EFFECT OF DIURNAL HIGH AMBIENT TEMPERATURE AND SUPPLEMENTAL LYSINE 0N PUBERTY ONSET AND REPRODUCTIVE PERFORMANCE IN GILTS

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by

Dien Juliana Mandey-Kumajas

In Partial Fulfillment of the

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of

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EFFECT OF DIURNAL HIGH AMBIENT TEMPERATURE AND SUPPLEMENTAL LYSINE ON PUBERTY ONSET AND REPRODUCTIVE PERFORMANCE IN GILTS

BY

DIEN JULIANA MANDEY-KUMAJAS

A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

ABSTRACT

Mandey-Kumajas, Dien Juliana. M.Sc., The University of Manitoba, June, 1994. Effect of Diurnal High Ambient Temperature and Supplemental Lysine on Puberty Onset and Reproductive Performance in Gilts. Major Professor; M. Laurene Connor.

Poor performance has been associated with high ambient temperatures and decreased nutrient intake. Lysine supplementation at high ambient temperatures may have beneficial effects on some performance characteristics associated with depressed feed intake. To study the influence of prolonged high ambient temperature and lysine supplementation on pubertal onset and the subsequent reproductive performance in gilts, 48 prepubertal Managra gilts were assigned at an average age of 105 days to one of two levels of ambient temperature, 20 °C (RA) or diurnal 32° to 26° C (RB) and one of the two levels of lysine, the NRC standard or 50% above the standard levels. The experiment ended at 45 days of gestation following breeding at second estrus.

High ambient temperatures had no significant influence on rectal temperature, feed intake or body weight gain but significantly increased respiration rate and water usage. As well, supplemental lysine had no significant effect on the physiological responses and growth performance observed. High ambient temperature (RB) had no significant effect on body weight, backfat, or first proestrus duration at puberty but tended ($P<0.10$) to increase age at puberty and first estrous duration and to decrease second ovulation rate. However, high ambient temperature significantly

decreased second estrous duration($P=0.0002$). High ambient temperature did not affect estrous-cycle length, ovarian weight, uterine weight or fetal numbers and development (weight and length) as measured at day 45 post-mating. Supplemental lysine had no significant effect on pubertal characteristics such as body weight, age, backfat thickness, and first estrous-cycle length. There was, however, a trend ($P<0.10$) towards supplemental lysine decreasing proestrus duration and increasing first ovulation rate. Also, lysine supplementation had no significant effect on second ovulation rate, ovarian weight or uterine weight with or without fetuses. However lysine supplementation significantly ($P<0.05$) decreased fetal number and fetal development. Interaction between lysine and high ambient temperature had no effect on growth performance, on pubertal onset characteristics or on second estrous characteristics. However, there was a tendency ($P<0.10$) for greater empty uterine weight in pigs with supplemental lysine in RA but lower empty uterine weight in pigs with supplementation of lysine in RB. Supplemental lysine significantly ($P<0.05$) increased uterine weight in RA but reduced uterine weight in RB.

In conclusion, lysine supplementation had a beneficial effect on first ovulation rate and no adverse effect on the overall gilt performance. However, supplemental lysine had a detrimental effect on fetal growth and development as measured at day 45 of pregnancy. Pigs adjusted to the diurnal high ambient temperature as indicated by the physiological responses, growth performance and by most of the reproductive performance characteristics.

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Thanks be to Almighty God for His mercy and blessing that enable me to gain knowledge.

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My very special thanks to my mother and my family for their love and continuous support with a never failed prayer during my study in Canada, to whom this thesis is dedicated.

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ACTH =adrenocorticotropic hormone
AI=artificial insemination
AM=morning
AOAC =Association of the Official Analytical Chemist
ARC=Agriultural Research Council of the United Kingdom
BXD= Crossbred of Barbados BlackbellyXDorset sheep
BW=body weight
CL=corpora lutea
CP=crude protein
CR=conception rate
CRL=crown-rump length
CRLM=mean crown-rump length
DE=digestible energy
DM=dry matter
EB=estradiol benzoate
E2=estrogen
FFA=free fatty acids
FSH=follicle stimulating hormone
GH=growth hormone
GnRH=gonadotropin releasing hormone
HHA=hypothalamo-hypophysial adrenal axis
HHG=Hypothalamo-hypophysial gonadal axis
LCT=lower critical temperature
LH=luteinizing hormone
LHRH=luteinizing hormone releasing hormone
LYS= basal ration with lysine supplementation
MFW=mean fetal weight
NRC=National Research Council of the United States
OR=ovulation rate
P4=progesterone
PM=afternoon
RA=room A with thermoneutral temperature(20°C)
RB=hot room with ambient temperature ranging from 32 to 26°C
REG=basal ration with regular lysine content
RH=relative humidity
RIA=radioimmunoassay
RR=respiration rate
RRM=mean respiration rate
RT=rectal temperature
RTM=mean rectal temperature

RTSD = standard deviation of the mean rectal temperature
RTRANGE = range of the rectal temperature from the mean
SHR = standing heat reflex
T4 = thyroxine concentration
TNZ = thermoneutral temperature
UCT = upper critical temperature

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INTRODUCTION

More food is required as the human population grows. Livestock have been considered 'factories' to convert nutrients of feedstuffs into forms useful and appealing to humans. As in any other factory, the ratio of useful output produced to the input of material, services and capital investment should be as high as possible. In many cases, the ratio of output: input is influenced by many components of the surrounding environment imposed by humans and nature. The rate and efficiency of the animals to convert feedstuffs into human food are drastically influenced by thermal environment and are economically important to both producers and consumers of animal products.

Either cold or hot weather can be a constraint on efficient livestock production (Hahn, 1981). That animal body weight gain is affected by climatic factors was reported as early as 1904, by Grisdale in the Experimental Farm Report in Ottawa (Heitman *et al.*, 1958). Low ambient temperature has been reported to reduce growth rate in pigs (Close and Mount, 1978; Lopez *et al.*, 1991b) and in most farm animals (Young, 1981). The degree to which it may affect animal performance is influenced by the nutritional status (Close and Mount, 1978) and degree of resistance or susceptibility the animals have to the environment (Aberle *et al.*, 1974 ; Kelley and Curtis, 1978) . Low dry matter intake was reported in dairy cows (McGuire *et al.*, 1991) and in finishing pigs a decrease in feed intake up to 10.9% was noted (Lopez *et al.*, 1991b) as a result of high

ambient temperature. Similarly, lost body weight in pigs (Heitman *et al.*, 1958; Morrison and Mount, 1971; Yamamoto *et al.*,1984; Lopez *et al.*, 1991a) and in goats (Alaku and Moruppa, 1983) has been reported due to high ambient temperature.

High ambient temperatures have also been reported to affect reproductive performance. It was demonstrated by Dutt *et al.*, (1964) and by Alliston and Ulberg, (1965) that ova and embryo survival were detrimentally affected in ewes subjected to high ambient temperature before estrus. An increase of return to service rate or a decrease in nonreturn rate, extended estrous cycles and high embryo mortality were reported in ewes exposed to heat stress between day one and day seven postmating (Ulberg 1958 ; Thwaites, 1971 ; Stott *et al.*, 1972). In dairy cows a decrease in fertility and an increase in serum progesterone values were associated with a rising environmental temperature and resulting hyperthermia (Vaught *et al.*,1977). Lower calf birth weight and poor lactation performance were reported when dairy cows were exposed to high ambient temperature in the last trimester of pregnancy (Collier *et al.*, 1982). In gilts exposed to cyclic high ambient temperature from day 8 to day 16, lower total wet weight of conceptuses at day 16 was reported (Wettemann *et al.*, 1988). As well, low feed intake and associated low pregnancy rate were reported earlier (Dyck and Strain, 1979). Reproductive efficiency is also influenced by the season of the year (Egbunike, 1986). Steinbach (1976) has reported a delay in puberty onset for about 2 to 6 weeks in gilts under natural tropical conditions.

A delay in the onset of puberty of pig herd replacement stock can delay the commencement of the whole herd productivity, potentially disrupt the breeding stock

replacement schedule and thereby lead to less than optimal numbers of animals being bred or farrowed (Dial, *et al.*, 1986). From the economic point of view, disruption of the replacement stock schedule also causes an increase in cost for maintaining non-producing and poor producing breeding stock in the herd (Dial *et al.*, 1986). It is therefore desirable to promote and in some cases to control the onset of puberty by using techniques for practical management to optimize the reproductive potential of pigs in tropical regions where high temperature and other environmental conditions can limit reproduction (Dial and Britt, 1986).

Exotic pigs or European pigs tend to dominate modern piggeries in the tropics due to their perceived genetic superiority over the local breeds. These exotic breeds, to be able to perform optimally, require good feed, optimum housing and management practices (Dede, 1983; Omeke, 1989). To achieve multiple or year-round farrowing, it is important to know the effect of temperature on reproductive performance and how to provide the best environment for the breeding herd (Warnick *et al.*, 1965).

Relatively little information is available that details the effect of heat stress on farm animal performance in the tropical climate of higher temperatures throughout the year. One could expect that in such areas the effect of heat stress would be more severe and several management practices have been suggested to reduce the detrimental effects. These practices include : designing an open or semi-open building; providing more concentrated feed so that although animals eat less, the nutrients required are still ingested; using high increment nutrients such as lysine to improve performance; and using specific crossbreds or establishing strains tolerant of high ambient temperature.

However, these practices still do not solve all the problems.

Although the adverse effects of heat stress on the reproductive performance of mature farm animals has been studied, very little research has been carried out on the physiological responses to prolonged high ambient temperature and how these may affect reproductive performance around the pubertal period in pigs. Therefore, this study was designed to examine the physiological responses to high ambient temperature as they relate to reproductive function. Additional lysine, implicated with improved growth rate (Fetuga *et al.*, 1975) and improved reproductive performance (Grandhi, 1991), was employed as a means to counteract the expected decrease in feed intake, growth rate and subsequent effect on reproduction.

The objectives of the present study were to investigate the effect of prolonged high ambient temperature on: 1. physiological responses of gilts (rectal temperature (RT), respiration rate (RR), voluntary feed intake (VFI), water usage (WU) and body weight gain (BW); 2. reproductive performance in terms of puberty attainment, sexual behaviour, length of estrous cycles, ovulation rates, uterine weights, pregnancy rate and foetal survival and development; 3. the response of gilts to supplemental lysine and; 4.progesterone concentration after puberty and its relationship to ovulation rate and embryo survival.

LITERATURE REVIEW

The Animal and Its Environment

The Environmental Component

Animals have three kinds of life processes, the maintenance process which maintains life and ensures day-to-day survival; the reproductive process which provides for perpetuation of the species as well as production of surplus animals for meat, milk and eggs; the production processes which yield products directly useful to humans. In some environmental situations, these three life processes can be supported but in others they can not be, therefore priorities must be established (Curtis, 1983). However, for food animals, the ultimate purpose is to convert animal feedstuffs to food for human consumption (Ames, 1980).

The performance of an animal during its lifetime is influenced by several environmental factors acting externally and internally. The external environment is all those physical, chemical and biological elements that surround the animal. The internal environment is where the animal's cells reside (Curtis, 1983). The external environmental factors sometimes produce changes in the internal environment of the animal (Curtis, 1983). However, the animal's cell body to function normally requires

that a constant steady state of its internal environment is maintained despite its external surrounding (Curtis, 1983; Steinbach, 1987).

Climate is a combination of several components including temperature, humidity, rainfall, barometric pressure and ionization (Payne, 1990). Each climatic component varies over space and time. It is therefore, understandable that the animal's environment is exceedingly complex (Curtis, 1983).

Various components of the external environment may either promote or impair animal performance by facilitating or inhibiting productive and reproductive processes (Hahn, 1981; Curtis 1983; Yousef, 1985). As animal production becomes more intensive, the environmental aspects in livestock management have become more important (Curtis, 1983; Pond and Maner, 1984). Although numerous connections between environment and animal performance have been recognized only a few of them have been studied recently and have become known as primary limiting factors in animal production. For example, under high temperature conditions, in an attempt to reduce internal heat production, animals often reduce feed intake and hence are inferior to their counterparts in cooler areas in term of milk production and growth rate (Egbunike, 1986).

A certain combination of climatic components such as temperature, relative humidity, air movement, radiation and photoperiod, form a climate that allow specific types of livestock to manifest their maximum productivity. The combination of these climatic components in space and time make it possible to classify climates into several categories such as arid, semi-arid, rain forest, etc (Payne, 1990). In addition to the

climatic components mentioned earlier, the genetic adaptability of a species, or breed or individual interacts with the climate to affect their productivity. In other words, different livestock require a certain climatic component combination for optimal production. Hence, the climate required by young growing animals will be different from the requirement for the same animals at a later age (Payne, 1990).

Thermal Environment for Optimum Productivity

A certain combination of environmental components is required for the animals to express their full capacity of production and reproduction (Curtis, 1983). This combination of climatic components, referred to as the thermoneutral zone or zone of thermal neutrality or the zone of energy equilibrium (TNZ), varies with several factors including species, age, feeding level and level of production (Hahn, 1981). The TNZ represents the range of ambient temperature within which metabolic rate is at a minimum and within which temperature regulation is achieved by non-evaporative physical processes. Heat production increases when environmental temperature decreases below the TNZ. The lower critical temperature (LCT) is the lower limit of the TNZ and is the temperature below which an animal has to generate additional heat to maintain constant body core temperature. This increase in heat production which is known as extra thermoregulatory heat production(ETH), can be considered to result in an increase in the maintenance requirement. Total heat production is composed of a maintenance requirement (related to the metabolic body size), normal activity, ETH and heat

production associated with the synthesis of fat and protein (Verhagen, 1987). The upper critical temperature (UCT) is the upper end of TNZ above which the increase in heat gain is greater than heat loss necessitating active heat dissipating mechanisms.

The interrelationship of an animal to its environment form a system in which both act and react upon each other (Yousef, 1985). Climatic environment affects animal production and the degree of its effect depends upon the combination of various components of climatic environment which influence heat loss (Verhagen, 1987). The response of animals to heat stress will be influenced by the nutritional status of the animal (Close and Mount, 1978; Ames, 1980), insulation and exercise (Ames, 1980) and susceptibility or resistance of the animal to heat stress (Aberle *et al.*, 1974).

The external environment may cause responses of stress, discomfort, disease etc in animals (Curtis, 1983). However, the responses that permit physiological functioning and survival of the animal in an initially stressful environment have been described by a variety of terms such as adaptation, acclimation, acclimatization, habituation *etc.* (Yousef, 1987).

The temperature of an object is a measurement of how much heat energy it contains or stores. The greater the heat energy stored, the higher the temperature (Seeley *et al.*, 1992). Mammals and birds are homeothermic, maintaining a relatively constant body temperature despite wide ranges of environmental temperature (Yousef, 1987; Payne, 1990). Homeothermy is the result of minimal fluctuations in the animal's body heat content and can be expressed by a heat balance equation (Yousef, 1987):

Heat production (HP) = Heat loss (HL) $\pm$ Heat storage.

Therefore, measurement of the average body core temperature in mammals and birds reflects the thermal equilibrium of the animal. If a mammal has a net gain of heat from metabolism or from its environment, hyperthermia sets in. When it has a net heat loss, it becomes hypothermic (Yousef, 1987). Heat production is a measure of the sum of energy transformation taking place in the animal body per unit of time (Yousef, 1987). Heat production rate is influenced by the size of the animal, species and breed, environmental temperature, feed and water consumption, level of productivity, outer body covering, reproductive and physical activity, and is controlled by the nervous and endocrine systems (Yousef, 1987). Heat loss from the body, depending upon the thermal environment, can be lost by non-evaporative (sensible heat loss, i.e. radiation, convection and conduction) or by evaporative processes (non sensible heat loss, i.e.sweating and panting) (Yousef, 1987). Animals evaporate water from the respiratory tract as respiratory vaporization (panting) and from the skin as cutaneous vaporization (sweating). Sweating and panting are complementary. Species with a low capacity for sweating usually have a high capacity for panting(Yousef, 1987). The significance of non evaporative heat loss is that it is evident in the cold environment as well as in the hot environment while the evaporative heat loss is important since it increases in the hot environment and decreases in the cold environment (Yousef, 1987).

Animals attempt to maintain their body temperatures within a range most suitable for biological activity. The normal range in most mammals is 37- 39°C, while in birds

it is 40 - 44°C, though there are some exceptions (Payne, 1990).

Moderate heat stress has been defined by Christison and Johnson, (1972) as resulting in a rectal temperature increase of 0.5°C.

Heitman *et al.*, (1958) stated that temperatures around 20°C were found to be optimum for production for pigs with body weights between 50 to 150 kg fed *ad libitum*. The knowledge of the UCT seems to be of greater importance in hot climates than the knowledge of the LCT. Christianson *et al.*, (1982), calculated the upper limit of the thermoneutral zone (UCT) for pigs in summer time based on their live body weight (LW) as follows:

$$UCT\ (°C) = 34.7 - 0.33LW^{.72}$$

Based on the above formula, the upper critical temperature for growing pigs ranging from 20 kg to 80 kg would be between 32°C to 27°C.

The TNZ is subdivided into three subzones: optimum, cool and warm zones. The optimum zone is the range of ambient temperature where optimum productivity, efficiency and performance is demonstrated without requiring metabolic or behavioral adjustments to maintain heat balance. The cool zone is the range of ambient temperature where heat production remains minimal and the animal conserves energy by behavioural or autonomic mechanism rather than increasing its heat production. The warm zone is the range of ambient temperature where heat production is minimal and the thermoregulatory responses are limited to vasodilation and increasing surface area by

behavioural means rather than increasing evaporative heat loss (Yousef, 1987).

Based on the above description it is obvious that temperature above UCT or below LCT could adversely effect animal performance, in their production and reproductive functions. These have been reported by many workers under laboratory conditions.

Studies have demonstrated how the animals respond to the changing ambient temperatures based on the changes in their rectal temperature or based on their feed intake. Morrison and Mount, (1971) noted that after the temperature was changed to 33°C from 22°C, there was a large increase in RR and RT and then a decline for 10 days. Also after the temperature was changed from 33 to 20°C, RR dropped immediately to a level of about 20 breaths min^{-1} and was maintained throughout the final period of treatment. They noted also that 24 h after the air temperature was increased, RT was more than 0.6°C higher than it had been before. Verhagen *et al.*, (1987), demonstrated that when young growing pigs with mean body weights of 21 kg at 10 weeks of age fed *ad libitum,* were kept below their LCT at 15°C there was a reduction in daily gain, and an increase in feed intake after 6 days at 15°C. This study also indicated that at 15° C, as opposed to 25° C, the maintenance requirement was increased by 58 KJ/kg $M^{.75}$ and energy retained as protein was reduced by 49 KJ/kg $M^{.75}$ for 6 days after exposure. However, thereafter for pigs kept at 15° and 25°C the maintenance requirement become equivalent to pigs kept at thermoneutral temperature. They concluded that the pigs required 6 days to acclimatize to the LCT.

In terms of reproduction, a recent study on the tropical breed of cattle, the Brahman, reported that they responded negatively to shorter photoperiod and colder

temperatures (Stahringer *et al.*,1990). During winter months their reproductive performance was reflected by increased occurrence of anestrus and/ or estrus without formation of functional corpora lutea. Also, there was a greater variation in serum progesterone concentrations (Stahringer *et al.*, 1990). However, many studies have reported that the more severe effect of environmental temperature to animals seems to be above the UCT.

Payne (1990), described the two ways in which climate can affect livestock production: a) a direct effect on the animal itself and b) an indirect effect through the animal's environment. The experimental studies dealing with the direct effect of climate on domestic livestock have been obtained in two ways: 1. direct observation in the field and 2. observation on livestock kept in controlled-temperature rooms or chambers. The direct effect of climate on animals can be evaluated from grazing behaviour, intake and utilization of feed and water, growth, milk production and reproductive processes. The indirect effect of climate on animals is measured by the quantity and quality of feed available to the livestock, for example how the climate affects the feed and water supply for animals (Payne, 1990). Ambient temperature, effective rainfall, length of daylight and intensity of solar radiation are the major climatic factors that limit plant growth and hence the quality of feed available. In addition, parasites and diseases which favour high ambient temperature for breeding environment and reproducing can affect animal performance (Payne, 1990).

In the more natural environments of extensive animal production, thermal and light factors tend to have the most influence. In these situations little can be done to alter

the environment but rather production schedules are formulated to correspond with seasonal changes. Attempts can be made to select animals that are better adapted genetically to particular climatic regions. This should be directed toward fitting the management system and the animal itself to the natural environment. In intensive systems, as in extensive animal production, temperature and light are important as well as the social and other behavioural elements. Attempts are made to meet the animal's needs and to stimulate animal performance by environmental modification (Curtis, 1983).

