Performance of the Pigs Maintained in a Highland and Coastal Area of Minahasa Region, North Sulawesi

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ABSTRACT : Pigs respond to extreme temperature (very cold or hot) by physiological and nutritional adjustments. Yet little is known about the effects of different environmental temperature (thermoneutral in the highland area, and hot temperature in the coastal area) where pigs are maintained on the performance of the pigs. Ten pigs each (10 pairs of littermates) were assigned to two treatments (2 locations): highland area (control=CA) or coastal area (hot/heat stress=HS). Experimental design was Paired 't' test. HS pigs had higher average daily water intake ($p<0.05$) compared to CA pigs (6.05 vs 3.89 kg/d). CA pigs had higher feed intake compared to HS pigs (2.9 vs 1.95 kg/d, $p<0.05$). CA pigs had higher daily gain compared to HS pigs (0.72 vs 0.58 kg/d, $p<0.05$). Feed conversion was not significantly different between CA pigs and HS pigs. The digestibility of dry matter, N, Na, K, Mg, Cl, Ca and P was not significantly affected by the treatments. High environmental temperature in the coastal area (heat stress) increased water intake, decreased voluntary feed intake and daily gain of the pigs. The results demonstrate that different environmental temperature in the coastal area (heat stress) and highland area (control) had no pronounced effect on digestibility of nutrients. ***(Asian-Aust. J. Anim. Sci. 2001. Vol 14, No. 7 : 1014-1018)***

Key Words : Pigs, Highland Area, Coastal Area, Heat Stress, Nutrient Digestibility

INTRODUCTION

High environmental temperatures have negative effects on pig performance. Under the conditions of high environmental temperatures, pigs will experience heat stress. Under the condition of heat stress, pigs respond differently compared to other animals. Pigs are particularly vulnerable to low temperature as neonates, but become progressively more susceptible to hot surroundings as they grow older. Some physiological characteristics of pigs are unique and cause them to respond differently. Acclimatization to hot environments can take place in animals as a result of changes in sweating, respiration, blood composition and blood circulation. In fact, pigs do not sweat effectively, with the exception of at the tip of the nose. Pigs rely on evaporative heat loss and the respiratory tract is the only channel for controlling evaporative heat loss (Mount, 1979; Curtis, 1984).

At a higher ambient temperature, heat loss will be less that heat production plus heat gained from the environment and body temperature will start to rise. A rise in core temperature will result in a rise in metabolic rate, and in such a circumstance body temperature will rise at an increasing rate until it exceeds 42-43°C, where in most species, there will be damage to the central nervous system and other structures (heat stroke) with fatal consequences (Bligh, 1985; Hahn, 1985). Several studies have implicated factors other than high temperature such as humidity can cause additional stress to reduce pig's growth rate since high humidity can create the most severely stressful conditions of heat (Morrison et al., 1968; Aberle et al., 1974; Devendra and Fuller, 1979).

Heat stress affects pigs' growth rate (Marrow-Tesch et al., 1994), reduces feed intake (Plata-Salaman and Borkoski, 1993), and alters nutrient balance, such as increased mineral loss (Christon, 1988), and nitrogen retention (Holmes, 1973). Pigs react to temperature extreme by adjustments in feed intake and heat exchange with their environments (Fuquay, 1981; NRC, 1981; Conrad, 1984). In the previous study (Umboh et al., 1992), heat stress increased rectal temperature, respiration rate, heart rate, and blood pressure, depressed circulating levels of triiodothyronine (T3), and lowered blood osmolality of the pigs.

The observed data showed that pigs raised in the coastal area of Minahasa region have lower reproduction performance of both male and female (D. J. Mandey-K, unpubl. data) and daily gain (J. F. Umboh, unpubl. data) compared to pigs raised in the highland area. Consequently, this could economically affect pig production in this region.

Much of our present knowledge regarding the physiological responses and quantitative effects of a given environment on pig performance is based on investigations with constant temperatures. Generally speaking, pigs are not raised under constant temperatures. Since many pigs in the tropical area are produced and maintained along the coastal area or in the condition where environmental temperatures are prevalent at least for part of the year, the present study was designed to characterize the effect of differences in environmental temperatures between the coastal (heat stress) and highland (control) area on pig performance.

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MATERIALS AND METHODS

Animals, diet and management

Twenty Large White×Veredelde Deutche Landvarken (VDL) crossbred barrows (10 pairs of littermates) were assigned to two treatments (two locations, 10 per treatment) highland area (CA) or coastal area (HS). The experiment was conducted for 35 days. Modoinding area (1150±50 m above sea level) was chosen to represent the highland area (CA), whereas Northern coastal of Minahasa (0-50 m above sea level) was chosen to represent the coastal area (HS). The diet based on corn, copra meal, rice bran, soybean meal, and fish meal was formulated (table 1) to meet or exceed all requirements for growing pigs as defined on a percentage basis by NRC (1988). Feed and fresh water was provided *ad libitum*. The diet was offered to the pigs as a coarse mash.

