve treatments, in a 2x2x3 factorial experiment: 2 sexes, 2 environmental conditions (high and moderate temperatures), and 3 EL (low, medium and high). The experiment was divided into two phases according to the age of animals: growing phase from 73 to 110 days old (Phase I, PI) and finishing phase from 111 to 149 days old (Phase II, PII).

Experiment with thermal comfort (TC) and moderate temperatures were carried out in the winter from July to September. The heat stress (HS) with high temperature conditions was conducted in climatic chamber (total area of 50 m^2; 2.5 m right foot, concrete floor, central heating system and incandescent illumination). The temperature inside the climatic chamber was daily controlled by a thermostat set at 35 ºC at 07:00 am and 22 ºC at 5:00 pm, in order to obtain similar summer thermal curves, to simulate heat stress condition. In both places, the environmental temperature was obtained by a black-globe thermometer.[11,15,16]

Rations were balanced with soybean oil, swine fat or wheat bran according to the EL (Table 1). As EL reference point it was used 13.6 MJ ME / kg DM, according to National Research Council [17] for growing barrows and gilts (20 - 120 kg). From the

Table 1 - Composition of the experimental diets in the different phases[a]

	Energy level (MJ ME/kg of DM)					
	12.2		13.6		15.0	
	PI	PII	PI	PII	PI	PII
Ingredients (%)						
Corn	58.00	69.16	80.83	86.26	71.38	77.47
Wheat meal	22.20	11.00	-	-	-	-
Soybean meal	13.02	10.20	16.00	10.70	17.85	12.33
Soybean oil	-	-	-	-	5.00	5.00
Swine fat	-	-	-	-	2.80	2.64
Dicalcium phosphate	0.92	0.92	1.82	1.38	1.82	1.39
Kaolin	4.11	7.23	0.16	0.44	-	-
Calcium carbonate	0.76	0.55	0.21	0.27	0.20	0.25
Vitamin and mineral mix	0.50	0.50	0.50	0.50	0.50	0.50
L-Lysine	0.19	0.14	0.18	0.15	0.14	0.12
Salt	0.30	030	0.30	0.30	0.30	0.30
Analyzed chemical composition (%)						
Crude protein	15.07	13.00	15.02	13.00	15.00	13.00
Calcium	0.60	0.50	0.60	0.50	0.60	0.50
Total phosphorus	0.50	0.40	0.50	0.40	0.50	0.40
Crude fiber	4.05	3.25	2.30	2.80	2.87	2.69

[a] PI = growing pigs; PII = finishing pigs

reference point, it was calculated approximately 10% less and 10% more of ME, which yielded 12.2 (low) and 15 (high) MJ ME/kg DM EL, respectively.

Pigs were individually fed *ad libitum*, and VFI (difference between food offer and leftover) and voluntary energy intake (VEI) were daily taken. Pigs were weighed at the start and final of each phase (PI and PII) to register DWG, average feed to gain ratio (FGR), and final body weight (FBW).

Animals were slaughtered at 149 days old. Following one day fast, pigs were stunned using electroshock (450 V / 2 seconds). Then, animals were submitted to standard commercial procedures of exsanguination, scalding, evisceration and carcass division. Hot and chilled carcass weights were taken. Backfat thickness (BT) was measured between the 10[th] and 11[th] ribs with a caliper while *longissimus thoracis* muscle (MT) was measured with plastic transfer and planimeter.

The lean meat content (MC) was calculated after bone removal from the right half-carcass. Lean meat yielding was obtained by the ratio between the weight of the ham with bones, *carré*, cup and palette (both boneless) and weight of the half-carcass without head, foot, tail, and anoint (standard carcass).

Data were decomposed per schedule submitting to the test of significant minimum difference (SMD) between the two environmental conditions. Data correspondent to each phase were analyzed using the General Linear Model (GLM) procedure of the Statistical Analysis System[18]. Effects of sex, EC, EL, and their interactions were included in the statistic model. Means of growth performance and carcass characteristics variables with EL effect were tested by Tuckey. Contrast test of GLM and regressions analysis were used when an interaction was detected.

Results

Obviously, the temperature was significantly higher ($P<0.01$) inside the climatic chamber than in the stall condition (Figure 1). Humidity also varied significantly ($P<0.01$) between both conditions (Figure 2). Higher drinking and lower feeding frequencies inside the climatic chamber indicated similar pattern of behavior of animals in heat stress.