Effect of Ambient Temperature on Animal Performance

Physiological and Behavioural Responses to High Ambient Temperature

As in many other homeotherms, pigs attempt to maintain deep body temperature at about 38°C to 39°C. As the ambient temperature rises above the TNZ it becomes difficult to maintain the exact equilibrium between heat produced by the body and heat lost from it (Feeding Standard for Australian Livestock, 1987). The heat is produced as a consequence of metabolic processes, heart action, blood pressure, muscular activity and digestion and utilization of feeds and nutrients. It is almost impossible to specify the point at which pigs become heat stressed because the exact temperature is influenced by a number of factors. A few days after birth, piglets grow best at 34°C which at a later age causes heat stress. The reasons for this are that as pigs age 1) dissipation of body heat becomes increasingly difficult; 2) there is an increase in skin thickness and

subcutaneous fat deposition resulting in a lower transfer of body heat to the environment; 3) with an increase in live weight, the ratio of surface area to body weight declines which means a reduction in the effective surface area for dissipating body heat.

Evaporation represents 90% of total heat loss from the pig at an ambient temperature of 38°C. Like other panting animals, the pig changes its pattern of breathing with high ambient temperature but can increase panting rate only to a limited extend. The pig has few active sweat glands and loss of moisture from the skin is limited to about 30 g $m^{2} hr^{-1}$ (Ingram, 1965). It is not surprising therefore to observe pigs kept at high ambient temperature, urinating and defecating indiscriminately over the pen floor and rolling in urine or any other available water and in feces (Feeding Standard For Australian Livestock, 1987).

The normal responses to environmental changes such as an increase in ambient temperature, are not only physiological but also behavioural in nature. In the upper range of the TNZ, thermoregulatory behaviour aims at reducing heat production and enhancing heat loss (Curtis, 1985; Pond and Maner, 1984). Wildt et al, (1975), stated that RT may indicate an animal is stressed or not after exposure to high ambient temperature. As was stated earlier, when rectal temperature rises about 0.5°C from the normal temperature then the heat stress is considered moderate (Christison and Johnson, 1972).

Tidwell and Fletcher,(1951), exposed Poland China and Duroc pigs at body weight of 53 to 83 kg, to direct summer sunlight for 15 min d^{-1} at average air temperature of 30.9°C or 30 min d^{-1} at average air temperature 31.5^{0} C, once a week

for five consecutive weeks. Rectal temperature (RT) and respiratory rate (RR) were increased by about 0.55°±0.09C and 49.8±5.8 breaths min^{-1} vs 1.1±0.10°C and 81.0±1.3 breaths min^{-1}, respectively, for the 15 min and 30 min exposures. Tidwell and Fletcher (1951) also noted that the 30 min d^{-1} exposure duration was significantly higher in RT and RR than the 15 min^{-1} d^{-1} duration of exposure. As well, RT and RR were higher in Poland China pigs than in the Durocs. The same results were reported earlier by Heitman and Hughes (1949) when pigs were kept at air temperatures ranging from 34.4°C to 37.8°C for 7 d in psychometric rooms. Edwards *et al.*, (1968) demonstrated that cycling gilts subjected to daily temperatures of 38.9°C for 17 h and 32.2°C for 7 h, had significantly higher RT than pigs continuously subjected to 23.4°C. There was a tendency for the animals in this study to gradually become acclimatized during the first 6-8 days of temperature exposure, but to maintain RT higher than the control pigs for the remaining 22 days of the treatment period. Similar results were reported by Morrison and Mount (1971). Holmes (1973), studying the effect of high ambient temperature in growing finishing pigs from liveweights of 25 to 70 kg, noted an increase in RT of 1.4 to 1.7°C, decreases in the apparent digestible coefficient of dietary dry matter and energy and increased urinary nitrogen losses.

The optimal temperature for growing finishing pigs falls between 18 - 21°C (Holmes, 1973).

In contrast to sheep and cattle, with their coats of wool and thick hair, pigs have only sparse hair coats, and are therefore very sensitive to extreme heat and cold which in turn can depress performance (Devendra and Fuller, 1979). Kelley and Curtis

(1978), noted a significant increase in RT and RR in sows and gilts before and during parturition when they were housed at 29 °C compared to sows and gilts kept at 21°C. The same pattern was also reported by Luiting *et al*, (1985) in dwarf West African goats when exposed to 35°C; RT and RR as well as heart rate and rumen contractions increased.

Teague, *et al.*,(1968) reported an increase in rectal temperature to as high as 41.7°C in individual mature cycling gilts at 225 to 234 d of age with body weights between 116 - 118kg after exposure to a dry bulb temperature of 33.3°C for 7 days. A significant increase in rectal temperature (RT) was reported by Edwards *et al.*, (1968) , when gilts were kept at 38.9°C for 17 hr and 32°C for 7 hr daily with the highest RT recorded during the first 8 days. The same pattern of increase in RR was also reported during that first 8 day period (Teague, *et al.*, 1968). In sheep, Ross *et al. (* 1985), reported the RT and RR were significantly higher especially in the temperate breed, the Dorset than its crossbred, (DorsetXBarbados Black Belly=DXBB) or the local sheep Barbados Blackbelly. They concluded that both the crossbred (DXBB) and the local Barbados Blackbelly were more heat tolerant than the Dorset as indicated by lower RT and RR. Respiratory rate can be an indicator of heat stress in adult animals and was suggested to be reduced in pigs by about 49% if provided with adequate shade or wallowing in the tropical climate (Egbunike, 1986).

Wettemann *et al.*, (1988) studying gilts noted a significantly greater increase in RT in the afternoon than in the morning after exposure to temperatures of average 37 ± 1°C for 12 h and 32 ± 1°C for 12 hr. Water intake was also increased significantly

under high ambient temperature. They concluded these significant increases in RT and RR coupled with an increase in water intake indicated the pigs were heat-stressed.

In ewes however, Ross *et al.* (1985), noted that heat stress did not always change morning and afternoon RR and RT, especially for the indigenous ewes (Barbados Blackbelly) and the crossbred between Dorset and Blackbelly(DXB). However, the temperate breed (Dorset) had a significantly higher RT both morning and afternoon when compared to the local tropical breed (Barbados Blackbelly) and its crossbreed (DXB). The study also suggested the local breed (BB) was heat tolerant as indicated by low RR, RT and supported by low concentrations of thyroxin(T4).

Effect of High Ambient Temperature on Growing Animals

In the very young animal, ambient temperature is very critical, and is of the most concern (Pond and Maner, 1984). The new-born pigs are prone to chilling and hypoglycemia which may lead to death (Pond and Maner, 1984). The ambient temperature required for optimum growth is different for different ages and body weights. The ambient temperature required for the newborn pig is around 32° C , for the grower pigs (<50kg), 20 -23°C and for the finisher pig (50-100kg), 17 -22° C (Pond and Maner, 1984; Sugahara *et al.*, 1970).

As the pig grows it accumulates subcutaneous fat. The fat cover becomes good for thermal insulation against cold but makes heat dissipation difficult. Along with the pigs inability to perspire, this makes the older pig sensitive to high ambient temperatures.

This was demonstrated by Heitman *et al.*, (1958) who noted that, the older and the heavier the pigs the more the severe the response to high ambient temperature. Heitman *et al.*, (1958) demonstrated that the most favourable temperature for pigs of 45 kg was between 21- 27°C and for pigs weighing between 70 - 160 kg the most favourable temperature was between 10 - 21°C. When pigs of this range of weight were exposed to 32 or 38°C they lost weight with the highest loss being the group with the highest body weight.

Ojeda *et al.*, (1984) studying growing and finishing pigs in the warm season, found that thermal stress influenced swine productivity by altering their heat exchange with the environment and thereby, affecting their feed intake, daily gain and nutrient requirement. Pigs in warm environments tended to reduce feed intake and have depressed growth rates. They suggested that this could be partially alleviated by lowering the heat increment of the diet. Although lowering protein content of the diet by adding synthetic lysine did not affect performance, addition of soybean oil increased body weight gain and, in spite of decreased feed intake, resulted in improved feed efficiency.

Effect of Heat Stress on Feed Intake

An early response of an animal to heat stress is reduced feed intake. This is an attempt by the animal to bring metabolic heat production in balance with its capacity to dissipate body heat (Conrad, 1985). In general, high producing and fast growing animals

have higher feed intakes per unit of body weight which results in greater metabolic heat. Under cold conditions greater metabolic heat may be advantageous, but hinders heat tolerance (Conrad, 1985).

As in other domestic animals, pigs react to extreme environmental temperature by adjustment in the feed intake, rate of gain and heat exchange with their environment (Conrad, 1985). However, some physiological characteristics of pigs are unique and cause them to respond differently. They do not have functional sweat glands, except at the tip of the nose, but moisture on the skin and air movement greatly affect evaporative cooling. The hair coat of pigs has little effect on heat exchange from the body to the environment.

If ambient temperature increases so that heat stress occurs it may cause a reduction in feed intake and consequently reduce growth rate (Curtis, 1985). Therefore, growing finishing pigs in high ambient temperature require high dietary protein concentration (Curtis, 1983 ; Babatunde 1972). Growing finishing pigs demonstrated a decrease in feed intake by 60 - 100 g and a decline in weight gain by 35 - 60 g for each ^{0} C above 21°C (Curtis, 1985). Heavier pigs tend to be affected to a greater extent than do lighter pigs. Therefore, protein concentration of the diet should be increased to compensate for the decrease in feed intake in response to high ambient temperature (NRC, 1988). In contrast to the above suggestion, others have found that increasing the lysine levels rather than the total CP level can improve growth performance (Fetuga, 1975; Bayley and Summers, 1968; Blair, 1969).

Forbes (1986), citing Brobeck (1948) stated that animals eat to keep warm and

quit eating to prevent hyperthermia. Therefore, commonly, animals eat more in cold weather and eat less in hot weather. In the warm weather, shearing sheep stimulates feed intake, because heat from the body can be lost more easily.

Vercoe and Frisch, (1983), stated that environmental stress affects growth in cattle, as a function of the degree of stress. Elevated RT as a result of environmental stress was associated with increased excretion of urinary nitrogen. They noted that food intake was depressed 30% for each °C rise in RT. The result of this was a reduction of growth rate under grazing conditions.

The study of effect of high ambient temperature on the metabolism of West African Dwarf goats, indicated that the responses differed slightly depending upon the housing system (Montsma *et al.*,1985). Goats kept in groups were more severely affected than those kept individually at 35°C. However, heat stress occurred in goats in both systems when compared to goats raised at 20°C. Increasing RT from 39°C to 39.9°C and the RR by 9 fold decreased hay intake by 40% (Montsma *et al.*, 1985).

Teague *et al.*, (1968) noted a significant decrease in feed intake by 21% and in body weight gain by 45% in sexually mature gilts as the ambient temperature was maintained at 33.3^0C for one estrous cycle prior to breeding and during the first 25 days of gestation. As well, Lopez *et al.*, (1991) observed a reduction in feed intake and body weight gain as ambient temperature increased in finishing pigs with body weight 90 ± 0.67kg. They calculated that for every 1°C above 20°C, pigs in the hot temperature gained 17.6 g day^{-1} less and consumed 43.5 g day^{-1} less than pigs raised in the thermoneutral temperature. As well, Wettemann *et al.,(* 1988) reported a decreased

feed intake of 35.29% when gilts were exposed to ambient temperatures of 32 - 37°C in early pregnancy.

Protein Requirements in the Tropics

Babatunde *et al.*, (1972) established the optimum level of crude protein in the diets for growing pigs in the tropics as being between 18 - 21%. The optimum crude protein requirement was based on the criteria of maximum nitrogen utilization, optimum growth performance, maximum feed efficiency and good economic return. This was somewhat higher than the recommended value for temperate regions at 13 to 15% (NRC, 1988). Holmes (1973), studying the effect of growth at high ambient temperatures, of 33 - 35°C found that high temperatures decreased the apparent digestibility of dietary dry matter and energy, while, urinary losses of nitrogen and heat production increased. The study also noted that nitrogen and energy retention decreased at high ambient temperatures and suggested that the maintenance requirement was increased. Therefore, protein requirement should be higher for pigs raised in high ambient temperatures.

The higher protein levels recommended for the tropics would also help counteract the lower quality of tropical protein sources in terms of essential amino acids, and allow the pigs to meet their protein requirement, despite any lower feed intake resulting from thermal stress (Payne, 1990).

Yamamoto *et al.*, (1983), measuring the relationship between physiological and biological responses in growing and finishing pigs found that in the 2 periods of growing

at 44 and at 71 kg of body weight, 3-week periods of high ambient temperature treatment at 32°C resulted in decreases in feed intake by 103 g $°C^{-1}$ and 144 g $°C^{-1}$ above 22°C for the first and second week respectively. The consequence was a reduction in daily gain by as much as 46 g and 55 g $°C^{-1}$, respectively. There was a significant correlation between these measurement and the environmental temperature.

LeDividich and Canope (1978) studying the growing finishing pig from 24 to 60 kg, found the requirement for protein was 16% and would be satisfied for growth and carcass performance when fed a corn and soybean based diet.

Lysine Supplementation

It has been demonstrated that lysine supplementation depressed growth rate and efficiency of feed utilization when pigs were raised at 22.5°C, but improved feed efficiency by 2.7% in pigs raised at 35°C (Stahly, 1979). The same results were reported in poultry especially when protein concentration in the diet was decreased but supplemented with amino acids (Waldroup *et al.*,1972).

Hsu *et al.*, (1990) studying the effect of dietary lysine and energy on the performance of finishing pigs in the tropics, noted that if the pigs were supplemented with 0.15% additional lysine when the basal diet contain 0.60% of lysine, their rate of gain and feed efficiency were improved. Costa *et al.*, (1983) found that 0.87% lysine in grower ration gave good performance for pigs in the tropics. Bell (1964) previously noted in the temperate climate that increasing lysine from the minimum NRC standard

of 0.65% to 0.75% resulted in significantly greater daily gain and better feed efficiency without increasing feed intake. However, Amubode *et al.*, (1985) found that the European broiler chicken raised under tropical conditions had similar lysine requirements under widely different environmental conditions if expressed on a daily intake basis. However, on a percentage basis, they seemed to have lower lysine levels when compared to broilers raised in the temperate regions.

Babatunde *et al.*, (1972), stated that protein requirement for weaned pigs in the tropic was not significantly different from pigs kept under temperate conditions with respect to feed utilization. However, for better average daily gain, feed utilization, cost per kg liveweight and N retention they recommended a dietary protein level of 22- 24%. The growth rate, however, was generally lower than in temperate regions. Later, Fetuga *et al.*,(1975), demonstrated that by supplementation of the diet with 1.11 to 1.17% lysine and 0.66% methionine+cystine, a 18 to 20% crude protein (CP) diet would support maximal gain at better feed efficiency than the higher protein diet suggested by Babatunde *et al.*,(1972).

Cole *et al.*,(1983), studying the requirement of lysine under restricted and *ad libitum* feeding for pigs given an ideal protein ration found that for maximum live gain, based on an air-dry diet, 0.9 and 1.1% lysine were required, respectively. Optimum carcass characteristics were achieved at lysine levels of 1.1% as associated with daily intake of 21.05 g protein for young growing pigs from 25 to 55 kg live weight.

Balogun and Fetuga (1982,1983) studied the requirement of lysine for European pigs under the humid lowland tropical climate. They found that on a yellow maize base

diet containing 20% CP and 15.18 to 15.23 MJ of digestible energy DM^{-kg}, the lysine requirement for pigs of 10 -23 kg was 0.98%. Providing this amount of lysine resulted in optimum performance, nitrogen retention and carcass leanness. High ambient temperature may increase the lysine requirement. Fetuga (1975) found that by increasing the standard 0.75% lysine to 0.90% in the 18%CP diet of growing finishing pigs improved growth performance. Fetuga felt this approach was preferable to 24% or 32% CP as recommended by Babatunde (1972) and by Steinbach (1973), respectively,

Earlier, Blair *et al.* (1969) studied the effect of increasing lysine level from 1.04% to 1.22% in the growing pig (25 - 50 kg) under normal temperature, significantly improved feed to gain ratio although had no significant effect on growth rate and efficiency of lean meat gain. Another study found that an adding 0.10% lysine would allow a decrease of 15% in the amount of ingredients of grower or finisher rations without compromising growth rate and feed efficiency (Bell, 1964).

Effect on Water Usage

Water is an integral part of the structure of the soft tissues of the body. The cells readily take up and release water as part of metabolism (Thulin and Brumm, 1991). Water accounts for about 53% of the weight of a 90 kg pig and 82% of the fasted body weight of a newborn pig. It plays a critical role in the reaction of energy-yielding nutrients in the body (Thulin and Brumm, 1991).

In mammals, under TNZ, voluntary water intake is related to the heat production of the animals and thus to its feed intake. ARC (1981) suggested that pigs drink about 2.5 to 3 times as much water as dry weight of feed intake (Australian Feeding Standard, 1987).

Water requirements and intake vary and are regulated by many factors such as the intake of dry matter, type of feed and its components, lactation, general health status, stress, body size, individual preference, environment temperature, location of water, water losses from the body and species (Conrad, 1985).

Studies in pigs, relating water requirement to ambient temperature and water temperature, indicated that 4 to 5 week old weaned pigs in a 5°C environment, showed improved body weight gain when drinking water was heated to 30°C, (Nienaber and Hahn, 1984). Earlier, Holmes (1971) reported that young growing pigs gain faster when fed whey heated to 40°C than those fed whey at 15°C. In the adult, water intake increases linearly with ambient temperature. Jensen (1991) reported also that water to feed ratio depended on the ambient temperature. The ratio was between 2.1 and 2.7 in the ambient temperature range between 7°C and 22°C and between 2.8 and 5 at ambient temperatures 30 and 35°C. Overall the range of daily water requirement was from 92 ml to 184 ml body weight $^{-kg}$.

European breeds of beef cattle consume water at a ratio of 3:1 water to the dry matter (DM) intake at 5°C but drastically change this to 8:1 DM as the environmental temperature increases to 32°C (Conrad, 1985). Similar observations have been made with dairy cattle (Conrad, 1985). Experiments showed that each kg DM consumed

required 3.1 kg of water at environmental temperatures ranging from -12.2 to 4.4°C. When temperatures increased from 4.4 to 26.7°C a linear increase in water intake was noted from 3.1 to 5.2 kg^{-1} DM. When air temperature increased to 37.8°C an increase to 15.6 kg^{-1} DM was noted.

Effect on Reproductive Performance of the Female

Puberty Under Normal Environmental Conditions. In gilts, puberty is recognized by the occurrence of the first estrus, which is almost always ovulatory. It is the starting point of reproductive capability of the gilt (Hughes and Varley, 1980). The estrous period is associated with physiological and behavioural changes (Signoret, 1970). The external morphological changes are reddening and swelling of the vulva. These changes begin and reach their maximum before the onset of estrus. The sequence of these behavioural changes culminates in the standing heat reflex indicating sexual receptivity (Signoret, 1970).

There are many factor that may influence the attainment of puberty. Most gilts attain puberty between 135 - 250 days of age (Hughes and Varley, 1980). This large variation in age of puberty is due to the stimulatory and inhibitory influences originating from both the external and internal environment (Hughes and Varley, 1980). The internal influences include breed and genotype of the gilts and endocrine status while the external influences include nutritional status, climatic environment, photoperiod and social factors surrounding the gilts (Hughes and Varley, 1980).

Paterson *et al.*, (1989) studied the effect of season and herd of origin (genotype) of gilts on the attainment of puberty. They noted that season of the year significantly affected the onset of puberty of the two different genotypes. By mimicking the summer daylength but keeping the ambient temperature at 20°C, they found a significant delay in age at puberty in pigs treated with longer daylength. They concluded that photoperiod rather than the high ambient temperature caused the delay in puberty onset. However, many studies have indicated that high ambient temperature may affect animal performance either under natural tropical environments (Steinbach, 1971, 1973, 1976) under summer heat stress (Paterson *et al.*,1978) or under controlled room temperature (Warnick, 1961; Flowers *et al.*,1989)

As well, Paterson *et al.*, (1989) noted a significant difference between the two genotypes in the proportion of gilts reaching puberty either in winter or summer. This genotypic influence has been noted before and Hutchins *et al* (1981) observed that crossbred gilts reach puberty at an earlier age and heavier weight than purebred gilts.

Boar exposure is also important in stimulating puberty onset. Paterson et al., (1989), noted an inverse relationship between the frequency of boar exposure and the interval between the time after first boar exposure and the puberty onset. Therefore, they concluded that daily contact with a boar is necessary for maximum stimulation of puberty in gilts.

Eliasson, (1989), studying clinical, endocrinological and morphological aspects of puberty in gilts , noted that the proestrus duration in pubertal gilts was significantly longer than it was at the second estrus. The Swedish Yorkshire gilts in their study

reached puberty at the mean age of 211 days ranging from 164 - 259 days with the mean backfat thickness 15.3 mm within a range of 7.0 - 30.0 mm.

Effect of Heat Stress on Puberty. When prepubertal gilts were exposed to 33.3°C for 11 weeks, a delay in puberty onset by 4 weeks was noted compared to gilts kept in a control temperature of 20 °C (Flowers *et al.*, 1989). Clegg and Ganong, (1969) reported a delay in sexual maturity in gilts kept at high ambient temperature and they suspected this was due to nutritional disturbances. Steinbach, (1976) also reported that gilts in tropical countries reached puberty later than the same breed in the temperate regions. A significant delay in age at puberty as well as lower body weight were observed under natural tropical condition when gilts were born in the hot dry season. Gilts that were born before the cool rainy season were heavier (81 kg vs 70 kg) and younger (224 d vs 256 d) at puberty than gilts born at the onset of the hot dry season (Steinbach, 1976).