Initial body weight of the pigs was 23.0 kg (±2.1 kg) for CA and HS pigs. The animals were placed in individual crates and adjusted to their surroundings, and the experiment was initiated after a 10-d period of acclimation.

Table 1. Composition of experimental diet (g/kg as fed)

Ingredients	
Corn	45.0
Rice bran	20.0
Copra meal	10.0
Soybean meal	9.0
Fish meal	15.0
Limestone	0.3
Salt	0.3
Vitamin premix[1)]	0.2
Mineral premix[2)]	0.2
	100
Nutrients, assayed	
Dry matter (%)	91.24
Protein (%)	16.27
Crude fiber (%)	5.43
Calcium (g/kg)	9.45
Energy concentration (kcal ME/kg diet)	3,250
Phosphorus (g/kg)	7.10
Chloride (g/kg)	3.42
Magnesium (g/kg)	2.14
Potassium (g/kg)	8.98
Lysine (%)	0.72
Threonine (%)	0.45
Methionine + cystine (%)	0.40

[1)] Provided per kg of diet: vitamin A, 4950 IU: vitamin D_3, 495 IU; vitamin E; 24 IU; menadione, 2.4 g; riboflavin, 3.0 g; niacin 21 g; d-pantothenic acid, 1.5 g; thiamine, 600 mg; d-biotin, 150 mg; vitamin B_{12}, 15 mg.

[2)] Provided per kg of diet: zinc, 60 g; iron, 48 g; manganese, 15 g; copper, 4.0 g; iodine, 0.3 g; selenium, 0.1 g.

After a 35-d treatment period, the experiment was terminated. The pigs in the CA and HS area were maintained in the same structure and size (1.5×2 m^2) of building with half open house system as usually used and practiced by pig producers in this region. Crates were built in a parallel way arranged from north to south, separated by a concrete wall, so that pigs were not be able to see each other. The housing system is merely constructed to avoid pigs from direct sun light, rain, and cool over night period during the wet seasons.

Data recording and measurement

Both environmental temperature and relative humidity were recorded 3 times daily (06:00, 12:00, and 18:00 h) using thermohygrometer (Cole Parmer, Model 37200-00). Feed and water intakes were recorded during the experimental period. Fresh water was provided in the trough *ad libitum* until the time of feeding. At feeding, unconsumed water was removed from the trough and weighed. Feed was then provided and after the next feeding, the uneaten portion was removed and weighed. The use of troughs to supply water eliminated spill, so that water intake measurements were quite accurate (other than evaporation). Attempts to measure spill revealed no significant losses.

The digestibility trial was conducted using total collection of feces during the last five days of the experimental periods beginning at 08:00 h. During feces collection period, pens and pigs were always observed to make sure that all feces were collected at the right time. The fresh feces was collected soon after defecation to avoid contamination of urine and other materials or substances due to the use of traditional pens / crates in this study. Fresh feces were treated by 0.25% H_2SO_4 to avoid N losses. Samples were then put in the bags and frozen. Fecal and feed samples were assayed for dry matter, N, Na, K, Mg, Cl, Ca, and P. Sodium, K, Mg, and Ca were analyzed using an atomic absorption spectrophotometer (4000 Atomic Absorption Spectrophotometer, Perkin Elmer), according to methods defined by the AOAC (1990). Feed and feces were digested using a mixture of perchloric and nitric acid, and diluted to 50 ml for each 0.5 g sample and then assayed for Na, K, Mg, and Ca. Phosphorus (inorganic) was analyzed using a commercial kit (Sigma No. 670). Nitrogen was analyzed using a commercial kit (Sigma No. 640), and chloride was analyzed using an Ion Analyzer (Orion Research Microprocessor Ion Analyzer / 901). The method is based on indirect titration of the sample, using AgNO3, against a standard (Cl) curve.

Rectal temperatures were recorded using a thermometer (Cole Parmer, Model L-05985-80); the probe was inserted 7–10 cm deep into the rectum, and temperatures were recorded. Respiration rates were determined by counting flank movements and recorded as frequency per minute. Three measurements were determined during each collection and averaged.

Statistical analysis

Twenty (10 pairs of littermates) pigs were assigned to two treatments (two locations, 10 per treatment) highland area (CA) or coastal area (HS). A Paired 't' test (Steel and Torrie, 1980) was employed to examine treatment differences. Differences between means were considered significant at $p<0.05$.