The adjusted means of data performance and daily intake are presented in table 2. In the phase I it was

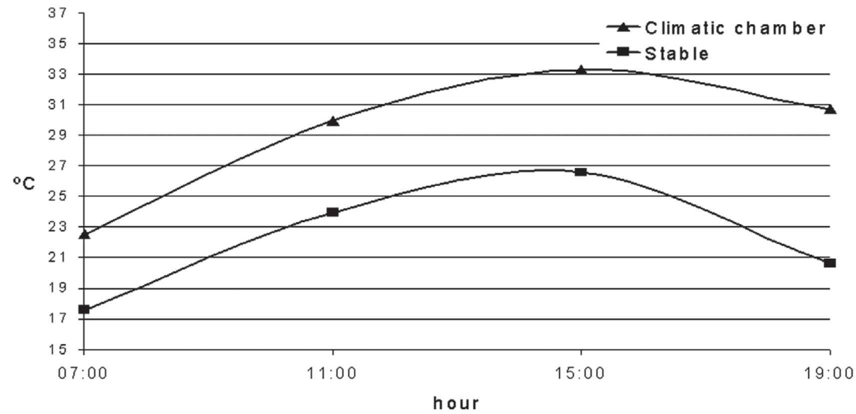

Figure 1 - Average variation of operative temperature in different environments during the experimental period

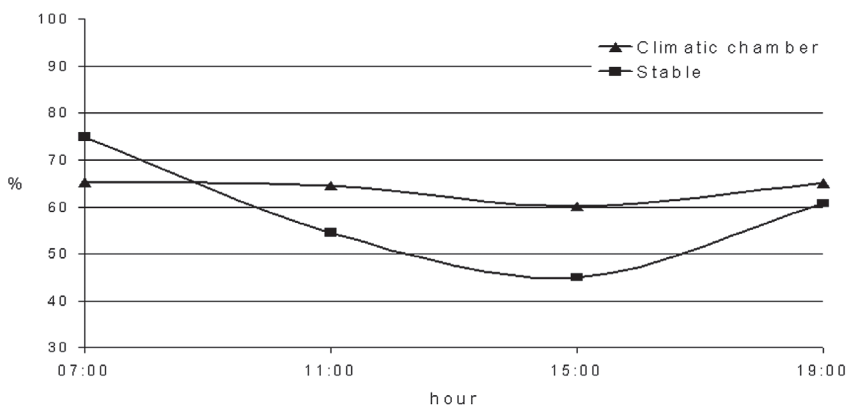

Figure 2 - Average variation of relative humidity in different environments during the experimental period

observed isolated effects (P<0.05) of sex and EC in VFI, VEI and FBW. All these characteristics were higher (*P*<0.01) in the males (M) than in the females (F) and at TC versus HS. EL showed a linear effect (*P*<0.05) on the VEI, independently of other factors,

Table 2 - Effect of environmental condition, energy level and sex on performance of conventional growing and finishing pigs[a]

	Environmental condition[b]				Energy level (MJ ME/kg)						Sex[c]				Statistical analysis[d]
	HS		TC		12.2		13.6		15		M		F		
	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	
Growing pigs (73 to 110 d)															
Initial body weight (kg)	14	24.786	14	24.928	8	25.000	12	24.625	8	25.062	14	24.964	14	24.750	-
Voluntary feed intake (kg.d^{-1})	14	1.687	14	1.913	8	1.859	12	1.786	8	1.763	14	1.904	14	1.697	EC**, S*
Energy intake (MJ ME.kg^{-1})	14	5.502	14	6.217	8	5.454	12	5.824	8	6.318	14	6.214	14	5.506	EC**, EL*, S*
Daily weight gain (kg)	14	0.656	14	0.770	8	0.696	12	0.692	8	0.763	14	0.747	14	0.680	EC**, EL×S*
Final body weight (kg)	14	51.041	14	55.786	8	52.931	12	52.297	8	55.569	14	54.871	14	51.955	EC**, S*
Feed to gain ratio	14	2.58	14	2.49	8	2.67	12	2.59	8	2.32	14	2.57	14	2.50	EL**
Finishing pigs (111 to 149 d)															
Voluntary feed intake (kg.d^{-1})	14	2.233	14	2.677	8	2.609	12	2.402	8	2.383	14	2.637	14	2.274	EC**, EL×S*
Energy intake (MJ ME.kg^{-1})	14	7.275	14	8.691	8	7.654	12	7.829	8	8.542	14	8.606	14	7.360	EC**, EL×S*
Daily weight gain (kg)	14	0.695	14	0.790	8	0.724	12	0.709	8	0.811	14	0.799	14	0.687	EC**, EL×S*
Final body weight (kg)	14	76.071	14	84.071	8	78.937	12	77.833	8	84.562	14	83.464	14	76.678	EC**, EL×S*
Feed to gain ratio	14	3.21	14	3.43	8	3.55	12	3.42	8	2.95	14	3.31	14	3.34	EL**

[a] Adjusted means.

[b] HS = heat stress (22.5 – 33.2 ºC, minimum and maximum mean values); TC = thermal comfort (17.6 – 26.6ºC minimum and maximum mean values).