Reviewing the report of Day *et al.*, (1986), Dunn and Moss (1992), reported that adequate fed heifers gained 0.79 kg d^{-1} and reached puberty at 428 days of age with a body weight of 308 kg while the inadequate fed heifers gained of 0.21 kg d^{-1} and did not reach puberty until 474 days of age at a weight of 250 kg. This could be similar to the situation with heat stress and decreased feed intake. Adequate fed heifers had higher mean levels of luteinizing hormone (LH) and greater numbers of LH pulses. Inadequate nutrition seems to inhibit reproduction by some action exerted ultimately on the hypothalamic neurons responsible for release of gonadotropin releasing hormone (GnRH) (Dunn and Moss 1992).

Dunn and Moss (1992), found that deficiencies of some nutrients such as minerals, phosphorus, vitamins A and B, carotene, protein and energy limited reproductive processes. They could not clarify the mechanisms of how these nutrient deficiencies affect the hypothalamic gonadal axis but they assumed that it impinged on hypothalamic regions that selectively regulate the production and release of pituitary trophic hormones.

Effect on Sexual Behaviour. Cycling heifers kept at 32°C have shown shorter duration of estrus (16 h vs 21 h) compared to heifers kept at a thermoneutral environment (Gwazdauskas *et al.*,1981).

In pigs, gilts confined in hot chambers for two estrous cycles, showed longer estrous cycles compared to gilts in a cool chamber (Edward *et al.*, 1968). Warnick *et al.,(1965)* noted, that a high ambient temperature of 32.2 ^{0} C affected sexual behaviour in some pigs and resulted in more silent ovulations. When mean daily maximum temperature exceeded 32°C during the week of service there was an increase in the number of sows failing to hold to service and caused delayed or irregular returns to estrus (Paterson, *et al.*, 1978).

Effect on Fertility. Wilmut, (1985) reviewing the works of Gwazdauskas *et al.*, *(*1973) and Ingraham *et al.*, (1976), noted that in many tropical and sub-tropical regions a reduction in conception rate has been demonstrated in dairy cattle. A negative correlation was found between environmental temperature around time of mating and

conception rate (Wilmut, 1985).

In the sub-tropical climate such as found in Iran, Friesian cattle fertility was lower during the very hot months of June and July (Ali *et al.*, 1983). Reduction in fertility during these summer months was indicated by an increase in calving to conception interval and in the number of services per conception. Seasonal depression of fertility due to heat stress, determined by the number of live born per number of first services , dropped to 23.6% in July from a high of 48.5% observed following breeding in February. There was a significant negative relationship between heat stress and fertility if heat stress occurred almost daily from day 11 before mating until two days before mating. However, the strongest relationship was found when heat stress occurred on day two before mating (Wilmut, 1985). However, Gwazdauskas *et al.*, (1981) demonstrated that the more detrimental effect of heat stress resulted when applied to cows shortly after mating.

Ulberg and Burfening (1967) observed that although dairy cows were exposed to heat stress for a relatively short period of time at the time of mating, this resulted in a considerable decrease in pregnancy rate. This was associated with a considerable increase in RT and uterine temperature which may have affected either the spermatozoa before fertilization or the ovum immediately after fertilization.

Cooling the anterior hypothalamus in goats increased feeding, while warming the anterior hypothalamus depressed feed intake. However, in pigs, heating or cooling the hypothalamic region did not affect voluntary feed intake (Forbes, 1986). Multiparous sows, however, showed markedly reduced farrowing rate. Several aspects of

reproduction were affected deleteriously by heat stress, especially during the first 3 week period just before and after mating and just before parturition. McGlone *et al.*, (1988), studying the effect of heat stress on sow performance, noted that feed intake was significantly reduced as were the number of piglets weaned litter^{-1}. Lactation weight loss was greater in heat stressed sows.

Lowered fertility in sows during hot weather is due partly to a higher frequency of early embryonic death (Curtis, 1985). Low fertility rate is especially due to the fact that the first 2 - 3 weeks after mating is a very sensitive period. After this period and until a couple of weeks before parturition, neither the fetuses nor the pregnancy ordinarily are in jeopardy (Curtis, 1985). However, sows subjected to severe heat stress from day 102 to 110 postmating farrowed fewer liveborn piglets and more stillborn piglets (Curtis, 1985). When severe heat stress was imposed on sows near the end of the gestation period for only 1 to 3 days, there was no evidence of adverse effects on the fetuses. Therefore, it seems that after the sows pregnancy has survived the first 3 weeks, heat stress must be severe and prolonged and /or it must come during the last 2 - 3 weeks of the gestation period if it is to have an effect (Curtis, 1985).

Wildt *et al.*, (1975) noted that when two groups of pigs were treated with ambient temperatures of 40°C ; one group during the first 2 weeks of gestation and the other group on week 3 - 4 of gestation, they responded differently. The rise of the body temperature was higher in the group of pigs exposed to high ambient temperature during the first two weeks of gestation. The study concluded that pigs at the preimplantation stage (the first two weeks postmating) were more responsive and susceptible to high

ambient temperatures and this in turn resulted in a more damage to the embryos.

Warnick *et al.*, (1965) found no significant difference in conception rate (CR) between groups of gilts kept at 16 and 32°C. However, it affected estrous behaviour resulting in silent ovulations in some gilts. Warnick *et al.* (1965) noted that although ovulation rates were not affected, embryo survival was non significantly lower in gilts kept at 32° C than those housed at 16°C. Gilts kept at 32° C experienced non significantly lower embryo survival than gilts kept continuously at 16°C before breeding to 3 day after breeding.

Steinbach, (1976) noted that tropical temperatures in Nigeria did not significantly affect the early stages of pregnancy, but did affect the terminal stage of pregnancy. The interaction between high ambient temperature during the hot season and high metabolic heat production during the terminal stage of gestation may affect the heat balance of the sow to such an extent that many piglets are born dead. In the extreme conditions, the sow may die from heat stroke when late pregnancy coincides with the hottest month of the year.

Steinbach, (1976) also noted that a high degree of heat stress during the second half of pregnancy, whether of endogenous (metabolic) or exogenous (climatic) origin affects mammary gland development, presumably through decreased feed intake and affects on thyroid activity, as well as through the other endocrine glands of importance to milk synthesis after parturition. Temporary infertility in sows that was associated with summer heat stress was reported by Paterson *et al.*, (1978).

In dairy cows in Israel, Francos and Mayer (1983) observed that overall

conception rate (CR) was 28.2% during summer compared with 40% during spring time. Conception rate from first insemination was 31.3% during summer and 45.3% during spring. This overall CR was negatively correlated with the temperature and the relative humidity. The same results were reported recently in dairy cows in South Africa (Du Preez *et al.*,(1991). They related CR to the mean monthly temperature-humidity index. Heat stress due to high ambient temperature with a high (>70) temperature -humidity index resulted in low CR (34 -57%) while a low temperature-humidity index (<70) was associated with high CR(60-80%).

Effect on Embryos. Teague et al, (1967) demonstrated that at day 25 post mating, the number of live embryos was lower from sows kept at 33°C than from sows kept at 20°C (8.4 and 11.2 respectively). Warnick et al (1965), reported that although gilts raised under high ambient temperature tended to have fewer live embryos at day 25 post mating, the ratio of CL present to live embryos at slaughter showed no significant relationship to temperature. This suggested that after ovulation had occurred fertilization and survival of embryos were not significantly affected by high ambient temperatures. Tompkins *et al.*,(1967) also reported fewer viable embryos when gilts were stressed one to five days postmating.

In sheep, Ross et al., (1985) demonstrated that when pregnant ewes were exposed to a high ambient temperature of 34°C from day 125 to about 7 days prior to the expected lambing day, there was no difference in mean birth weight, crown rump-length, number of functional caruncles and the caruncle weight and size. They also

noted no indication of fetal dwarfing as was reported earlier as the result of exposure to high ambient temperature. However, they did note that serum T4 varied markedly among breed groups. Barbados ewes had the lowest concentration when compared with other breeds that were used such as the Dorset and the crossbred (Ross, et al, 1985). In goats, Ross et al., (1985) reported that subjecting ewes to high ambient temperature during the gestation period resulted in low birth weights and high lamb mortality. This situation was referred as "fetal dwarfing" and seemed to be independent of ewe nutrition. They also noted from earlier findings that the reasons for this low birth weight and poor survival rate were suggested as premature parturition, hypothyroidism, reduced blood flow and impaired placental development (Ross *et al.*, 1985).

Edward *et al.*, (1968) noted that when gilts were exposed to 39°C for 17 hr and 32°C for 7 hr, for one cycle before breeding, the onset of the following estrus was delayed by over 2 days. However, ovulation rate (OR), number of embryos and embryo size were not affected. They also found that if gilts were subjected to 32°C to 39°C at day 5 to day 3 prior to breeding, there were no significant differences in the length of cycle, CL number, fetal number and size at day 30 - 35 post breeding. However, when heat stress was applied at day 15 - 30 post breeding, more serious detriments to productivity occurred including lower conception rate, fewer viable embryos and lower survival rate compared with gilts in lower temperatures. Edwards et al.,(1968) concluded that gilts were more susceptible to high temperature at the first days after breeding than after implantation had occurred. Heat stress during early gestation appeared to be more detrimental than before breeding.

Wettmann et al., (1988) found when gilts were heat-stressed for 12 h at 37°C and 12 hr at 32°C on day 8 to 16 postmating, the conceptus wet weight was lower at day 16 post mating compared with the wet weight of conceptuses of the control gilts. Forty percent of the heat stressed gilts had fragmented conceptuses and the total wet weight of the conceptuses per horn on day 16 of pregnancy was significantly lower (233 $\pm$ 66 mg vs 366 $\pm$ 75 mg) in heat stressed gilts.

Effect on Male

It was noticed early in this century that cryptorchid males could not produce sperm. This situation can be mimicked experimentally by placing the testis into the abdominal cavity (Ulberg, 1958). Ulberg (1958) citing Moore, (1932; Phillips and McKenzie,(1934) and McKenzie and Berliner (1937) noted that higher temperatures of the abdominal cavity cause degeneration of the germinal epithelium. The testes are normally maintained at a lower than body core temperature by thermo-regulatory mechanisms in the spermatic cord and the scrotum wall. Therefore, when temperature of the testes was raised, it resulted in decreased semen quality. In males of most mammalian species high ambient temperature lowers semen quality (Ulberg, 1958; Bearden and Fuquay 1992; Ashdown and Hafez, 1993). This particular condition in rams during summer months is usually referred to as'summer sterility' (Ulberg, 1958). In dairy farms the effect of summer ambient temperatures on spermatogenic activity and sterility was reflected in a decrease in the percentage of 60 to 90-day non return rate of

cows bred during summer months (Ulberg, 1958). However, researchers from areas which are generally cooler during the summer months were unable to demonstrate this decrease in fertility (Erb and Waldo, 1952). A lowering of boars' semen quality especially during the hot dry season of natural tropical environments was reported by Steinbach (1976). Inability of the body's cooling mechanism to keep the testes cool enough during high ambient temperature has been attributed to this low semen quality.

Curtis, (1985) stated that when the deep body temperature of a boar reaches 40°C, semen quality was affected. It affected certain spermatogenic stages therefore semen quality remained below normal for several weeks. Boar libido was affected when environmental temperature rose above 30°C. In the tropics, Steinbach (1976) reported that young boars reach puberty one month later than boars in temperate regions. This was largely the result of retarded growth of these heat-stressed boars, which was due to lowered feed intake. Semen quality was affected by temperature, which in turn may cause changes in sexual behaviour. Steinbach (1976) noted a lack of sexual interest during the hotter season, which may have been related to reduced testosterone concentrations. The study noted that sperm concentration in the hot season was about 50% of the concentration in the cool season. Curtis (1985) indicated that the farrowing rate percentage of sows was influenced by boar fertility. Pregnancy rates of the sows bred by the heat stressed boars was only 59% compared to 82% pregnancy rate from sows bred by boars kept under thermoneutral temperatures. The same is also true in sheep in which the conception rate was influenced by ram fertility. Semen quality was higher when rams were kept at 18 °C and more ewes settled when rams were kept

at natural high summer temperatures (Alexander and Williams, 1971).

Since body temperature, as a reflection of ambient temperature, may affect semen quality, keeping the male cool during the periods of high environmental temperature should maintain their fertility (Ulberg, 1958).

Hormonal Profile in High Ambient Temperature

Thermal or restraint stress as well as injection of adrenocorticotropic hormone (ACTH) or adrenal corticoid have been implicated in impaired reproductive function in many species (Wildt *et al.*, 1975). Plasma ACTH as well as adrenal corticoid hormone level was markedly increased in heat-stressed pigs (Becker et al, 1985). The increase in glucocorticoids produced by a stressed animal can blocked or reduce the secretion of pituitary gonadotropin, especially LH (Wildt *et al.*, 1975). In dairy cows, a significant decrease in preovulatory and basal LH level was seen in thermally stressed animals (Miller and Alliston, 1973).

The progesterone (P4) concentration and the preovulatory LH surge were not significantly different between heifers under high ambient temperature (32°C), suggesting that hyperthermia did not alter factors which regulate hypothalamic control of LH release. However, estrogen (E2) concentrations were significantly lower (Gwazdauskas *et al.*, 1981). As well, corticoid responses following ACTH injection were of lower magnitude, showed an earlier peak and were of shorter duration in heat stressed heifers (Gwazdauskas *et al.*, 1981). Earlier, Warnick *et al.*, (1961) noted some of the gilts

maintained at 32°C had silent ovulations. Since E2 was not measured, it is possible there was insufficient E2 to stimulate behavioural estrus.

Reporting on T4 levels, Ross *et al.*, (1985) noted that serum T4 concentrations during a complete estrous cycle varied significantly between sheep breeds. Local breeds (Barbados Blackbelly) showed the lowest level while the crossbred (BarbadosX Dorset) showed the highest concentration. They noted that T4 levels during the luteal stage did not vary among breed groups, although T4 decreased significantly during the follicular stage(2 days before estrus) and 2 days after estrus.

Dorset and Corriedale breeds showed significant decreases in T4 levels during hot weather (Ross *et al.*, 1985). It was suggested that Dorset ewes were reducing metabolic heat production in an attempt to maintain homeothermy in a hot environment. However, the reduction of T4 levels in the Dorset did not sufficiently affect body weight and the caruncles of their lambs. Therefore, T4 was not considered as an important factor affecting body weight and survival rate of their fall-born lambs. Local breeds (Barbados blackbelly) and cross breeds (Barbados X Dorset) were more tolerable to heat stress due to their lower metabolic heat production, as supported by T4 data and reflected in RR and RT data (Ross et al., 1985).

In pigs, Omeke (1989), reported no significant differences in fertility in Landrace and Large White breeds between rainy and dry seasons in the subhumid tropics (RH 60-82%). However, a significant effect on postweaning and preweaning mortality was observed between rainy and dry seasons. Based on the results from earlier studies Omeke (1989) suggested that high ambient temperature disturbed the

hormonal balance and in turn lowered reproductive efficiency. This was also suggested by Steinbach, (1976), for high producing pigs in Nigeria which showed retarded growth, shortened and suppressed heat periods and estrus behaviour and reduced ovarian activities. Many of these are E2-dependent activities.

Dunn and Moss, (1992), reviewed the role of nutrition on reproductive efficiency of livestock and stated that successful reproduction is dependent on a host of macro and micronutrients and that reproductive function ceases before an animal expires from deficiency of a particular nutrient. Dunn and Moss, (1992) noted the effect of nutrition on embryonic survival in ruminants and found a negative relationship between P4 concentration and nutrition level. Low levels of nutrition were associated with higher levels of P4 and vice versa. In the ewe fed small amounts of feed after mating, the mean P4 concentrations on days 2, 6 and 10 were 0.3, 2.9 and 6.8 ng ml^{-1} compared with 0.3, 1.9 and 4.8 ng ml^{-1} in adequately fed ewes. However, both groups had similar ovulation rates. In underfed ewes, P4 concentration increased more rapidly between day 2 and 6 post mating than in the ewes receiving adequate feed. Therefore, the lower rate of embryo survival in the underfed ewes may have been associated with the more rapid increase of P4. Overfeeding and under feeding has also been associated with embryo loss in sheep. Because of the negative relationship between level of feeding and P4, Parr and Cumming (1982) suggested that ewes fed 25 % of maintenance diet have significantly fewer and smaller embryos as measured by crown rump length at day 21 post mating than ewes fed 100% maintenance. Diminished survival of embryos is one of the major inefficiencies of livestock production. Animals that receive inadequate

nutrition after mating have a higher incidence of embryo mortality than animals that receive adequate nutrition (Parr and Cumming, 1982).

Flowers *et al.*, (1989) observed P4 concentrations in prepubertal heat stressed gilts were doubled compared to those in non heat stressed gilts. The same pattern of P4 concentration has been reported by Hoagland and Wetteman (1984). In dairy heifers, E2 concentrations were significantly lower when the heifers were kept under 32°C. On the other hand, no significant differences were detected in the mean LH concentration. The same was true for the preovulatory LH concentration between heifers kept at 32°C and heifers kept at 21°C (32.2 vs 33.2 ng ml^{-1}) suggesting that hyperthermia in this case did not alter factors which regulate hypothalamic control of LH release (Gwazdauskas *et al.*, 1981).

Mean basal concentrations of prolactin and cortisol were not significantly different between heifers kept at 32 and those at 23.1°C, although the rectal temperature increased 1.4°C and skin temperature increased 3.6°C (Gwazdauskas *et al.*, 1981). In chickens, Donoghue *et al.*(1989) measured the LH concentration and found that acute thermal stress at 35 °C was able to suppress LH concentration in mature laying hens. The same pattern of LH concentration had been reported earlier in dairy cows (Vaught, *et al.* 1977) and in buffalos (Rao and Pandey, 1983).

Season of the year has an effect on estrus and LH in ovariectomized sows injected with estradiol benzoate (EB) . Frequency of LH peaks was not affected by season but amplitude and baseline were significantly greater for summer than for other seasons (Cox et al, 1987).They noted also that estradiol-17β concentration was greater

in summer than in fall. The conclusion was that environmental factors associated with season alter responsiveness of the brain to E2, thereby controlling behaviour and LH secretion. Temperatures however in this study were not extreme.

Marple *et al.*, (1972) found in pigs treated with high ambient temperature (32°C, low RH=29%), that plasma ACTH, growth hormone (GH), glucose and free fatty acid were higher while plasma corticoid was low. Elevation of the relative humidity to 88% at 32°C resulted in decreases in ACTH, GH, glucose and FFA concentrations and a slight increase in cortisol concentration. These results suggested that stress may change the turnover rate of corticoid in the body.

Becker *et al.,(1985)* using several types of stressors such as restraining pigs in a box, electrical stimulation, or heat stress at 38°C, noted that the types of stressors used all substantially increased the adrenal cortical hormone, ie., cortisol concentration, in crossbred pigs. The decrease in cortisol concentration starting with the removal of the stimuli, indicated that the assigned treatment stimulated the hypothalamo-hypophyseal-adrenal axis.

Suggestions to Overcome High Ambient Temperature Impact

There are some good native breeds in the tropical countries which can be utilized. Ross *et al.* (1985), utilizing the native breed by crossbreeding to exotic breeds of sheep, produced crossbreeds which were more heat tolerant than the exotic breeds. This method was easy to do and practical.

By applying some extra management practices such as cooling, sprinkling (Devendra, 1979) or providing a wallow or shade (Egbunike, 1986) weight gain in exotic breeds of pigs can be improved to some extent in the tropical conditions. In mature animals it has been established that the very sensitive period for heat stress is the breeding time throughout the preimplantation stage which influences embryonic survival. If more attention can be paid to this particular stage by providing cooling or sprinkling it can help to maintain animal productivity.

Since reduced feed intake is the most immediate response indicated by animals under heat stress, more concentrated feed will be helpful to maintain the nutrients required for production. Another possibility is by adding certain dietary constituents which produce less heat increment and others such as lysine which can improve gain and feed efficiency (Hsu et al., 1990)

Conclusion

From the literature it is widely accepted that ambient temperature may either promote or impair animal performance by facilitating or inhibiting the productive and the reproductive processes in farm animals. A certain combination of environmental components which form a condition known as the TNZ facilitate optimum conditions for farm animals to express their maximum capacity of production, when coupled with good quality and quantity of feed. Very low or very high ambient temperature normally inhibits animal performance.

Animals may respond differently to ambient temperature depending upon the degree of ambient temperature, the duration of exposure and the stages when and at which the ambient temperature was exposed. Young animals were more sensitive to cold environments while mature animals are susceptible to high ambient temperature. Therefore the TNZ, LCT and UCT are different for different ages. These will also be different depending upon the body weight and condition, type of feed intake, type of production (milk, meat, wool, growth, pregnancy), type of housing (floor, bedding, number of animals in a pen). Since the sweat glands do not function properly in pigs, the finishing to mature pigs are more sensitive to high ambient temperature compared with other mature species.