RESULTS

The environmental temperatures in both CA and HS were recorded over the course of the experiment. The temperature in the control area was 20 (±2.5°C), while in the heat stress area ranged between 25-33.5°C (±4.25°C). The relative humidity in the control and heat stress area was 50±15 and 70±15%, respectively.

Table 2 summarizes the effects of treatments on the average respiration rate and rectal temperature. Pigs raised in the coastal area (HS) had significantly ($p<0.05$) higher average respiration rate and rectal temperature compared to pigs maintained in the control (CA). Pigs in HS increased average daily water intake ($p<0.05$) over the CA pigs (6.05 vs 3.98 kg/d) (table 2). Significant differences in feed (dry matter) intake ($p<0.05$) were found between CA and HS pigs. Pigs in CA had higher feed intake compared to HS pigs (2.9 vs 1.95 kg/d). Pigs in CA had higher ($p<0.05$) daily gain compared to HS pigs (0.72 vs 0.58 kg/d). Feed conversion was not significantly different between CA and HS pigs.

Environmental temperatures (CA and HS pigs) did not significantly affect the digestibility of dry matter, N, Na, K, Mg, Cl, Ca, and P (table 3).

Table 2. Effects of treatments on respiration rate, rectal temperature, feed (dry matter) and water intake, daily gain and feed conversion

Parameters	Treatments	
	CA	HS
Respiration rate (breaths /min)	19.00 (±1.20)[a]	95.00 (± 3.20)[b]
Rectal temperature (°C)	38.20 (± 0.20)[a]	39.70 (± 0.30)[b]
Dry matter intake, kg/d	2.31 (± 0.30)[a]	1.89 (± 0.45)[b]
Water intake, kg/d	3.98 (± 1.10)[a]	6.05 (± 1.15)[b]
Daily gain, kg/d	0.72 (± 0.07)[a]	0.58 (± 0.06)[b]
Feed conversion (kg feed/ kg gain)	3.20 (± 0.65)	3.25 (± 0.61)

[ab] Means with different superscripts within a row differ (P< 0.05).

Table 3. Effect of treatments on total nutrient digestibility (%)

Parameters	Treatments	
	CA	HS
Dry matter	86.8 (±1.70)	84.5 (±1.60)
Sodium	50.1 (±1.10)	52.4 (±1.15)
Potassium	73.5 (±1.90)	74.4 (±1.85)
Magnesium	33.2 (±0.90)	34.5 (±1.02)
Chloride	45.4 (±1.10)	46.5 (±1.15)
Calcium	47.0 (±1.10)	48.3 (±1.15)
Phosphorus	31.3 (±0.80)	32.3 (±0.90)

DISCUSSION

Comparisons were made between animals that maintained under heat stress (coastal area) and those kept in control or thermoneutral (highland area) conditions. Data in the literature indicated that the temperature range of 18-21°C generally has been found to be optimal or thermoneutral for growing-finishing pigs in terms of productive performance (Curtis, 1984; Geuyen et al., 1984; Mount, 1979; NRC, 1981; Yousef, 1985). In this study, control temperature of 20±2.5°C in the highland area was chosen to represent a thermoneutral environment. Defining the concept of thermoneutrality, Mount (1979), NRC (1981) and Yousef (1985) stated that within the range of effective ambient temperature (EAT) over which the body temperature remained normal and panting did not occur and metabolic heat production remained at a minimum. We observed that the control (highland area) pigs were maintained within a thermoneutral environment as indicated by the respiration rate and rectal temperature which remained normal and constant (table 2). Panting and the consequent increase in respiratory rate were involved in response to heat stress. Increasing hypothalamic temperature caused panting in animals. Panting is defined as a reduction in tidal volume associated with an increase in respiratory rate (Ingram and Legge, 1972; Hampson et al., 1987). Panting did not occur in the control (highland area) pigs and they were more comfortable compared to the heat-stressed pigs (coastal area) during the experiment. Pigs in CA spent most of their time resting and sleeping during the experiment. The environmental temperature of 25.0-33.5°C (±4.25°C) in the HS pigs was sufficient to increase respiration rate and rectal temperature of the pigs, which suggested that thermal balance was different between CA and HS pigs. These findings were in agreement with those of Bull et al. (1996); Fasheun et al. (1994); Flowers et al. (1989) and Giles et al. (1991). The large increase in rectal temperature found at HS pigs represented the degree of heat stress. In the condition of heat stress sensible losses (by radiation, convection and conduction) are very low because ambient temperature is comparable to the body temperature and consequently, evaporation is the main process for eliminating excess body heat. Compared to many mammalian and avian species, the pig is poorly equipped to handle high environmental temperature stress. The respiratory tract is the major channel to dissipate the heat load from the body. As a result, the pig has to increase respiration rates when body temperature increases. In the present study, respiration rates increased dramatically in HS pigs to about five times that of CA pigs.