[c] M = castrated male; F = female.

[d] From analysis of variance of environmental condition (EC), energy level (EL), sex (S) and their interaction effects at statistical significance of **P<0.01 and *P<0.05

according to the equation:

VEI_{PI} MJ ME day^{-1} = 6.1686 – 1.3442EL (r^2 = 0.17)

Both males and females DWG were higher (P<0.01) at TC than at HS condition. Males exhibited response (P<0.05) to a sex and EL interaction, which yielded a linear regression:

$DWG_{PI,M}$ kg day^{-1} = 0.5154 + 0.0188EL (r^2 = 0.05)

The FGR in the PI was influenced (P<0.01) by EL, according to the following linear regression:

FGR_{PI} = 4.2276 - 0.1243EL (r^2 = 0.39)

At PII voluntary feed and energy intake were increased (P<0.01) when animals were at TC. Also VFI of females and VEI of males were affected (P<0.01) by the interaction between sex and EL, according to the respective linear regression equations:

$VFI_{PII,F}$ kg day^{-1} = 5.0127 – 0.2014EL (r^2 = 0.33)

$VEI_{PII,M}$ MJ ME /kg day^{-1} = - 7.583 + 3.198E (r^2 = 0.45)

DWG was significantly higher (P<0.05) in the animals at TC condition. Also, males were affected (P<0.05) by the interaction between sex and EL, according to the linear regression:

$DWG_{PII,M}$ kg day^{-1} = - 0.0615 + 0.0633EL (r^2 = 0.43)

Finishing pigs in TC condition were (P<0.01) heavier than animals at HS condition. FBW of males was also (P<0.01) affected by the interaction between sex and EL according to the linear equations:

$FBW_{PII,M}$ = 20.321 + 4.6429EL (r^2 = 0.46)

EL affected (P<0.01) FGR in animals at PII, according to the linear regression:

FGR_{PII} = 6.47 - 0.23EL (r^2 = 0.41)

Carcass yield and its characteristics (Table 3) were not affected by sex or their interactions (P>0.01). However, HCW and CCW were influenced (P<0.05) by EL, following their respective linear regression equations:

HCW = 62.452 + 1.1892E (r^2 = 0.28)

CCW = 61.310 + 1.1422EL (r^2 = 0.34)

BT was affected only by EL (P<0.05), according to a multiple regression:

BT = - 1.1239 + 0.252EL (r^2 = 0.18)

MT was smaller (P<0.05) in animals at HS condition. However, MC was increased (P<0.05) in that condition independently of sex or dietary energy level.

Discussion

The higher temperature in the climatic chamber compared to conventional stall temperature indicated that environmental temperature can be manipulated to simulate HS condition for growing-finishing pigs; HC and TC conditions are those as discussed by

Table 3 - Effect of environmental condition, energy level and sex on carcass yield and carcass characteristics of conventional pigs[a]

	Environmental condition[b]				Energy level (MJ EM/kg)						Sex[c]				Statistical analysis[d]
	HS		TC		12.2		13.6		15		M		F		
	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	
Hot weight (kg)	14	78.885	14	78.451	8	76.979	12	78.802	8	80.158	14	78.387	14	78.950	EL*
Cold weight (kg)	14	77.256	14	76.432	8	75.133	12	76.993	8	78.331	14	76.888	14	76.799	EL*
Backfat thickness (mm)	14	2.145	14	2.456	8	2.054	12	2.159	8	2.759	14	2.424	14	2.176	EL*
Long. thoracis thickness (mm)	14	21.829	14	37.780	8	22.870	12	22.357	8	23.904	14	22.355	14	22.535	EC*
Lean meat content (%)	14	40.46	14	37.78	8	39.31	12	40.20	8	37.31	14	38.18	14	40.06	EC*

[a] Adjusted means.
[b] HS = heat stress (22.5 – 33.2 ºC, minimum and maximum mean values); TC = thermal comfort (17.6 – 26.6 ºC, minimum and maximum mean values).
[c] M = castrated male; F = female.
[d] From analysis of variance of environmental condition (EC), energy level (EL), sex (S) and their interaction effects at statistical significance of *P<0.05

Ewing, Lay Jr. and Von Borell[10], Silva[11] and Muller[15]. From July to September the local temperature was 16 ºC to 24 ºC. From January to March it was 24 ºC to 34 ºC. Thus, the physical conditions observed in the stall and in the climatic chamber fulfilled the objectives of this work as for being representative of natural environment in winter and summer.