The literature indicated acute constant high ambient temperature reduced feed intake, growth rate and carcass quality as well the reproductive performance in the young and mature animals. Chronic high ambient temperatures have been reported to cause failure in overall performance, depending on the degree, the susceptibility of the breed or individual animal and the age at which the high temperature was initially imposed on the animal. Some may just get adjusted after a certain period of time while others may perform very poorly or may even die. The most critical period in gestating animals was noted at the preimplantation period, although the effect also occurs when heat stress is applied during the last trimester of pregnancy.

There are several ways that heat stress may attack animal performance: through decreasing feed intake or by suppressing certain hormone concentrations such as metabolic hormones (growth hormone, thyroxine) or glucocorticoid hormone which in

most cases affects reproductive hormones. It acts via the hypothalamo-hypophyseal-adrenal axis (HHA) or hypothalamo-hypophyseal-gonadal axis (HHG) in both the female and the male.

Some management practices have been suggested, such us increasing protein in the ration, using low increment feedstuffs, using cooled drinking water, adding lysine and using fans. The choice will depend upon the cost of these practices weighed against the actual performance benefits.

MATERIALS AND METHODS

Animals

Forty eight Managra gilts were used, ranging in age from 91 to 107 days with an average initial body weight of 40 kg. Gilts were from 12 litters, and four gilts from each litter, were balanced across treatments. The experiment began in September when the gilts were on average 105 days of age and ended in March when the last gilts in the trial reached 45 days of gestation following breeding at their second estrus. At the average gilt age of 145 days, two mature vasectomized Managra boars were used alternately between the two rooms every day for 10 minutes of fence line contact until all gilts reached puberty or by the cut off age of 210 days. It was planned that all gilts reaching second estrus would be inseminated artificially. However, due to difficulties in timing the transportation of semen from the AI centre to the Animal Science Research Unit, where this experiment was conducted, all gilts were naturally inseminated. Three mature intact Managra boars were used in a random manner, but each boar was restricted to 6 possible matings per week. Two boars were designated to service each gilt on two consecutive days (with a 24 h interval) during the first two days of its second estrus.

Housing

The gilts were housed in two environmental control rooms with 24 gilts per room. There were six pens in each room (pen size 1.50 X 2.35 m), holding four pigs per pen. Upon arrival at the research unit, animals in both rooms were kept at a temperature of 20°C for one week as an adjustment period. Following this period, the temperature in RB (hot room) was gradually increased daily by 2°C between 0600 h and 1800 h for six days until it was set at 32°C for the 12 daytime hours. The night time (1800 to 0600 h) temperature was gradually increased 1^0 C for 6 days until it was set at 26°C for the 12 night time hours. The temperature in RB was intended to mimick the temperature in tropical countries such as in Indonesia as reported by Soeharsono (1976). RA (control room) was maintained at thermoneutral temperature of 20°C. Temperatures in each room were recorded at 0700h and 1600h every day by using maximum and minimum thermometers which were placed in the centre of each room at a height of about 1 meter above the floor.

The relative humidity (RH) was not controlled in either room but was observed and recorded in the morning after cleaning the room at 1000 h and in the afternoon at 1600 h. The average RH was about 50% in RA and 65% in RB. Immediately after cleaning the rooms and washing the pigs in the morning, RH rose to 92%.

Each pen was equipped with a single space feeder hung on the front gate which could be easily emptied to measure feed weighbacks every morning at 0900 h. Water was provided by nipple waterers located to the rear of the pen and a water meter was

attached to each line serving a pen. The water usage was recorded daily at 1600 h for each pen.

Every morning between 0900 and 1000 h, both rooms and pigs were cleaned using a low pressure sprayer with warm water of 38-39°C.

Procedures

The experiment was designed in a 2 x 2 factorial arrangement of treatments based on a randomized complete block design (Steel and Torrie, 1980). The two factors and levels in this experiment were ambient (room) temperatures and lysine levels. The control room (room A) was set at 20° C continuously for the whole study period (thermoneutral). In room B the temperature was set at a diurnal high ambient temperature of 32°C during day time and 26°C during night time. In each room (A and B) lights were on between 0600 - 1800 h (day) and lights were off between 1800 - 0600 h (night).

The barley based grower, finisher and dry sow maintenance (adult) basal rations (Table 1 and 2) had protein and lysine contents slightly above the NRC (1988) recommendations. In each room (A and B) half of the gilts received the basal ration (REG) and half received the basal ration with an additional 50% lysine above the lysine content of the basal diet (LYS). Litter mates were randomly assigned to each treatment combination so as to have equal representation in each treatment combination. A period of one week adjustment at the thermoneutral temperature (20°) was allowed for all

animals prior to the gilts in room B being exposed gradually to the diurnal ambient temperature fluctuations of 26 to 32°C.

Grandhi, (1991) used an additional 50% lysine above the basal diet lysine content for sows with high weight loss after first parity. This was used to improve nitrogen retention, weight gain and their reproductive performance. Earlier, Fetuga (1975) demonstrated that growing pigs raised under high ambient tropical environment, with an additional 15% lysine above the standard lysine requirement, had improved growth rate and feed efficiency. It was therefore hypothesized that additional lysine would lessen the adverse effects of high ambient temperature on weight gain and on reproductive performance of gilts in the present study.

Rations.

Gilts were fed *ad libitum*. Rations were formulated to meet the NRC (1988) standard and in some respects exceeded it slightly. Composition of the rations is shown in Table 1. Table 2 shows the results of proximate analysis of rations determined by the method of the Association Official Analytical Chemist (AOAC method, 1984) and amino acids analyses by the modified methods from Andrews and Baldar (1985).

Grower ration was fed until the average pig weight per pen reached 57 kg. The finisher ration was fed from when the average body weight in a pen was 57 kg until it was 105 kg. Thereafter dry-sow maintenance (adult) ration was provided until 45 days of pregnancy. Half of the pigs in each room (12/24) received the regular ration with

TABLE 1. Composition of ration used during the experimental period

Ingredients	Grower	Finisher	Drysow
Barley, %	79	83	89
Soybean meal, %	17.5	8.5	-
Canola meal, %	-	5.0	4.0
Dehydrated alfalfa, %	-	-	3.5
Tallow, %	1.0	1.0	1.0
Pre-mix, %[a]	2.5	2.5	2.5

[a] Feed-Rite Pre-mix for Swine contained:

Minerals:Calcium..... 23%	Vitamins: A..... 4500.000 iu/kg
Phosphor..... 11%	D3..... 60.000 iu/kg
NaCl 11%	E..... 1.100 iu/kg
Sodium 4.5%	K ..... 125 mg/kg
Magnesium..... .2%	Choline Chloride 15.000 mg/kg
Manganese ..... 1.200 mg/kg	Niacin..... 1.700 mg/kg
Iron..... 5.500 mg/kg	Calcium panthothenate1.300 mg/kg
Zink..... 5.000 mg/kg	Riboflavine..... 375 mg/kg
Copper..... 425 mg/kg	Thiamine ..... 40 mg/kg
Iodine..... 28 mg/kg	Pyridoxine..... 40 mg/kg
-	B12..... 1.000 mcg/kg
	Biotin..... 5.000 mcg/kg
	Folic acid..... 20 mcg/kg

TABLE 2. Proximate analysis of nutrient and amino acid composition of the feed used during the experimental periods.

Ingredients	Grower		Finisher		Dry-sow feed (Adult)	
Lysine supplementation	REG	LYS	REG	LYS	REG	LYS
CP, %	17.0	18.4	16.2	16.0	14.0	15.1
Gross Energy (kcal/kg)	4106	4063	4085	4133	3998	4053
Calcium, %	0.73	0.81	0.72	0.76	0.72	0.77
Phosphorus, %	1.01	0.99	1.03	0.99	0.97	1.00
CF, %	3.18	2.37	3.21	2.96	2.95	2.82
NDF, %	18.1	13.3	23.5	20.4	18.8	18.8
Amino Acids,%:						
Threonine,	0.65	0.66	0.56	0.56	0.48	0.49
Alanine,	0.67	0.71	0.62	0.62	0.53	0.54
Cystine,	0.35	0.35	0.32	0.32	0.32	0.33
Methionine,	0.27	0.28	0.24	0.23	0.27	0.26
Valine	0.78	0.87	0.68	0.71	0.67	0.67
Isoleucine	0.51	0.59	0.42	0.43	0.39	0.39
Leucine	1.08	1.19	0.96	0.98	0.84	0.85
Tyrosine	0.50	0.53	0.45	0.44	0.41	0.34
Phenylalanine	0.90	0.98	0.85	0.84	0.76	0.74
Histidine	0.38	0.39	0.35	0.33	0.28	0.28
Lysine	0.76	1.09	0.65	0.95	0.48	0.71
Arginine	0.93	0.99	0.79	0.82	0.64	0.66
dry matter, %	92.2	91.2	92.5	92.7	91.7	90.6

CP=crude protein, CF=crude fat NDF=neutral detergent fibre (REG)=standard lysine, NRC, 1988 (LYS)= 50% above standard lysine

additional lysine at 50% above the calculated standard ration levels.

The composition of the rations was determined by proximate analysis and are shown on Table 2. The grower ration was formulated to contain 17.2% CP, 0.83% lysine and 3159 kcal DE/kg; the finisher ration to contain 14.9% CP, 0.68% lysine and 3109 kcal DE/kg and dry sow ration to contain 12.3% CP, 0.47% lysine and 3021 kcal DE/kg. As demonstrated by the proximate analysis the rations exceeded these values only slightly.

Biological and Physiological Responses

Various biological, physiological and physical measurements were taken to monitor the gilts' responses and adjustments to the thermal environments and lysine supplementation.

1. Respiration rate (RR), as breaths minute^{-1}, were counted as flank movements while the pigs were asleep or lying down. These were taken twice daily between 0630 to 0730 and between 1500 to 1600 h for the first two weeks of the study (ie. during increasing room B temperature, plus one week at 32°C) then weekly thereafter.
2. Rectal temperature (RT) in °C was taken twice daily after RR, sometime between 0700 to 0800 h and between 1530 to 1630h for the first two weeks of the study then weekly thereafter using Ivac Temp plus II measurement system, (model 2080 A. Ivac Corporation San Diego, Ca).
3. Daily feed intake (VFI) was measured on a per pen basis (kg feed given minus kg

feed remaining the next morning). Feeding and weighbacks were done between 0800 - 0830 daily. Recording of feed intake in both rooms began on day 1 of the trial.

4. Daily water usage (WU),(m^3 pen^{-1} day^{-1}) was recorded from daily reading of water meters at 1600 h. Recordings began on day 6 when the set ambient temperature in room B had reached 32°C.
5. Body weights (BW). (kg), were recorded at the beginning of the experiment when the average pig age was 105 d and then weekly thereafter. Additional data on body weights were recorded at the onset of puberty, at time of mating and at 45 days post mating.
6. Backfat thickness (using ultrasound, Scanmatic SM-1 Backfat Medimatic, Denmark) was measured while weighing weekly after the gilts reached 90 kg or at puberty onset, whichever came first. Backfat thickness (mm) was expressed as the average of four measurements, two taken above the last rib and two taken 20 cm in front of the tail (about 4 cm to the left and right hand side of the midline at each location).

Reproductive Performance and Responses

The following were observed and monitored as indicators of responses to thermal environments and lysine supplementation affecting reproductive performance.

1. The duration of first and second proestrus (days), was the period from when the vulva began reddening and swelling until when the gilts first showed the

characteristic of standing heat reflex (SHR) in the presence of a boar and /or to the back pressure test. Gilts were checked twice daily at approximately 0630 h and 1600h for SHR once signs of proestrus were noted.

2. Puberty onset was defined as the first SHR (estrus).
3. Duration of the first and second estrus was determined as the time period during which the gilt stood for the boar and/or for back pressure. The first day of estrus was taken as day zero of the cycle.
4. Ovulation rate at first estrus (OR1) was represented by the number of corpora lutea (CL) counted at laparotomy of selected gilts between days 8 and 10 after pubertal estrus. First ovulation rate data were obtained within each treatment for every second gilt reaching puberty in each treatment; a total of 24 gilts.

For laparotomy pigs were given 3 to 4 ml Atravet - Acepromazine maleate (Ayerst Lab.Montreal) intramuscularly(im), as a tranquilizer, and 10 to 15 minutes later laparotomy was performed under general anaesthesia maintained with 8 to 12 ml Ketamine hydrochloride (to effect) (Ayerst Lab. Montreal Can) given intravenously through an ear vein. Ten ml 2% Lidocaine hydrochoride im.(M Pharmaceuticals Cambridge, Ontario) was used as a local anaesthetic. Using aseptic procedures the ovaries were exteriorized and inspected. The gross appearance was appraised and the number of corpora lutea were counted. After surgery, 5 ml of penicillin (Derapen Ayerst Lab. Montreal Can) was injected im into each gilt before being returned to its room. Each gilt remained overnight (20 hrs) in the hallway within the room and was returned to its pen the next morning after regaining full consciousness and

mobility.

5. Pregnancy rates were determined as the number of gilts pregnant at 45 days post-mating from the total gilts bred in each treatment group. The gilts were slaughtered between days 42 and 47 (mean 44.18 ± 1.47) post-mating at a local slaughter house. Reproductive tracts were removed and stored overnight at 5°C then examined macroscopically the next day (within 24 to 30 hrs of slaughter).
6. Ovaries were weighed keeping left and right identified separately.
7. Ovulation rate at second estrus (OR2) was determined from CL counts from the 44 animals that completed the trial and were slaughtered.
8. Uterine weight, was determined by trimming each uterus at about 5 cm from the uterine horns towards the cervix and weighed with and without fetuses. Fetuses were removed from left and right uterine horn, counted, appraised for potential viability and measured for normal growth and development.
9. Fetal number was the number of fetuses surviving at day 45 post-mating.
10. Fetal survival rate was defined as the number of apparently viable fetuses divided by the number of corpora lutea from the second estrus (day 45 post-mating) expressed as a percent.
11. Fetal mortality was determined as the number of CL less the number of apparently viable fetuses at 45 days of pregnancy, expressed as % of the number of CL.
12 Fetal development was determined by measuring fetal weight and fetal crown-rump length (CRL). The crown-rump lengths were measured while fetuses lay

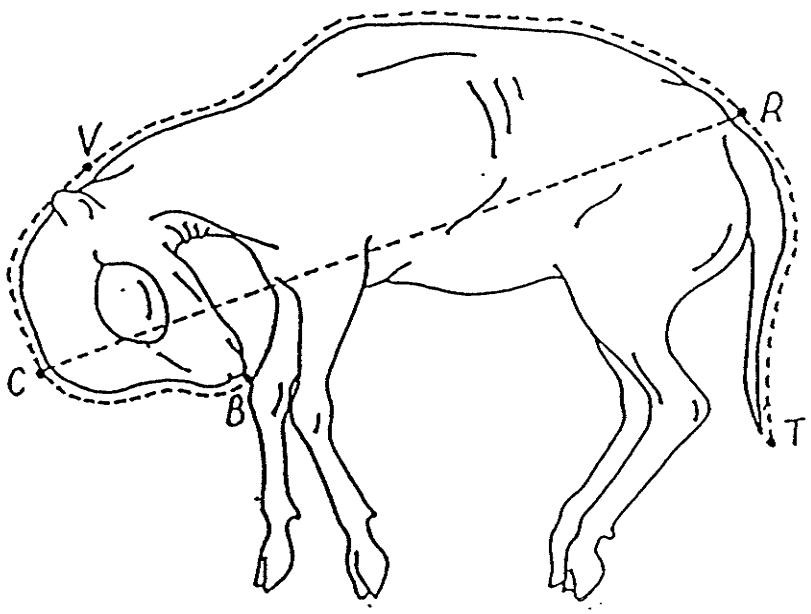

Fig 1. Diagram to illustrate measurement used for estimation of growth rate and age of mammalian fetuses
C-R Crown-Rump length
CVR Curved Crown-Rump length
VR Vertebral Column length
VRT Vertebral Column and Tail length
BCVRT Total length
(Adapted from Harvey, 1959)

in a prone position within the intact amnion. If the amnion ruptured, the fetus was suspended in the fluid in a position approximating that of an embryo within the amnion. The CRL was defined as the length of a straight line that began at the tailhead and ended when it cut the profile of the head after passing directly below the eye (Harvey, 1959; Noden and de Lahunta, 1985) as shown in Figure 1. Fetal wet weight was measured individually after removing the fetus from the amnionic sac.

Blood Sampling and Saliva Collection and Analyses

Progesterone (P4) and cortisol concentrations, were determined for each gilt in a single blood sample taken at laparotomy on day 8 to 10 post-puberty and at day 45 postmating. The first blood samples for progesterone and cortisol determination were taken via ear vein while the gilts were anaesthetized for laparotomy. This first progesterone ($P4^1$) determination represented mid-luteal P4 concentration and was to determine if it had any relationship to ovulation rate. At day 45 post-mating (from day 42 to 47), 45 animals were blood sampled for the second progesterone ($P4^2$) determination.

These P4 concentrations were taken to determine if there was any detectable treatment effect and to determine if there was a relationship between $P4^2$ and fetal survival (number of embryos or fetuses/CL). The 8 to 10 ml blood samples for the second progesterone ($P4^2$) concentration determination were taken from the ear vein

of each pig, just before being weighed and shipped to the slaughter plant.

The cortisol determination was taken as a potential indicator of the degree of stress experienced by the pigs kept under circumstances of high ambient temperature in this study. Blood serum and saliva cortisol measurements were taken to determine if any relationship exists between the two sources of cortisol in young pigs. Originally, saliva samples were to be taken from conscious pigs later in this study, but this did not materialize. Earlier studies indicated that there were significant and positive correlations between blood and saliva cortisol in humans (Riad-Fahmy *et al.* 1979; Vining *et al,* 1983; Tunn *et al.*, 1992) and ruminants (Fell and Shutt, 1986).

Blood was drawn through the ear vein once (8-10 ml from each pig) at laparotomy. At the same time saliva was collected directly into dry and clean tubes (8 to 10 ml per pig). Blood and saliva samples were then left over night at 5°C and were centrifuged on the next day for 15 minutes at 2000 rpm at 5°C. The serum and saliva supernatant were stored at -20°C until assayed.

Hormone Assays.

Progesterone concentrations and cortisol concentrations in serum and saliva were determined by competitive solid phase radioimmunoassay (RIA) using Coat-a-Count kits (Diagnostic Products Corporation (DPC) Los Angeles, Ca.).

For the P4 assay using a kit DPC TKPG2 No.892, the unknown sample,i.e 100 μl of serum, was incubated with 1.0 ml of (^{125}I) labelled progesterone in tubes coated

with antiprogesterone antibodies for 3 hr at room temperature. After aspirating the liquid from each tube, the radioactivity in each tube was counted for 1 minute in a gamma counter (LKB Wallac 1282 Compu Gamma Universal Gamma counter). The concentration of unknown samples were computed from a standard curve (linear-log transformation). The standards for progesterone calibration used were in the concentration ranging from 0.1 - 40 ng/ml. The intrassay coefficient of variation (cv) was 2.28 % at a mean concentration of P4[1] 35.66± 7.86 ng /ml and an intraassay cv of 9.09% at a mean concentration 20.14 ± 5.73 ng/ml. The sensitivity of this procedure according to the supplier was 0.03 ng/ml.

For the cortisol, the procedure was similar to P4 using kit number DPC TKC01 No.690. The unknown samples of 25 μl of serum or 200 μl of saliva were incubated for 45 minutes at 37°C for serum and 5 hours at room temperature for saliva with (^{125}I) labelled cortisol in tubes coated with anticortisol antibodies. After aspirating the liquid from each tube, the radioactivity in each tube was counted in a gamma counter (LKB Wallac 1282 Compu Gamma Counter). The concentrations of cortisol in the unknown samples were computed from the standard curve (linear log transformation). Cortisol standard for serum ranged from 1 - 50 ng/ml and for saliva from 0.1- 5 ng/ml. Intra assay cv was 8.96% for serum cortisol at a mean concentration 16.76±3.1 ng/ml and 2.87% for saliva cortisol at a mean concentration of 3.11±1.5 ng/ml. The sensitivity of this assay according to the supplier was approximately 0.02 ng/ml.

Statistical Analysis

Statistical analysis for the physiological and biological responses parameters (respiratory rate, feed intake, and water usage) were analyzed using stepwise regression to predict the pattern of response to treatments (SAS, 1985). No significant patterns were observed, in response to treatment, for rectal temperature and body weight gain. Therefore, analysis was performed on individual animal means within each growth phase. Means were analysed using a split plot design, the main plot being a completely randomized block design with time of the day as a sub plot. Room, feed and litter effects were tested using room by feed by litter as the error term. All values were expressed as least square means $\pm$ standard error.

Backfat thickness at puberty and reproductive performance parameters such as weight and age at puberty, which were measured once, were analyzed as a randomized complete block design. Correlation analysis was performed to find the relationship between backfat thickness and reproductive performance. General information on the behaviours observed will be discussed but no statistical analysis was performed.