Heat stress causes pigs to decrease voluntary feed intake (Hawton, 1990; Kurihara et al., 1996; Lopez et al., 1991; Marro-Tesch et al., 1994; Nienaber et al., 1996; Plata-Salaman and Bokorski, 1993). Different environmental temperatures affected feed intake in this experiment. The temperature of 25.0-33.5°C (±4.25°C) for HS pigs in this experiment was sufficient to reduce feed intake. Pigs in the highland area (CA) had higher feed intake compared to HS pigs (2.31 vs 1.89 kg/d, $p<0.05$). The results indicate that the pigs reduced their feed intake in an attempt to minimize the effect of heat load burden and eventually, particularly when pigs experienced heat stress during the hot period. It is understandable because pigs used in this study weighed about 60 kg at when the study terminated. In this growing-finishing stage, pigs become progressively more susceptible to the effect of heat stress when they grow older.

Water intake was higher for heat-stressed (HS) pigs compared to control (CA) pigs (6.05±1.15 vs 3.98±1.10). In the conditions of heat stress pigs increase their water consumption up to 6.12 kg/d compared to 4.32 kg/d for control pigs (Umboh, 1993). The increased water intake in this experiment is in general agreement with those of Ames (1982), Conrad (1984), Curtis (1984), Fuquay (1981), Lopez et al. (1991) and Taylor and Bogart (1988) who found that water intake is increased in a condition of hot environment, which is understandable because evaporation of water for thermoregulatory purposes in hot environments increase an animal's rate of water use. Pigs used in most of these studies were housed in the individual metabolic crates. In the present study, pigs were housed in the concrete pens that could help pigs taking advantage by lying down on the cooler floor. Even such, pigs still experienced heat stress in this study as indicated by the degree of heat stress experienced by pigs in the present study. Water intake was offered as fresh water for CA and HS pigs. We observed that HS pigs took the drinking water and played on it in an attempt to cool their head or body, or it might be just one indication of restlessness showed when HS pigs experienced heat stress. This would be one potential error in values of water intake and the bias toward wore water intake of HS pigs that we could not be able to accommodate in the present study.

Changes in the thermal environment induce a number of specific physiological responses in the digestive system. The redistribution of blood flow that occurs during thermal stress may divert blood away from the gut and results in an impairment of digestive function. There appears to be a reduction in blood flow to tissues of the digestive tract during acute heat stress (Conrad, 1984). A reduced capillary blood flow could result in a limitation of nutrient absorption and, therefore, could be associated with a slower rate of nutrient uptake from the gut in a hot environment. If the presence of end products of digestion in the lumen of the gut play a role in determining satiety, then decreases in gastrointestinal blood flow may contribute to the suppression of appetite in a hot environment (Christopherson, 1985).

Since we did not perform true ileum digestibility in the present study, we could not be able to elaborate more about the effect of two different environmental temperatures on the fermentation of feed in the hind gut.

In this study, the digestibility of dry matter, N, Na, K, Mg, Cl, Ca, and P was not significantly affected by environment temperature (CA and HS). A higher daily gain in the CA pigs and a lower daily gain observed in the HS pigs were not a reflection of the digestibility values which were not significant between two treatments but merely a result of the lower voluntary feed (dry matter) intake observed for pigs in the HS pigs compared to CA pigs. Individual crate, concrete floor, and half open house pen where pigs were housed during the experimental period might have contributed to the moderate effects of heat stress in the present study, especially the digestibility values, which are not different between CA and HS pigs. The effect of heat stress might have been extreme when pigs were housed in group.

IMPLICATION

High environmental temperature in the coastal area increased respiration rate, rectal temperature, and water intake and decreased voluntary feed intake and daily gain of the pigs. Since the direct effect of heat stress observed in this experiment is the decreased voluntary feed intake, protein concentration in the diet must be increased to offset the reduced feed intake of growing pigs in the coastal area. The addition of fat or tallow (low heat increment) will also help improve the efficiency of energy utilization of the pigs in the tropics. The use of water as a cooling agent, through direct sprinkling (not fogging) on the pig's skin is an excellent technique for reducing heat stress. But the consequence is an additional cost of doing such a managerial strategy in coping with heat stress. When pigs are to be raised in the highland (cooler) area, pigs will grow faster and there is no additional cost of feed additive or other related costs in reducing the effect of heat stress.

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