There were no differences on VFI between phases and they were similar to the observed by Van Der Hel et al.[19], Quiniou et al.[2], and Dividich and Noblet[4]. Like another studies[1,3,4,8,20] it was observed a great association between environmental temperature, feed intake and growth rates. That relationship was seen in both growing and finishing phases where it was detected a reduction of 335 g/day of feed intake (equivalent to 1MJ EM/day) in the heat stress compared to the thermal comfort condition. As reported in another studies[14], a relationship between weight gain and sex was observed, where males gained more weight than females. Feed intake of growing pigs was also influenced by level of energy in the diet, such that males received an additional of 708 MJ ME /day than females. Obviously, that condition influenced directly the weight gain, being that males incremented the feed intake in 18 g.d^{-1}/MJ ME. Finishing pigs also had a good performance in thermal comfort condition and responded markedly to energy level, yet interacting with sex. Females showed 201 g.d^{-1}/MJ ME reduction in feed intake and males increased around 3 MJ ME.d^{-1} of energy intake when maintained at thermal comfort, implying a 63 g.d^{-1}/MJ ME of weight gain. As a result, feed efficiency was better for males, since those pigs produced more with no increase in feed intake.

Carcass yield and quality were affected by environmental condition and dietary energy level. Both hot and cold carcass weight increased as energy of ration increased. Cold carcass weight increased by 1.142 kg/MJ ME whereas backfat thickness was up to 252 mm/MJ ME. *Longissimus thoracis* muscle thickness was around 16 mm smaller in pigs under heat stress, but lean content was 2.68% higher in those animals. This work showed no effect of sex concerning carcass characteristics, contrary to some other works[5,6] who found a thicker backfat in castrated males as compared to females.

Conclusions

Backfat thickness increased whit increasing in dietary energy level and the *longissimus thoracis* muscle showed larger area in thermal comfort condition. Higher levels of energy in the diet must be used in studies of pigs in thermal comfort conditions to investigate the ideal dietary energy level. The regression equations were valid to predict the performance values in the different situations studied. Technicians and producers must use the manipulation of both energy level and environment conditions of temperature in swine facilities in order to obtain not only better production, but also desirable meat quality.

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Resumo

Suínos são sensíveis a altas temperaturas e os mecanismos de termorregulação representam custos energéticos direcionados à perda de calor corporal, reduzindo o bem-estar e o desempenho produtivo, e alterando a qualidade de carcaça. O objetivo deste estudo foi avaliar

Palavras-chave:
Estresse térmico.
Crescimento.
Carcaça.
Energia da dieta.
Suínos.

os efeitos do sexo e do nível energético da dieta em suínos em crescimento-terminação submetidos às variações sazonais de temperatura características de clima subtropical úmido e propor um modelo matemático que prediga o desempenho dos animais e características de carcaça. Vinte e oito leitões mestiços foram distribuídos aleatoriamente a 12 tratamentos em arranjo fatorial 2x2x3 (2 sexos, 2 condições ambientais e 3 níveis de energia na dieta). A condição de estresse calórico (câmara climática) apresentou temperaturas de 31 °C às 7:00 e 22 °C às 17:00 (com máxima de 33 °C) e a condição de conforto térmico (galpão) apresentou temperaturas de 18 °C às 7:00 e 24 °C às 17:00 (com máxima de 27 °C). Os animais foram alimentados *ad libitum* com dietas contendo 12,2 (baixo), 13,6 (médio) e 15,0 (alto) MJ EM/kg MS. O consumo voluntário de ração, ganho de peso diário e peso corporal final foram maiores ($P<0,01$) na condição de conforto térmico e sofreram influências do sexo ($P<0,01$) para os suínos em crescimento. A conversão alimentar decresceu conforme aumentou a energia da dieta ($P<0,01$), com valores de 2,67, 2,59 e 2,32 (para 12,2, 13,6 e 15,0 MJ EM / kg MS, respectivamente). Houve interação entre nível dietético de energia e sexo somente para ganho diário de peso. Para os suínos em terminação, também se observou efeito da condição ambiental ($P<0,01$) sobre o consumo voluntário de ração, ganho diário de peso e peso corporal final, com o desempenho dos animais sendo melhor na condição de conforto térmico. Os valores de conversão alimentar foram 3,55:1, 3,42:1 e 2,95:1 para níveis de energia baixo, médio e alto, respectivamente. Foram observadas interações entre nível de energia e sexo para as variáveis consumo de ração, ganho diário de peso e peso final ($P<0,05$). O rendimento e qualidade de carcaça foram afetados pelas condições ambientais e nível dietético de energia. Tanto o peso da carcaça quente, como da carcaça resfriada aumentaram com o aumento da energia na dieta. Após o resfriamento, o peso da carcaça aumentou em 1,142 kg/MJ EM, enquanto a espessura de toucinho esteve acima de 252 mm/MJ EM. A espessura do músculo *longissimus thoracis* foi 16 mm menor nos animais em estresse calórico, mas o conteúdo de carne magra foi 2,68% maior nestes animais. Equações de regressão para predição de valores de desempenho nas diversas situações estudadas foram propostas.

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