Reproductive performance parameters were analyzed using a randomized complete block design, with litter (gilt's litter) as blocking factors. Fetal weight and length (CRL) were analyzed by using the day of gestation as a covariate. As there was no significant effect of laparotomy on any traits, data from laparotomized and non laparotomized animals were pooled for analyses. Hormonal concentrations were analyzed as a randomized complete block design.

RESULTS

Daily ambient minimum (night temperature) and maximum (day time temperature) room temperatures were recorded over the entire experimental period in the two rooms. The ambient room temperatures are plotted in Figures 2 and 3. Day 1 on the plot represents the first day of the experimental period, 24th of September 1992 while day 164 represents the last day of the experimental period, the 6th of March 1993. Days 1 to 5 represent the grower phase; days 6 to 61 represent the finisher phase; days 62 to 164 represent the adult phase. The above classification of phases was based on the animals' body weight and was in accordance with the NRC 1988 reference for the ration classifications.

Room A, was the control room with the thermostat set at 20°C for the entire experimental period. After the initial 6 days of increasing temperature, room B, which was the hot room had the thermostat set at 26°C during the night (1800 h to 0600 h) and 32°C during day time (0600 h to 1800 h). The temperature in both rooms was kept as close as possible to what was scheduled. However, due to some circuit and system adjustment in the new research unit there was more variation than planned. Although humidity in both rooms was not controlled, it was recorded in each room and ranged from 23 to 74% in room A and 32 to 84% in room B. The higher humidities were associated with or were the result of the daily washdown of pens.

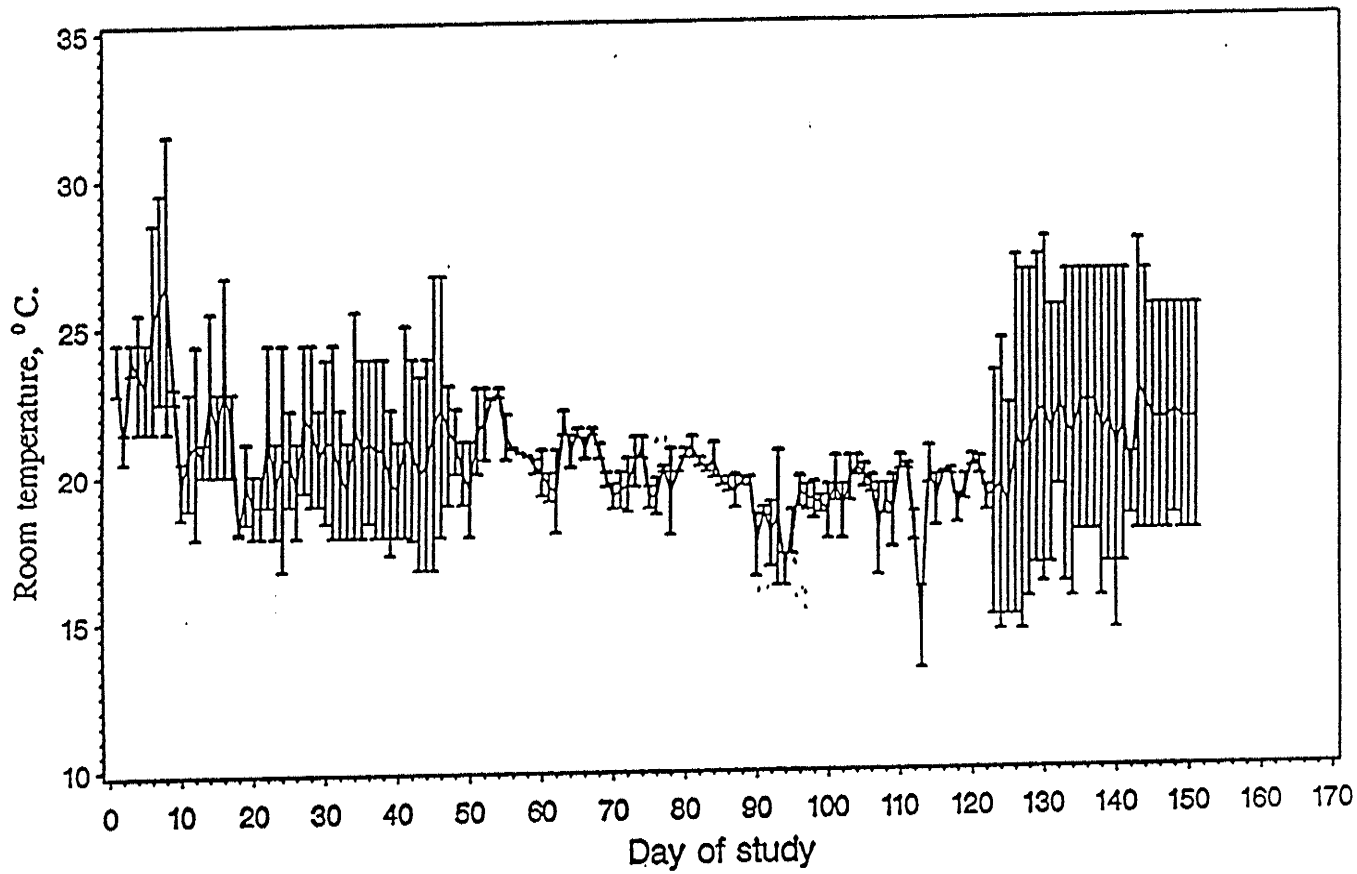

Figure 2. Daily minimum and maximum ambient temperatures in room A (Control). The thermostat was set at 20° C. The light and dark ratio was 12 L : 12D throughout the study period.

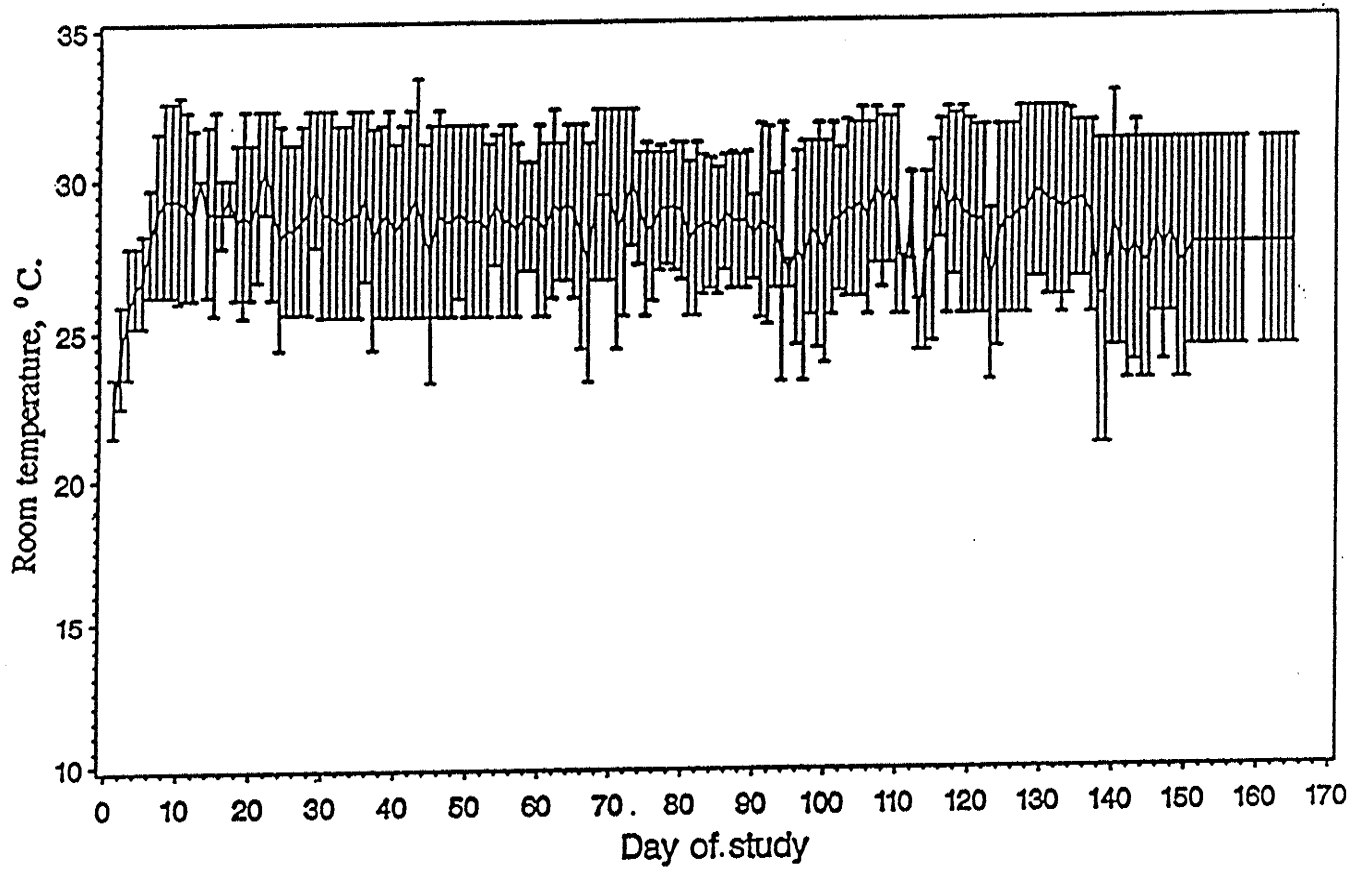

Figure 3. Daily minimum and maximum ambient temperatures in room B (Hot) Room temperature started at 20° C and was increased by 2° C each day and 1 ° C each night for the first six days. The final thermostat setting was then 32° C for 12 h and 26° C for 12 h from day 7 to day 164. The light and dark ratio was 12 L:12 D throughout the study period.

The recorded mean, standard deviation (SD) and ranges of the night and day temperatures are shown in Table 3

Of the 48 animals used, 45 animals completed the experiment. The three pigs not finishing were from room B. Two pigs died, one before the onset of puberty (from room B, LYS) due to an infection associated with an abscess in its leg and the other one shortly after the onset of puberty (room B, REG), from unknown causes. One pig (from room B, LYS) was removed from the data set for not reaching puberty by the cut-off age of 210 days. As well, one pig from room B (REG) had no indicators of ovulation at laparotomy on day 10 following observed estrus, and was removed from the data set for first ovulation rate and $P4^1$ statistical analysis.

From the 45 animals that completed the trial, two pigs from Room A (REG) were not pregnant by day 45 of gestation. One of these pigs, found to have only one uterine horn and one ovary, did not display a strong standing estrus and did not accept boar mounting. That pig required a crate for its mating. In addition, due to loss of an ovary at the slaughter plant, one pig from Room B (LYS) was excluded from the data set for statistical analysis to determine the second ovulation rate (OR2) and the fetal survival rate.

Most of the laparotomized pigs recovered from surgery within 3 to 5 days but three pigs had to have their incision resutured. The resutured pigs took 5 to 7 days to recover. Those that recovered within a few days cycled approximately 22 days after the first estrus and those that required re-suturing cycled 24 to 29 days after first estrus.

For all reproductive variables (second estrus, estrous duration, estrous cycle

TABLE 3. Mean ± SD and range of ambient room temperature (^{0} C) in room A (control) and Room B(hot) during the trial.

	Night		Day	
	mean±SD	range	mean±SD	range
Room A:				
Day<45	18.9 ± 1.8	16.7 - 23.5	23.7 ± 2.5	18.0 - 31.5
Day 45-120	19.2 ± 1.6	13.2 - 22.9	20.4 ± 1.4	16.0 - 26.7
Day> 120	16.9 ± 1.5	14.5 - 19.8	25.5 ± 2.1	19.4 - 27.8
Room B:				
Day<45	25.8 ± 1.5	21.5 - 30.0	31.2 ± 1.9	23.5 - 33.3
Day 45-120	25.9 ± 1.0	23.3- 28.0	31.2 ± 1.1	26.0 - 32.2
Day>120	24.6 ± 1.3	21.1 - 26.7	31.4 ± 0.6	28.9 - 32.7

length, ovulation rate, fetal number and survival rate), laparotomy did not have any significant effect (Appendix Table 1). Therefore the data from both laparotomized and non laparotomized were pooled for the analysis of variance and treatment comparison.

Rectal Temperature

Adaptation Period

Adaptation period is the period for which the ambient temperature in room B was increased gradually by 2^0 C during day time and 1^0 C at night for the first six days of the trial and another eight-day period for the pigs to adjust to that treatment temperature. In order to determine how pigs may have adapted to ambient temperature a separate analysis of the initial 14 days was performed. It was determined that day had a significant ($P<0.05$) effect on RT and therefore the pattern of response over the 14 days was analyzed. There were significant room by time, room by feed and also feed by time of measurement interactions for RT observed in response to diurnal ambient temperature and lysine supplementation during the adaptation period. The interactions between room temperature by time of measurement are shown in Figure 4. In room A, no significant pattern of response was seen in the morning (AM); that is RT (analysed as mean rectal temperature, RTM) remained relatively constant at 39.75 ± 0.01 ^{0} C, while the afternoon rectal temperature (PM RT), which was initially high (0.19^0 C higher than AM RT) , decreased in a quadratic fashion over the 14 day adaptation period

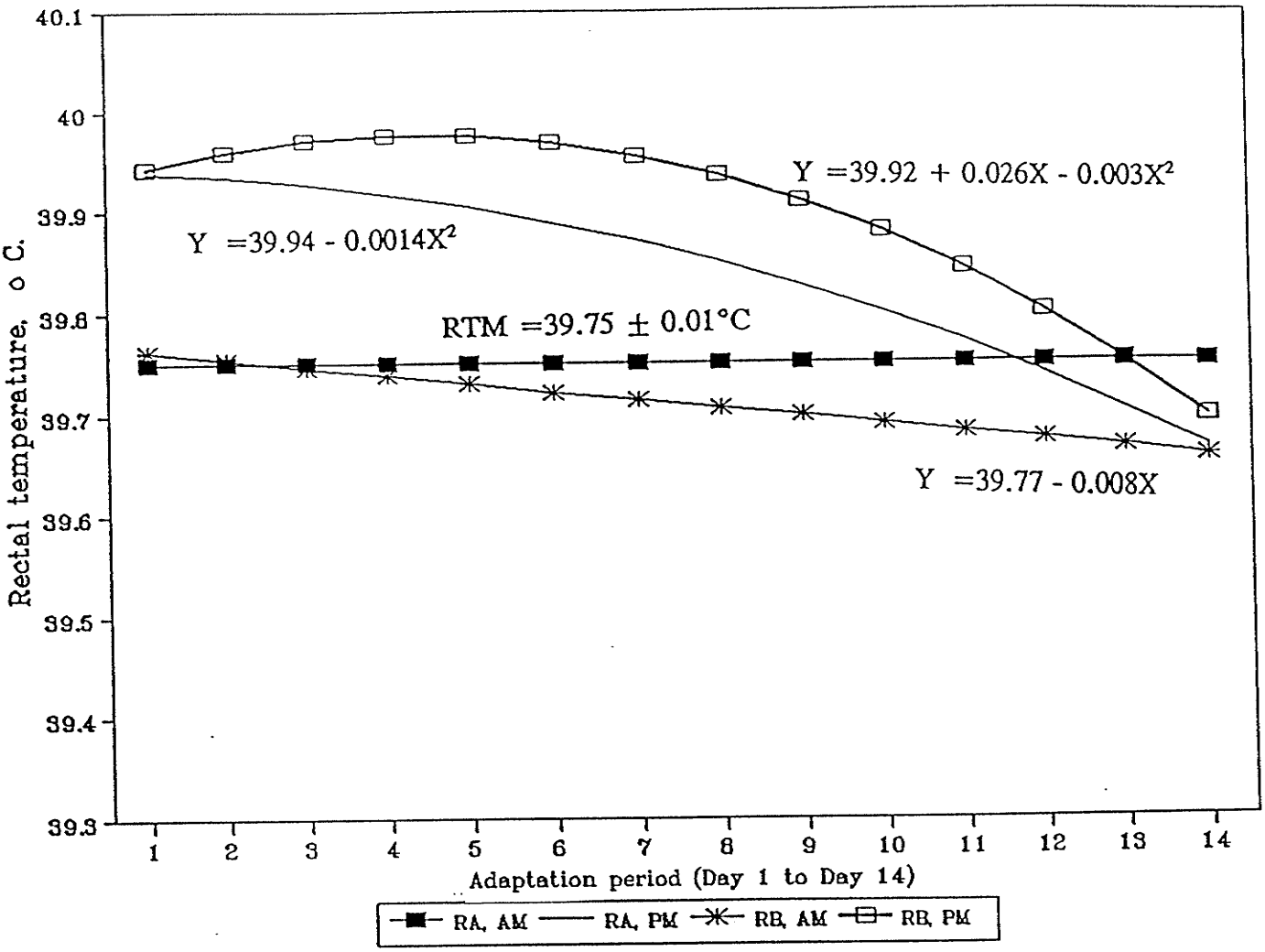

Figure 4. Pattern of response for rectal temperature of gilts in each room (RA,RB) and time of measurement (AM,PM) during the adaptation period (day 1 to day 14). Pattern was generated from stepwise regression procedure.

(39.94 - $0.0014X^2$). However, in room B, there was a linear decrease in AM RT over the 14 day adaptation period (39.77 - 0.008X). As with room A, room B PM RT was initially higher than the AM temperature. There was both linear and quadratic components to the pattern of response for room B PM RT (39.92 + 0.026 X - $0.003X^2$). That is the PM RT gradually increased until day 4 of the trial and then decreased over the rest of the period.

There was also a significant ($P<0.05$) interaction between ambient room temperature and lysine supplementation for RT (Figure 5). Pigs in RA, REG diet had lower initial RT than all other pigs. For RA, pigs on REG diet showed a linear (39.8 - 0.006X) decrease in RT over the 14 day period. However, the pigs on the lysine supplemented diet in RA showed an initial increase in RT then a more rapid decrease (39.86+0.02X - $0.0025X^2$). For room B, RT decreased in a quadratic manner for both the LYS and REG diet, but this decrease was more pronounced for pigs on the REG diet.

The significant interaction between feed and time on RT is plotted on Figure 6. There was no pattern of response observed for morning measurement for pigs fed additional dietary lysine (AM RT LYS) with RT remaining relatively constant at 39.75 $\pm 0.01^0$ C. The PM RT LYS was relatively high (initially 0.25^0C higher than the AM RT) then decreased in a quadratic manner over the adaptation period (40.0085 - $0.0014X^2$). For pigs with REG diet, both AM and PM, the pattern of response had both linear and quadratic components. The AM RT REG decreased over the first nine days and then gradually increased (39.82 - 0.03X + $0.016X^2$), while for PM RT REG it was

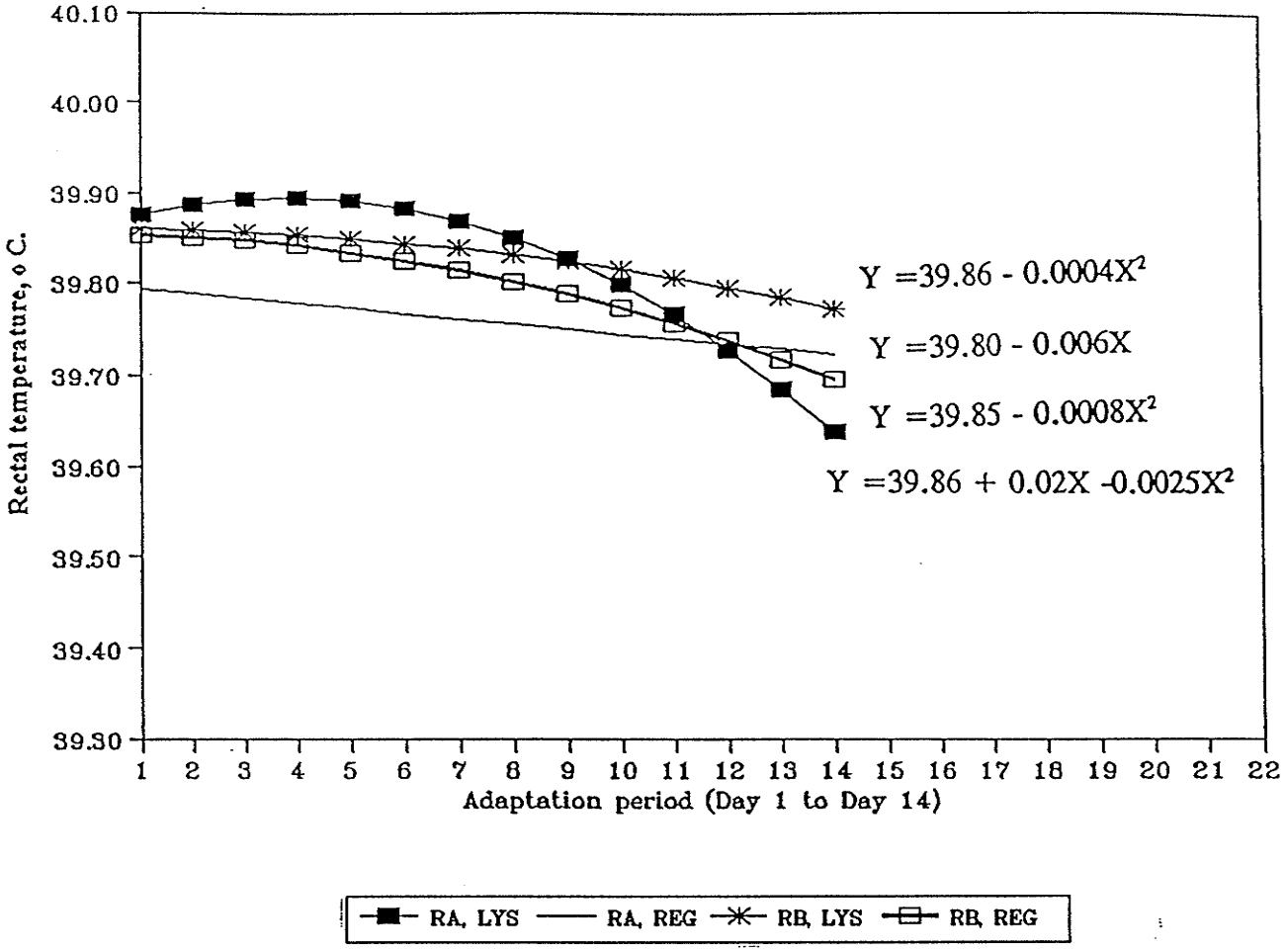

Figure 5. Pattern of response for rectal temperature of gilts in each room (RA,RB) and on each feed (REG, LYS) during the adaptation period (day 1 to day 14). Pattern was generated from stepwise regression procedure.

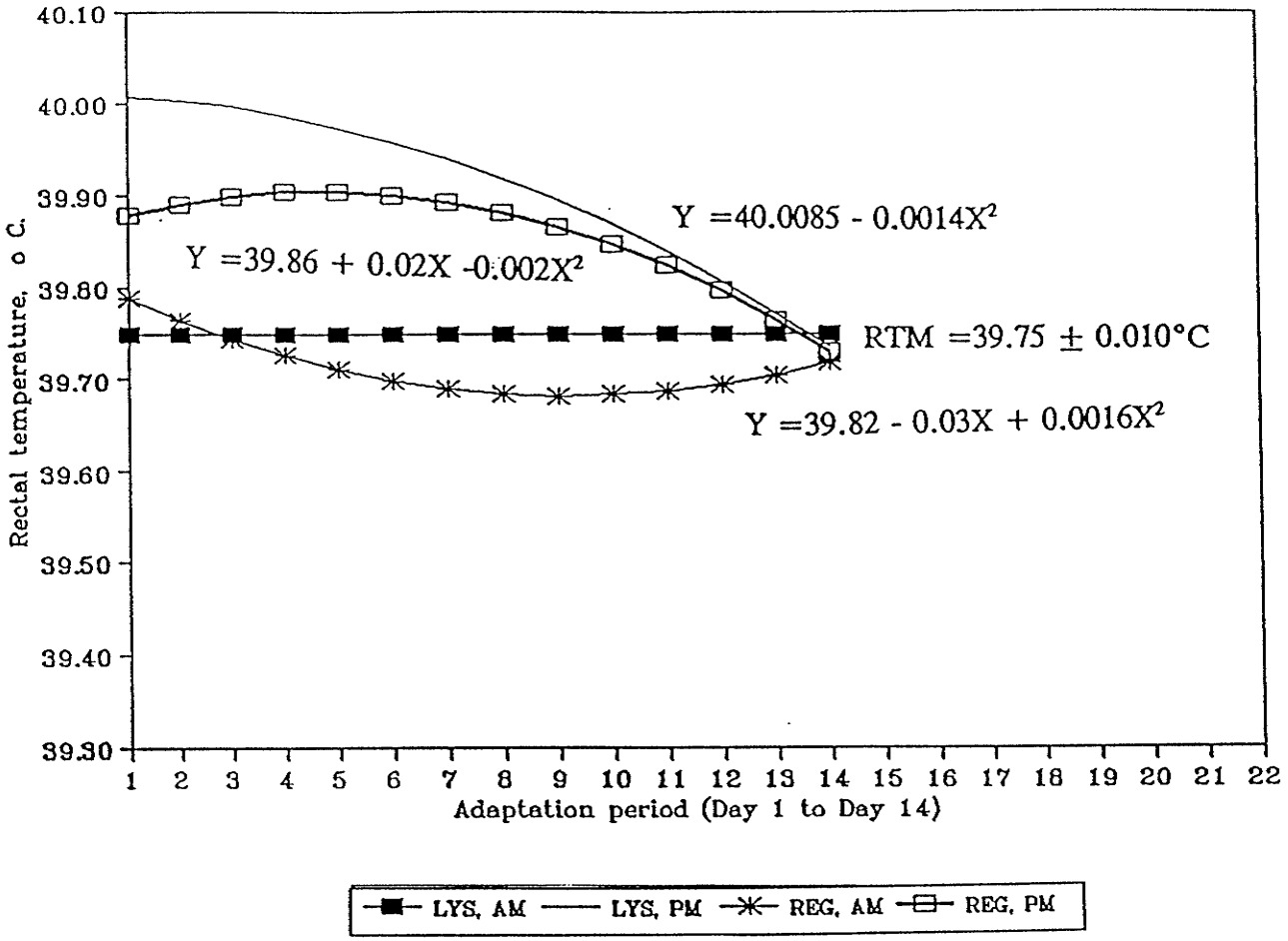

Figure 6. Pattern of response for rectal temperature of gilts on each feed (REG, LYS) and time of measurement (AM,PM) during the adaptation period (day1 to day 14). Pattern of response was generated from stepwise regression procedure.

slightly increased for the first 5 days then decreased until the end of adaptation period ($39.86 + 0.02X - 0.002X^2$).

There was a positive and significant correlation between ambient room temperature and rectal temperature, ($r=0.13$, $P<0.001$ for morning ambient temperature; $r= 0.13$, $P<0.001$ for afternoon ambient temperature) in RA and a negative and significant correlation was found in RB($r=-0.15$, $P<0.001$ for morning ambient temperature; $r=-0.13$, $P=0.001$ for afternoon temperature). As shown in Figure 5 the RT of pigs in RB were initially high then decreased gradually over the adaptation period an indication that the pigs adjusted to the changes in ambient temperature and were able to maintain normal body temperature.

Grower Phase

As the grower phase was part of the adaptation period , the pattern of response can be seen during the first five days of that period.

Finisher Phase

The first eight days of the finisher phase were in the adaptation period but all days were included in the analyses for this phase. There was no significant ($P>0.05$) effect of ambient temperature or dietary lysine on the RTM during the finisher phase. However, there was a significant ($P<0.01$) effect of time of day on RTM ($39.6 \pm$

0.009 vs 39.7 $\pm$ 0.009 °C for AM vs PM), and a significant ($P=0.001$) time by ambient temperature interaction for RTM (39.62 $\pm$ 0.013 vs 39.65 $\pm$ 0.013 °C for AM vs PM in RA and 39.57 $\pm$ 0.013 vs 39.78 $\pm$ 0.013 for AM vs PM in RB). The difference between the AM and PM RT was more pronounced in RB than RA. It should be noted that this was not just the result of a higher PM rectal temperature but also a lower AM rectal temperature for RB than for RA.

Adult Phase

In the adult phase, since two gilts died before the end of the experiment, the value of RTM, RTSD and RTRANGE was adjusted for this phase by deleting the litter mates of the two dead pigs in order to correct for litter effects. There were no significant effects of ambient temperature, supplemental lysine nor any interaction of the two treatments. The results show that RTM was significantly affected by the time of measurement ($P<0.05$, 39.00 $\pm$ 0.015 vs 39.20 $\pm$ 0.015 for AM vs PM respectively). However, RTSD and RTRANGE were not affected by any of the factors tested (Table 4).

Mean rectal temperature (RTM), standard deviation of the mean rectal temperature (RTSD) and the range of the mean rectal temperature (RTRANGE) of morning and afternoon for the three phases of the trial are shown in Table 4. Ambient temperature and lysine supplementation had no significant effect on the RTM, RTSD or RTRANGE ($P>0.05$). However, time of measurement significantly ($P<0.001$) affected

TABLE 4. Mean (RTM), standard deviation (RTSD) and range (RTRANGE) of rectal temperature of gilts as effected by ambient temperature and dietary lysine supplementation. Values are least square means±se.

Room			A(Control)		B (Hot)		SE
Feed		T	REG	LYS	REG	LYS	
RTM	GROWER	AM	39.75	39.77	39.77	39.73	0.021
		PM	39.81	40.00	39.91	39.94	0.021
	FINISHER	AM	39.61	39.64	39.56	39.59	0.019
		PM	39.65	39.66	39.74	39.83	0.019
	ADULT	AM	38.98	39.01	39.03	39.05	0.030
		PM	39.14	39.16	39.16	39.27	0.030
RTSD	GROWER	AM	0.22	0.21	0.16	0.18	0.023
		PM	0.13	0.18	0.14	0.17	0.023
	FINISHER	AM	0.26	0.25	0.25	0.25	0.023
		PM	0.26	0.29	0.25	0.27	0.023
	ADULT	AM	0.29	0.25	0.26	0.28	0.022
		PM	0.30	0.27	0.28	0.25	0.022
RTRANGE	GROWER	AM	0.54	0.53	0.41	0.45	0.058
		PM	0.34	0.46	0.36	0.42	0.058
	FINISHER	AM	1.025	0.89	0.85	0.92	0.097
		PM	0.90	1.04	0.88	0.99	0.097
	ADULT	AM	0.82	0.80	0.74	0.79	0.066
		PM	0.74	0.70	0.72	0.63	0.066

Room A: 20^0 C Room B: 32^0 C (12h) : 26^0 C (12h). T=Time; REG=Standard Lysine ; LYS= 50% above standard lysine..

mean rectal temperature over the three phases. Morning RTM was significantly lower than the afternoon RTM for all treatment groups. The correlations between room temperature and rectal temperature for the entire study period were positive at $r=0.29$ and $r=0.48$ in RA for morning and afternoon measurement respectively, but were negatively correlated in RB at $r=-.20$ for both morning and afternoon measurement.

Respiration Rates

Adaptation Period

There was a significant ($P<0.05$) effect of day on RR, therefore the pattern of response was investigated. The pattern of response for RR during the adaptation period was significantly ($P<0.05$) affected by ambient temperature, time, and a significant ($P<0.05$) ambient temperature by time interaction. In RA, RR decreased in a quadratic fashion throughout the adaptation period ($30.5- 0.018X^2$) (Figure 7) . Initial RR in RB was higher than RA and continued to increase until day 9 of the trial. From day 9 to day 14 there was a slight decrease in RR.

Time of measurement affected the pigs' response. The RR pattern in the morning and afternoon are shown in Figure 8. While PM RR remained relatively constant at 43.3 $\pm$0.24 breaths min^{-1} , AM RR actually increased until day 9 and then leveled off.

In room A, AM RR was constant throughout the adaptation period (28.55 ± 0.34 breaths min^{-1}), while the PM RR, which was initially high, decreased in a linear fashion

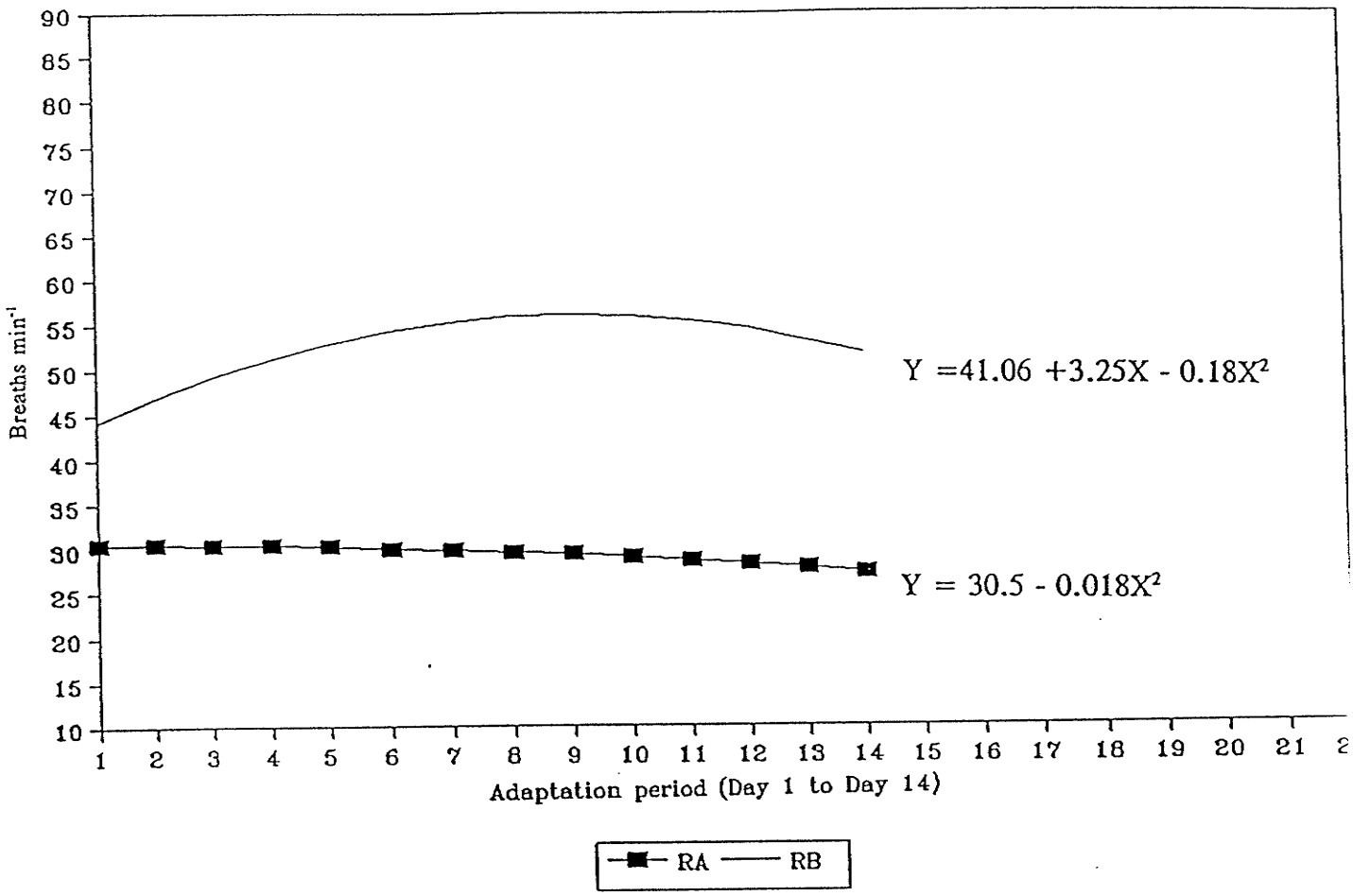

Figure 7. Pattern of response for respiration rate of gilts in each room (RA,RB) during the adaptation period (day 1 to day 14). Pattern was generated from stepwise regression procedure.

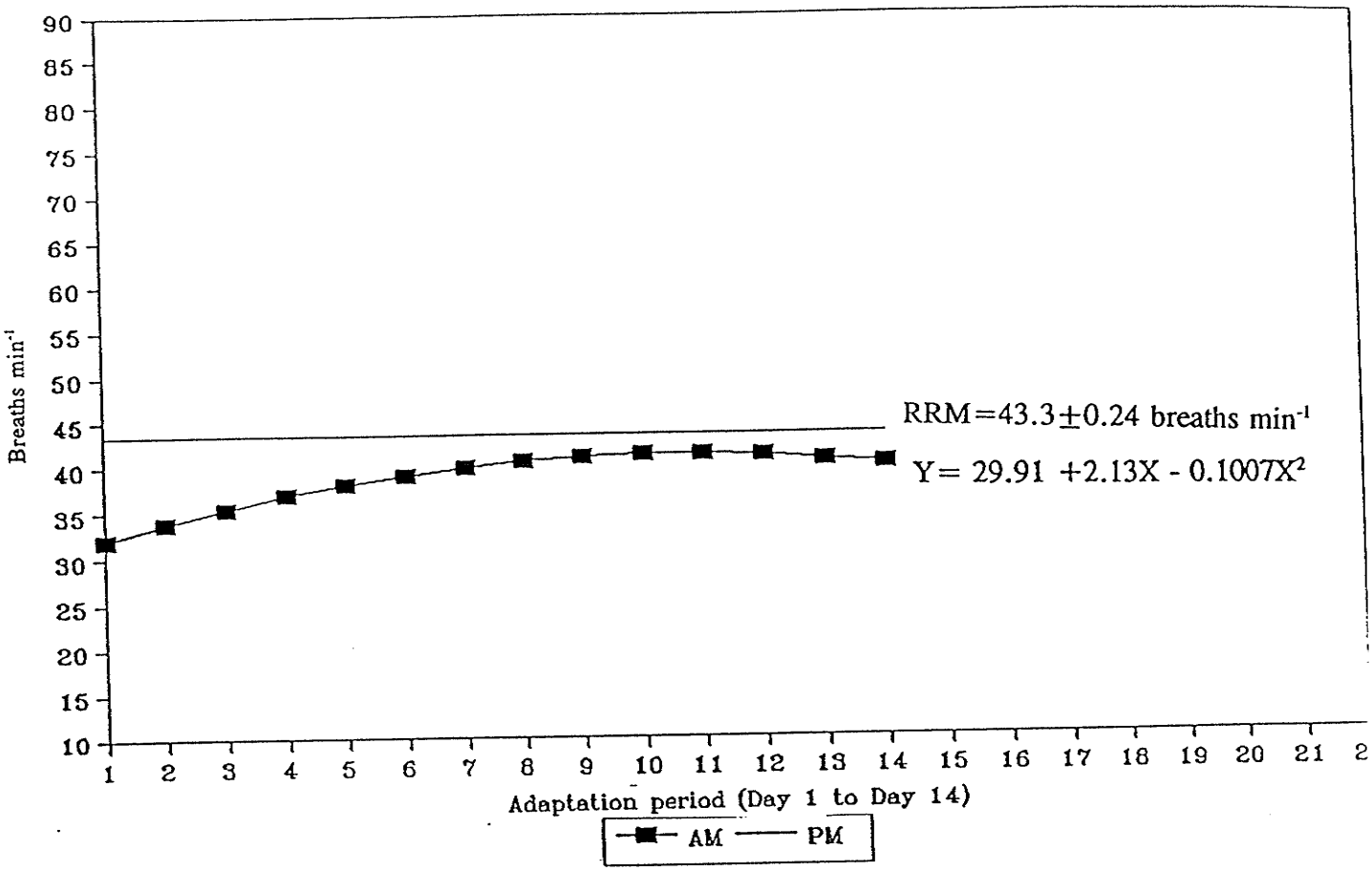

Figure 8. Pattern of response for respiration rate of gilts at each time of measurement (AM, PM) during the adaptation period (day 1 to day 14). Pattern was generated from stepwise regression procedure.

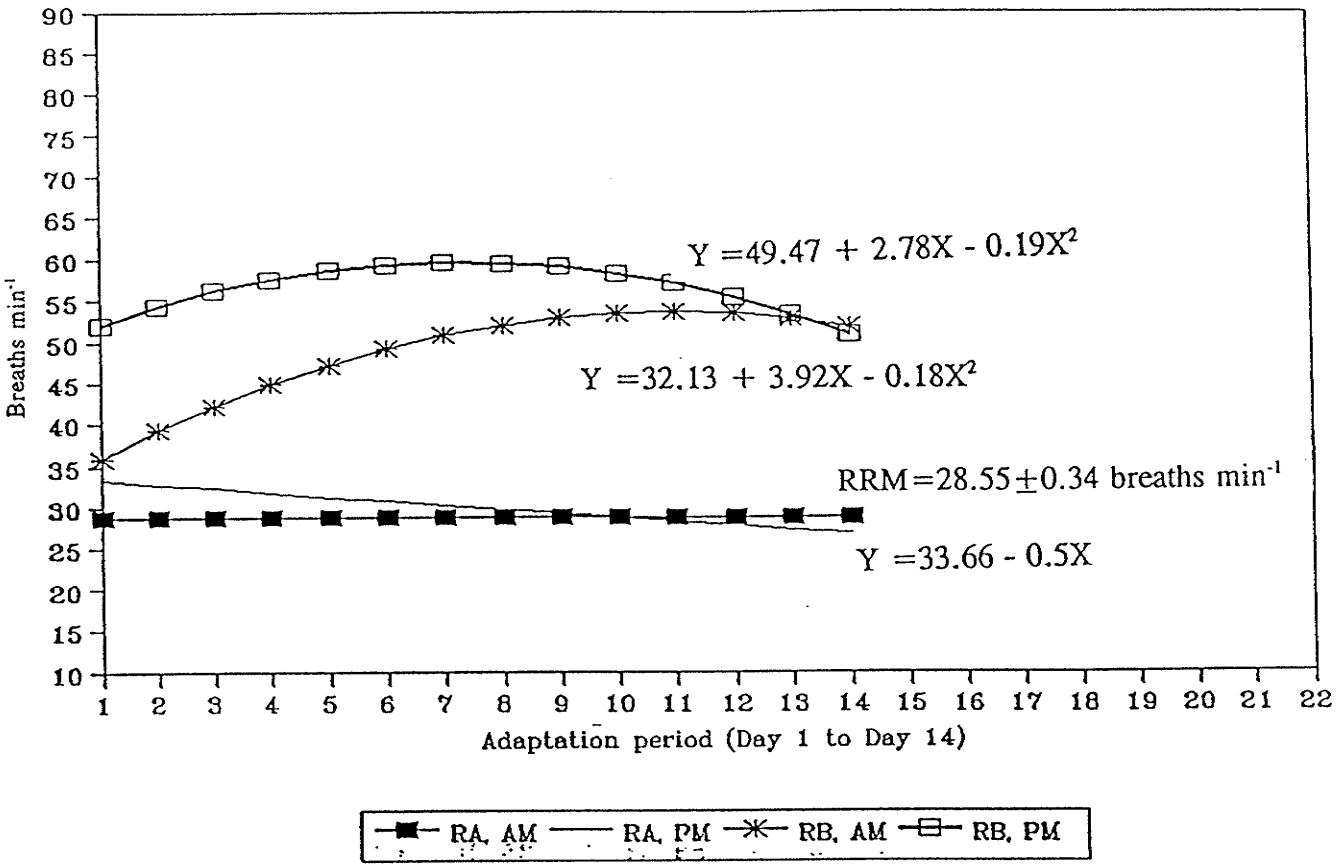

Figure 9. Pattern of response for respiration rate of gilts in each room (RA,RB) and time of measurement (AM,PM) during the adaptation period (day 1 to day 14). Pattern was generated from stepwise regression procedure.

(33.66 - 0.5X) so that by day 14 there was very little difference between AM and PM measurements (Figure 9). In RB, AM RR increased throughout the adaptation period until day 12 then leveled off ($32.13+3.92X - 0.18X^2$) , while the PM RR, which was high initially, continued to increase to day 9 of adaptation period and then decreased ($49.47 +2.78X-0.19X^2$), (Figure 9). As with RA, by day 14, RB AM and PM RR were similar.

Plots of predicted RR throughout the trial are shown in Figure 10. For RA, RR decreased in a quadratic manner, while in RB, AM RR increased until around day 60 of the trial for AM and then decreased slightly over the rest of the trial. For RB, PM RR peaked at day 50 of the trial and then decreased gradually towards the end of the trial, until almost no difference was seen between AM and PM RR.

The coefficient of correlation between room temperature and RR was 0.36 for both morning and afternoon measurements in RA, and were $r=0.18$ and $r=0.30$ for morning and afternoon measurements, respectively in RB.

Feed Intake

Plots of feed intake (VFI) assessed over three phases against the days of the trial are shown in Figure 11. Ambient room temperature or supplemental lysine had no effect on feed intake for the entire study period in all treatment groups ($P>0.05$). However, VFI was influenced by a significant ($P=0.003$) room ambient temperature by dietary lysine interaction, as shown in Fig 11. In all cases feed intake increased over the

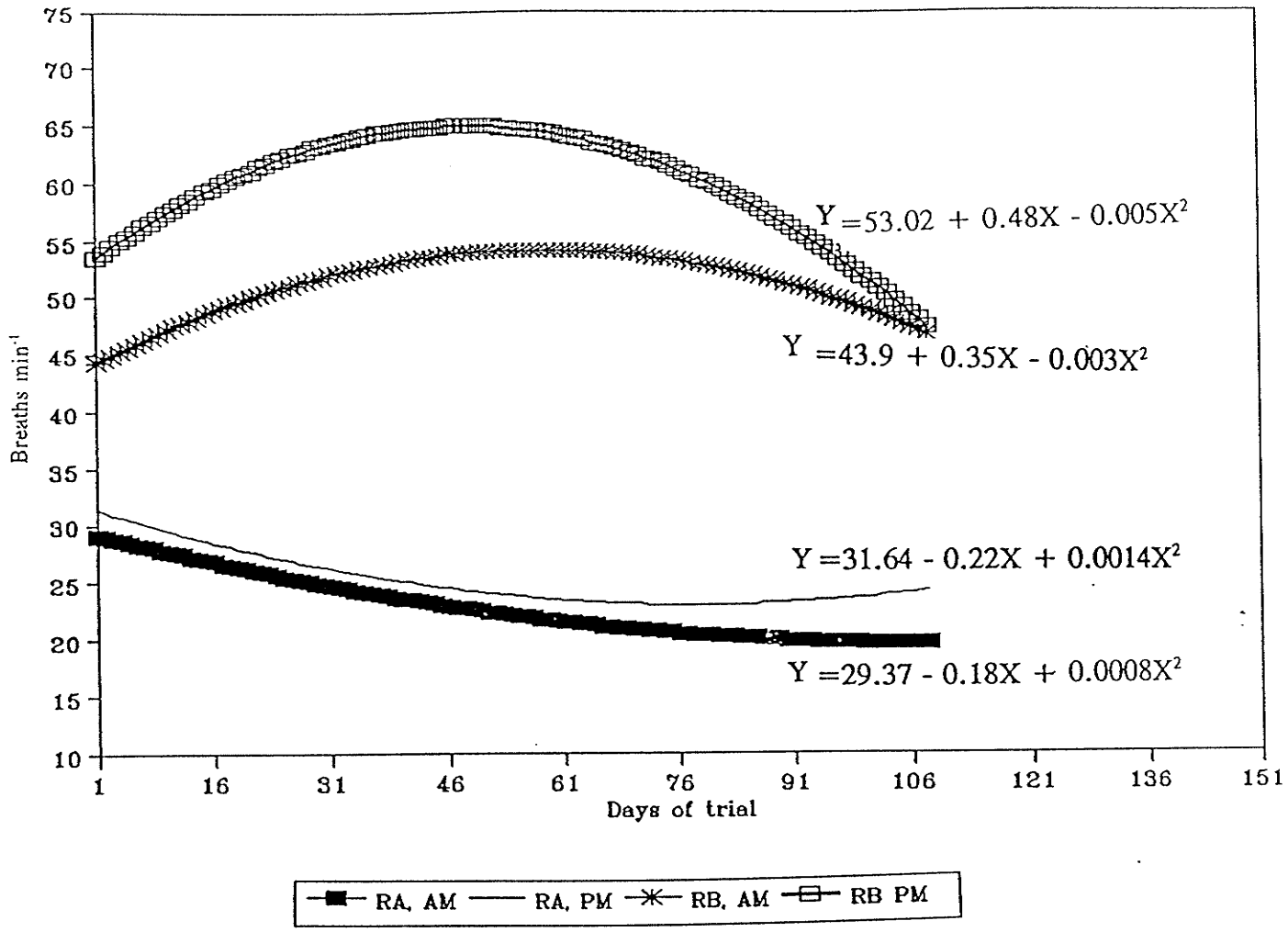

Figure 10. Pattern of response for respiration rate of gilts in each room (RA,RB) and time of measurement (AM,PM) during the trial. Pattern was generated from stepwise regression procedure.

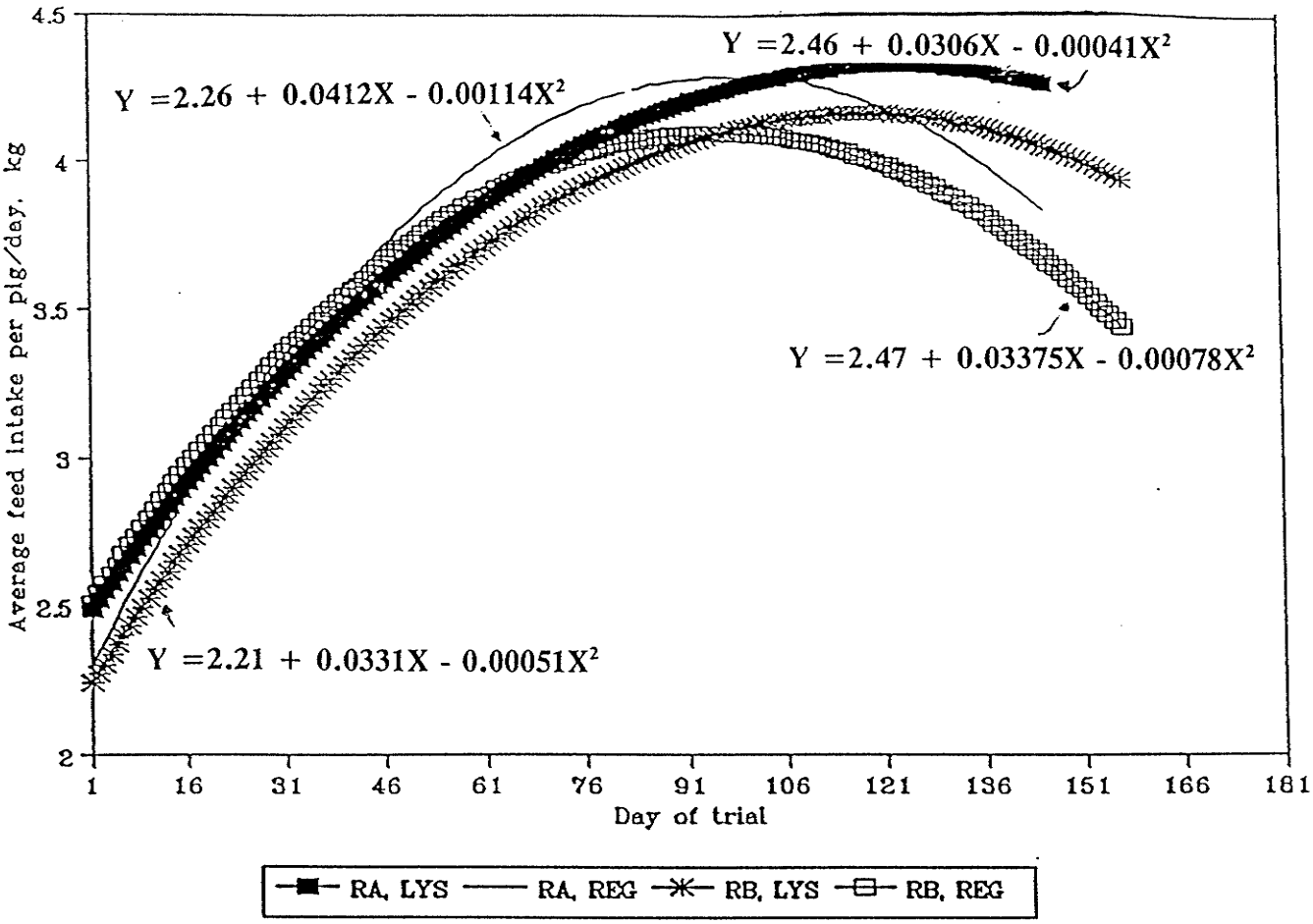

Figure 11. Pattern of response for feed intake of gilts in each room (RA, RB) and on each feed (REG, LYS) during the trial. Pattern was generated from stepwise regression procedure.

trial and then decreased. Maximal feed intake occurred earlier (around day 100) in the pigs with REG diet for both rooms than for the LYS supplemented pigs (around day 120).

Water Usage

Plots of water usage (WU) predicted over all days of the trial are shown in Figure 12. (See also Appendices Figure 3). The first day for WU recording was on day six of the trial. The pattern of response throughout the day of trial differed depending upon the interaction between room ambient temperature and supplemental lysine ($P=0.047$). Figure 12 shows the predicted value of WU. WU increased in a linear fashion for pigs in RA. The magnitude of this increase was greater for REG than for LYS supplemented pigs. In RB, WU for LYS supplemented pigs increased in a quadratic manner throughout the trial. For pigs in room B with REG diet, there was an increase in WU until approximately day 100 at which time the amount of WU started to decline. However, throughout the trial, RB pigs used more water than RA pigs ($P<0.05$).

Body Weight Gain

Ambient room temperature or supplemental lysine had no significant effect on body weight gain during the trial in the three phases, grower finisher and adult phases.(See Appendices Figure 4). However, there was a significant ($P=0.0037$)

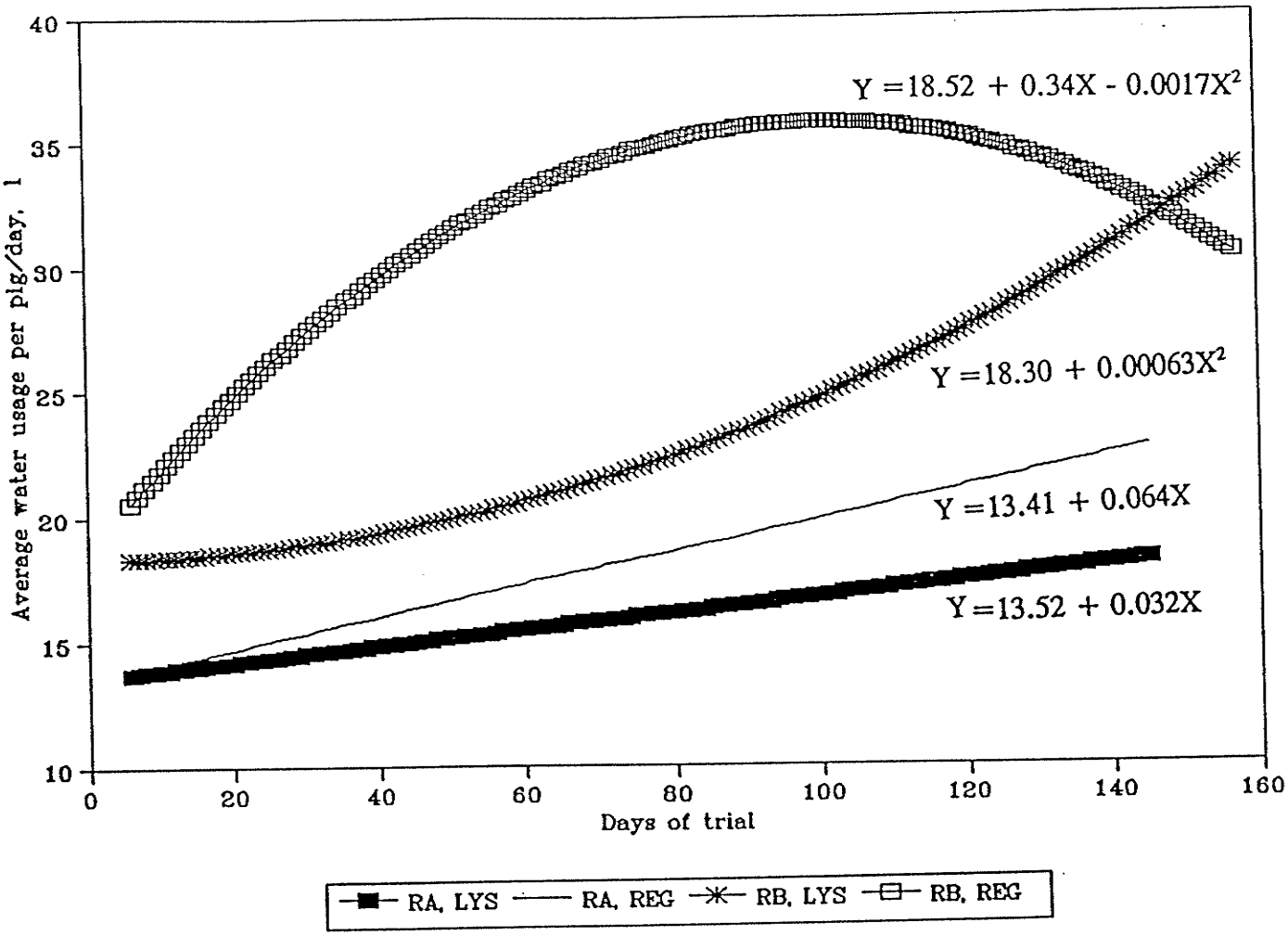

Figure 12.Pattern of response for water usage of gilts in each room (RA,RB) and on each feed (REG,LYS) during the trial. Pattern was generated from stepwise regression procedure.

interaction between ambient room temperature and dietary lysine in the grower phase, during which supplemental LYS increased body weight gain in RA (0.84 $\pm$ 0.07 vs 1.03 $\pm$ 0.07 REG vs LYS, respectively) and decreased weight gain in room B (1.07 $\pm$ 0.07 vs 0.85 $\pm$ 0.07, REG vs LYS, respectively). However, the grower phase lasted for only one week and therefore this may not indicate a true biological response. Body weight gain of pigs during the trial demonstrates that high ambient temperature and lysine supplementation has no effect on body weight gain over the three phases.

Bodyweight gain and feed intake are shown in Table 5.

Feed Efficiency

Feed efficiency for the entire trial was not affected by ambient temperature or dietary lysine or the interaction between ambient temperature and dietary lysine. However there was a significant ($P < 0.05$) effect of week of observation with older animals having a poorer feed efficiency (Table 6).

Reproductive Performance

The effects of high ambient temperature and lysine supplementation on reproductive performance are shown in Table 7 and 8.

TABLE 5. Effect of high ambient temperature and supplemental lysine on weekly feed intake, weekly body weight gain and feed efficiency over the 14 week period. Values are least square means ±SE.

Room	A (CONTROL)		B (HOT)		SE
Feed	REG	LYS	REG	LYS	
Weekly Body weight gain, kg	6.70	6.59	6.74	6.57	0.27
Weekly feed intake, kg	25.37	24.90	24.84	23.65	8.56
Feed efficiency	4.06	4.06	4.06	3.88	0.12

TABLE 6. Effect of ambient temperature and supplemental lysine on feed efficiency. Values are least square means ±SE

Room	A (Control)		B (Hot)		P =		
Feed	REG	LYS	REG	LYS	Rm	Fd	Rm* Fd
Grower	2.2 ± 0.4	1.7 ± 0.4	1.9 ± 0.4	2.3 ± 0.4	0.78	0.99	0.27
Finisher	4.1 ± 0.1	4.1 ± 0.1	4.2 ± 0.1	3.9 ± 0.1	0.97	0.42	0.44
Adult	5.6 ± 0.7	5.6 ± 0.7	5.3 ± 0.7	5.3 ± 0.7	0.72	0.63	0.97

Puberty Onset Characteristics

In RA, puberty onset began on November 3. Throughout the month 18 out of 24 gilts (75%) attained puberty (day 40 to day 66 of the trial) and the remaining six gilts reached puberty by mid December (from day 66 to day 80 of the trial). As a result the duration between the time for the first gilt to attain puberty and the last gilt was 40 days in RA. In RB the first estrus occurred on November 9. Throughout the month 13 out of 24 pigs reached puberty. One gilt died before puberty. Of the remaining ten gilts, 9 gilts attained puberty by December 30 (overall from day 46 to day 96 of the trial). In RB, the duration between when the first and the last gilt attained puberty was 50 days. All but one gilt reached puberty after the cut-off age of 210 days. This one gilt reached puberty at 216 days of age. The age of puberty onset in this study was comparable to age at puberty of crossbred pigs as reported by Burnett and Walker (1988) and (Young *et al.*, 1990)

The total number of gilts reaching puberty by the cut-off date was 24 of 24 in RA and 22 of 23 (one pig died) in RB. The overall average age at puberty in this trial was 171.5 $\pm$ 13 (mean $\pm$ SD) ranging from 147 to 203 days of age. Age at puberty tended to be greater ($P=0.096$) for pigs kept in the hot room (RB) than pigs kept at control temperature (RA),(169.0 $\pm$ 2 d vs 174 $\pm$ 2 d , RA vs RB, respectively). Lysine supplementation had no effect ($P>0.05$) on age at puberty (172 $\pm$ 2 d vs 171 $\pm$ 2 d , REG vs LYS, respectively), nor were there any significant interactions. In RA, two pigs reached puberty before day 150 and 19 of the 24 pigs reached puberty between 151 and 180 days of age. All showed estrus by 190 days of age. In RB, 21 pigs of the

22 pigs reaching puberty did so between 151 and 200 days of age and one pig reached puberty at 203 days of age. In RB, one pig died before puberty and one pig did not attain puberty by 210 days of age and, therefore were excluded from the data set.

Overall average body weight of all pigs at puberty onset was 112.2 ± 13.0 kg (mean ± SD), ranging from 88.4 to 139.6 kg. Neither ambient temperature nor dietary lysine had any significant effect on body weight at puberty (Table 7).

Likewise backfat thickness at puberty was not significantly affected by room temperature or lysine supplementation (Table 7).

Proestrus duration was not significantly affected by room temperature. However, there was a tendency (P=0.09) for lysine supplementation to reduce proestrus duration (3.9 ±0.4 vs 3.0±0.4 d for REG vs LYS respectively). First estrous duration tended to be shorter for pigs in the hot room than those kept in the normal ambient temperature (1.7 ± 0.1 d vs 2.0 ± 0.1 d respectively, P=0.07). Dietary lysine had no effect on the first estrous duration (1.9 ± 0.1 d vs 1.9 ± 0.1 d).

The plan was to laparatomize half of the gilts from each treatment at the mid-luteal phase to determine first ovulation rate, however, two gilts from RB (one died and one did not ovulate) and one gilt from RA (having one uterine horn and one ovary) were removed from the data set. Therefore 21 animals (11 from RA and 10 from RB) were available for statistical analysis. The same set of data were used for P4[1] statistical analysis. High ambient temperature did not affect first ovulation rate. However, there was a trend towards increased ovulation rates with supplementation of lysine (14.9 ± 0.8 vs 12.5 ±0.9 CL, P=0.09, LYS vs REG respectively).

Second Estrus Performance Characteristics

Estrous cycle lengths (Table 7) and number of gilts showing a second estrus (Table 8) were not affected by ambient temperature or dietary lysine supplementation. Estrous cycle length of pigs raised in the two different room temperatures were 22.8 $\pm$ 0.4 d vs 22.4 $\pm$ 0.4 d (RA vs RB). Mean cycle lengths for pigs was 22.6 $\pm$ 0.4 d regardless of lysine supplementation.

Second estrus characteristics are also shown in Table 7. The duration of the second proestrus was similar for all treatment groups. However, pigs kept in the hot room had shorter second estrous duration than pigs kept in the control room (1.4 $\pm$0.2 vs 2.3 $\pm$0.2 d respectively P=0.0002). Lysine supplementation had no effect on either proestrus or estrus duration.

Breeding for pigs in RA began on Nov 25 (day 62 of the trial). Twenty-one pigs from RA were bred throughout December (day 68 to day 98 of the trial). Two remaining gilts were bred by early January 1993 (day 106 of the trial). In RB, 15 pigs were bred between day 68 and day 98 and the rest were bred by January 17, 1993 (day 116 of the trial).

Second ovulation rate as shown in Table 7 and Table 8 (recorded as corpora lutea number) was not affected by any treatments. However, there was a trend for pigs kept under control temperature (RA) to produce more ova at second estrus than pigs kept under hot temperature (14.1 $\pm$ 0.4 vs 13.0 $\pm$ 0.4 respectively, P=0.08). Lysine

TABLE 7. Effect of high ambient temperature and lysine supplementation on reproductive performance in gilts. Values are least square means ± se.

Room	A (Control)		B (Hot)		P=		
Feed	REG	LYS	REG	LYS	main effect		
Pigs reach puberty at 210 days,n	12	12	12	10	Rm	Fd	R*F
Age at puberty, days	166.4 ± 2.8	171.5 ± 2.8	175.7 ± 2.9	172.3 ± 3.2	0.09	0.78	0.16
Body Weight at puberty,kg	108.1 ± 2.9	112.3 ± 2.9	115.1 ± 2.9	113.7 ± 3.2	0.18	0.60	0.33
Back fat, mm	11.5 ± 0.5	12.4 ±0 .5	12.2 ± 0.5	12.6 ± 0 .5	0.32	0.18	0.62
Proestrus, days	3.7 ± 0.5	3.1 ±0.5	4.2 ± 0.5	3.0 ± 0.6	0.78	0.09	0.66
First estrous duration, days	2.0 ± 0.2	2.0 ±0.2	1.7 ±0.2	1.7 ± 0.2	0.07	0.92	0.88
First ovulation rate	12.4 ± 1.1	15.2 ± 1.0	12.6 ± 1.1	14.5 ± 1.1	0.78	0.09	0.66
First estrous-cycle,days	22.7 ± 0.5	22.9 ± 0.5	22.5 ±0.6	22.3 ±0.6	0.49	0.91	0.74
Second proestrus, days	2.8 ± 0.4	2.5 ± 0.4	2.9 ±0.5	2.2 ± 0.5	0.91	0.42	0.94
Second estrous duration, days	2.4 ± 0.2	2.3 ± 0.2	1.4 ± 0.2	1.3 ± 0.3	0.0002	0.63	0.95
Second ovulation rate	14.1 ± 0.5	14.1 ±0.5	13.8 ± 0.5	12.5 ± 0 .6	0.08	0.15	0.16

Room A 20° C ; Room B **32**^{0}C(12 h) **26**^{0} C(12 h); REG= Feed contain standard Lysine(NRC, 1988); LYS=REG+50%Lys.

supplementation had no effect on the second ovulation rate (13.1 ± 0.4 vs 14.0 ± 0.4, P=0.12, for LYS and REG, respectively).

Pregnancy and Fetal Characteristics

Pregnancy rate was similar across treatments (Table 8). Ambient temperature had no significant effect on fetal number as seen in Table 8 (10.3 ± 0.6 vs 8.9 ± 0.6, P=0.12, RA vs RB respectively). Pigs fed REG feed had more fetuses on average, than those fed with additional LYS (10.6 ± 0.6 vs 8.6 ± 0.6, P=0.038).

Fetal survival rate was not significantly affected by room temperature (74.2 ± 4.4 vs 67.6 ± 4.7%, RA vs RB respectively, P=0.31) nor by dietary LYS (64.4 ± 4.3 vs 73.4 ± 4.5% P=0.17, LYS vs REG diet).

Ovarian weight and uterine weight of pigs at 45 days post mating(Table 8) were not affected by high ambient temperature or LYS supplementation. However, a significant (P=0.034) interaction between room and feed was observed for uterine weight, pigs fed LYS in RA had higher uterine weight than REG but LYS had lower uterine weight in RB. A trend (P=0.08) also was observed for pigs fed LYS in RA to have larger empty uterine weight than pigs fed REG diet while LYS had lower empty uterine weight in RB.

Mean fetal weight (FWM) and mean fetal length (CRLM) were significantly affected by dietary lysine (P<0.05) but not by ambient room temperature. Fetal length

TABLE 8. Effect of high ambient temperature and lysine supplementation on breeding performance in gilts at day 45 postmating. Values are least square means ± se

Room	A (Control)		B (Hot)		P=		
Feed	REG	LYS	REG	LYS	main effect		
Number of gilts/ treat	12	12	12	10	R	F	R*F
Corpora lutea number	14.1 ± 0.5	14.1 ±0.5	13.8 ±.5	12.5 ±0.6	0.08	0.15	0.16
Number of gilts pregnant	10	12	11	10			
Pregnancy rate, %	83.3	100	100	100			
Ovarian weight, g	17.9 ± 0.6	18.1 ± 0.6	18.6 ± 0.6	18.8 ± 0.8	0.26	0.77	0.98
Empty uterine weight, kg	2.4 ± 0.2	2.7 ± 0.2	2.7 ± 0.2	2.3 ± 0.2	0.99	0.94	0.08
Uterus weight, kg	2.8 ± 0.3	3.4 ± 0.3	3.5 ± 0.3	2.7 ± 0.3	0.95	0.76	0.03
Fetal survival rate, %	77.7 ± 6.6	70.6 ± 6.0	73.1 ± 6.2	62.2 ±7.1	0.31	0.17	0.76
Fetal number	10.8 ± 0.9	9.8 ± 0.8	10.4 ±0.9	7.5 ±0.9	0.12	0.04	0.29
Fetal weight, g	23.0 ± 1.4^{a}	20.8 ± 1.2^{b}	24.3 ±1.3^{a}	20.1 ± 1.4^{b}	0.82	0.03	0.46
Fetal length, cm	7.1 ± 0.1^{a}	6.9 ± 0.1^{b}	7.2 ± 0.1^{a}	6.8 ± 0.2^{b}	0.95	0.03	0.48

Fetal weight=mean fetal weight at day 45 post mating. Fetal length= mean crown-rump length.
* ^{ab} Values within row with different superscript are different ($P<0.05$).

and weight from LYS fed pigs were 6.8±0.1 cm and 20.5±1.0 g respectively. Fetal length and weight from REG diet gilts was 7.2±0.1 cm and 23.6±1.0 g. Therefore fetuses from REG fed pigs were both longer and heavier than from LYS supplemented pigs.

Hormonal Profile

The first blood samples and saliva collection were taken when laparotomy was performed. Saliva cortisol samples were obtained from 20 of 21 animals since one pig did not secrete saliva during laparotomy. Neither diurnal room ambient temperature nor dietary lysine supplementation had any effect on serum cortisol concentrations ($P > 0.10$, Table 9). Similarly, saliva cortisol concentration was not affected by diurnal ambient temperature or lysine supplementation or the interaction of the two . However, there was a trend for pigs in RA to show slightly higher($P = 0.066$) concentrations of saliva cortisol than pigs from RB (hot room) (3.3 ± 0.2 ng ml^{-1} vs 2.7 ± 0.2 ng ml^{-1} for RA vs RB respectively). Pigs fed additional lysine tended to have lower mean saliva cortisol concentrations (2.6 ± 0.2 ng ml^{-1} vs 3.3 ± 0.2 ng ml^{-1}, $P = 0.10$ for LYS vs REG respectively).

Progesterone concentrations at the mid-luteal phase ($P4^1$) as shown in Table 9, demonstrate no significant differences due to feed or ambient room temperature. There was a positive correlation between mid-luteal progesterone concentration and first ovulation rate ($r = 0.61$). Progesterone concentrations at day 45 of gestation ($P4^2$) were

TABLE 9. Hormonal concentrations in gilts at day 10 post puberty (progesterone= $P4^1$) and at day 45 post mating (progesterone= $P4^2$) and cortisol concentration (salivary and serum cortisol) as an effect of high ambient temperature and lysine supplementation. Values are least square means ± se.

Room	A (Control)		B (Hot)		P=		
Feed	REG	LYS	REG	LYS	main effect		
Hormones, ng ml^{-1}					Room	Feed	R*F
Progesterone, $P4^1$	37.1 ± 3.1	33.9 ± 3.1	38.8 ± 4.2	36.3 ± 3.4	0.54	0.53	0.92
Progesterone, $P4^2$	21.1 ± 1.6	18.1 ± 1.5	20.3 ± 1.6	20.0 ± 1.7	0.70	0.33	0.41
Saliva cortisol	3.6 ± .03	2.9 ± .03	2.9 ± 0.3	2.4 ± 0.3	0.06	0.10	0.70
Serum cortisol	16.9 ± 1.6	17.0 ± 1.6	18.2 ± 1.8	16.7 ± 1.7	0.77	0.72	0.63

also not significantly affected by room ambient temperature and dietary lysine supplementation (Table 9).

Correlations Among Variables

Analysis of correlations between variables indicated there were some positive and significant correlations. There was a positive and significant correlation between age and body weight at puberty ($r=0.65$, $P<0.001$); between backfat and body weight at puberty ($r=0.50$, $P<0.01$); between serum cortisol and $P4^1$ ($r=0.47$, $P<0.05$); between $P4^1$and $P4^2$ ($r=0.43$, $P<0.05$); between $P4^1$ and OR1 ($r=0.61$, $P<0.01$); between $P4^2$ and OR1 ($r=0.66$, $P<0.01$); between $P4^2$ and fetal number ($r=0.40$, $P<0.01$); between initial body weight and OR1 ($r=0.55$, $P<0.001$); between pubertal body weight and OR1($r=0.47$, $P<0.05$); and between breeding body weight and OR1($r=0.46$, $P<0.05$).

DISCUSSION

In many studies investigating the optimum ambient temperature and relative humidity for maximum economic gains in pigs, rectal temperature and respiration rates have been used as tools for assessment. Studies conducted under either laboratory or field conditions have established the relationship between rectal temperature and ambient temperature and how this is manifested in the subsequent performance of the animals. The present study was conducted to determine the effect of simulated tropical temperature on reproductive performance in young gilts, using physiological and performance parameters. Compared with other species of farm animals, pigs are relatively sensitive to high ambient temperatures. They respond to high ambient temperature by invoking a complement of physiological, anatomical and behavioral mechanisms aimed at facilitating heat loss to, and minimizing heat gain from the environment.

Physiological Response and Adaptation to Thermal Environment

Although there was a tendency towards slightly lower rectal temperature in control room pigs, housed at 20°C, prolonged diurnal high ambient temperature and supplemental lysine had no significant effect on the overall mean rectal temperature measured in the three growth phases. Similarly, the RTSD and the RTRANGE were not affected by treatments. However, RR was greater in the hot room. Others have found

increases in both RT and RR associated with elevated ambient temperature. These responses were in part dependent upon the body weight of the pigs, the relative humidity, the type and the duration of exposure (Heitman and Hughes, 1949; Tidwell and Fletcher, 1951; Hoagland and Wettemann, 1984).

Increases in rectal temperature by as much as 0.6 to 1.2°C were reported by Flowers *et al.*,(1989) when prepubertal gilts were exposed to a constant ambient temperature of 33 ° C vs 16° C with 35% RH from 140 days of age until reaching puberty at 230 days of age. Christon (1988) observed an increase of 0.9°C (from RT of 39.3° C in the control temperature) in RT of young growing pigs raised in a tropical climate, with ambient temperature ranging from 21 to 32°C. Christon (1988) also observed an increase of RR from a control temperature (20.5 to 21 ° C) rate of 26.2 breath min^{-1} to 106 breaths min^{-1}. The RT results are not in agreement with the present study but the increase in RR agrees with results reported herein and elsewhere (Tidwell and Fletcher, 1951; Hoagland and Wettemann, 1984; Ross *et al.*, 1985; Flowers *et al.*, 1989). The highest RR from an individual pig in the hot room was 120 breaths min^{-1} and the average mean RR for pigs in the hot room were 56 breaths min^{-1} which was lower than what was reported by Christon (1988). Lysine supplementation in the present study had no effect on respiration rate.

Porcine skin contains sweat glands which respond to drugs but are not responsive to heat stress. Water vapor does diffuse passively through the pigs' skin but the maximal rate is only around 30 g $m^2 h^{-1}$. Therefore, pigs are dependent on evaporative heat loss from the respiratory passage (Curtis, 1985). The pigs RR response to heat stress

commences when the skin temperature rises above 35^0 C, at which time breathing rate increases while tidal volume drops (Curtis, 1985).

A decrease in feed intake and subsequent decrease in growth rate was not observed in this study. Although feed intake was slightly lower in pigs under hot ambient temperature, statistically it was not significant. Theoretically, one of the responses of animals to high ambient temperature above their thermoneutral zone is a reduction in feed intake. Steinbach (1987) speculated, based on previous studies, that under tropical conditions a decrease in feed intake of up to 40% would occur when ambient temperature rose from 20 to 35°C.

The results of the present study are in agreement with Flowers *et al.*, (1989) although their study was conducted under different feeding protocols. In their study, feed intake was restricted to 2 kg pig^{-1} day^{-1} while in this study feed was offered *ad libitum* in order to assess how the high ambient temperature affected the voluntary feed intake. However, with the diurnal ambient temperature, pigs in the hot room (room B) spent more of their time eating during the lower temperature (26°C) of the night. During the higher daytime temperature (32°C) they spent much of their time lying in full lateral recumbency on the concrete pen floor or on the metal grating over the gutter. So, although feeding pattern was different between the two rooms, the feed intake and body weight gain were not significantly affected. A similar pattern of eating behaviour was observed in pigs in the tropical climate (Steinbach, 1987).

Feed intake pattern by pigs in this study are comparable to the grazing pattern of livestock under extensive management in the tropical climates (Payne, 1990). The

length of daytime grazing of cattle varies according to the environmental temperature, the breed and type of animal utilizing the grass and the quality and quantity of pasture available. When high-grade *Bos taurus* type cattle (grading up of *Bos Taurus* with local breed) were grazed in the humid tropical climate the length of daytime grazing was radically curtailed and confined almost entirely to early morning and the late afternoon periods. The length of the night grazing period fluctuated according to the degree of climatic stress (Payne, 1990). If the climatic stress was excessive during the middle of the day, part of that extra grazing took place at night. Joblin (1960), working with *Bos indicus* in Uganda where seasonal fluctuation in the quality and quantity of feed is considerable, concluded that the restriction of night grazing led, under that tropical environmental condition, to a significant decline in liveweight gain of up to 30%. Similarly, Christon (1988), reported a significant decrease in feed to gain ratio and daily gain of pigs kept under tropical climate although feed intake was not significantly different from the feed intake of pigs in a controlled thermoneutral temperature.

Water usage as a direct effect of thermal environment is very complex, as water is required by the animals for at least two different purposes (Payne, 1990). First, as an essential nutrient and component of the body, and second, to assist the animal in losing heat by conductive or evaporative cooling. Although in general, water intake of livestock increases with increasing ambient temperature, the relationship between water intake and ambient temperature is not simple. For example, in *Bos taurus* type milking cows, water intake increases with ambient temperature up to 29.5°C but above this temperature it declines and this decline has been attributed to a decline in feed intake and

productivity and to a rise in body temperature.

Water usage was significantly higher for pigs in the hot room than for the pigs in the control room. These results are in agreement with most earlier studies in which high ambient temperatures increased water usage dramatically (Flowers *et al.*, 1989). The requirement of pigs for water in the hot climates is high because of more frequent drinking in response to rising ambient temperature and the need to replace the water expended as evaporative heat loss (Steinbach, 1987). The increased water usage and increased RR are attempts to compensate for the extra heat load associated with high ambient temperature. The pattern of water usage for pigs in the control room was linear with their age. Water usage increased as animals aged, while in the hot room, the pattern was associated with feed intake pattern as noted by Payne (1990) in dairy cattle at temperature above 30°C. In the present study, pigs with REG diet ate more and therefore used more water than those with LYS supplemented diet in both rooms. Water intake decreased gradually as the feed intake decreased. Any water, with a temperature below that of body temperature consumed in excess of metabolic needs , then excreted at body temperature as urine or in the feces assists in reducing the heat load on the animal (Holmes, 1973). It was suggested that lowering the temperature of ingested water has a more marked effect on the heat load than increasing the volume ingested. The practical significance of this was demonstrated by Baker (1987). Under conditions of relatively high humidity, chilled drinking water can assist lactating dairy cows to maintain production through periods of high environmental temperature. Flowers *et al.*, (1989) recorded an increase of water usage by pigs from 23.8 ± 10.2 to 81.3 ± 12.4 liters

pen^{-1} day^{-1} for control temperature and thermal stressed animals respectively.

Pubertal and Estrous Cycle Characteristics

From the present study prolonged diurnal high ambient temperature tended to increase the age at puberty. Additional lysine had no effect on the age at puberty. Overall, 46 of the 47 gilts (98%) reached puberty by 210 days of age; of these, 24 gilts were from RA (100%) and 22 were from RB(96%). The percentage of gilts reaching puberty from this study was higher than the results reported earlier by King (1989) using the same number of animals with the same feeding protocol. In King's (1989) study 83% of gilts attained puberty by 230 days of age. Flowers *et al.*, (1989) noted that heat stress delayed puberty attainment for four to six weeks in 75% of the heat stressed gilts. However, for those gilts that reached puberty before 230 days of age, there was no significant difference between the control and heat stressed gilts (204.5 ± 5 vs 213.5 ± 7 d). Field studies in tropical environments have shown that pigs of European descent attain puberty earlier when they are born before the cold rainy season than when born at the beginning of the hot dry season (Steinbach, 1976). Gilts born prior to the cool rainy season gained weight faster and attained puberty earlier (224 d) at a heavier weight (81 kg) than those born at the onset of the hot dry season (256 days and 70 kg respectively). This was an indication that retarded body growth occurred during the growing period due to exposure to ambient temperatures averaging 28°C and above, which probably caused reduced feed intake, and subsequent delay in sexual maturation

(Steinbach, 1976). The retardation of body development most likely originated with the sow. During high ambient temperatures reduced feed intake would result in less milk production and reduced piglet growth (Steinbach, 1976). The low growth rate as a result of long term feed restriction during the growing phases was reported to delay the age at puberty attainment (Van Lunen and Aherne, 1987).

However, overall, pigs in the current study attained puberty relatively faster than from the other studies (Young *et al.*, 1974; Andersson *et al.*, 1984; Dalin, 1987; Connor and Van Lunen, 1988; Flowers *et al.*, 1989; King, 1989; Eliasson *et al.*,1991). While breed differences may be the source of these differences, these pigs did not significantly reduce feed intake nor show any strong adverse effect due to heat treatment. The time range required for the pubertal onset was slightly longer (50 days) for pigs in RB compared to time range required for pigs in RA (40 d), an indicator of more variability in puberty attainment for gilts under high ambient temperature. This is in agreement with Steinbach (1987) who stated that an increase in variability is a common feature of animal performance data from stressful environments.

Body weight at puberty was not affected by treatments, although it seemed that pigs in the control room had slightly lower body weight than pigs in the hot room ($P=0.18$). This lower body weight at puberty was mainly the result of an earlier age when puberty was attained. The relationship between age and body weight at puberty showed a significant and positive coefficient of correlation. The same was true for backfat thickness and body weight at puberty. There was no treatment effect observed on the backfat measurement. However, backfat thickness at puberty was slightly higher

from pigs in the hot room, probably due to higher body weight for pigs in that treatment room. Backfat thickness in this study showed a positive and significant correlation to body weight. Backfat thickness at puberty has a positive and significant correlation to body weight at puberty. The same was true at breeding weight and at day 45 of pregnancy. As shown in the previous studies, pigs which attained late puberty consequently had high body weight, and higher backfat (Young *et al,* 1974; Dalin, 1987).

Behavioural Thermoregulation

The normal responses to ambient temperature changes are not only physiological but also behavioral in nature (Steinbach, 1987). In the upper range of the TNZ, thermoregulatory behavior aims at reducing heat production and at enhancing heat loss (Curtis, 1985; Steinbach, 1987). A reduction in heat production is attained by decreasing feed intake and by limiting motor activity, while an increase in heat loss is achieved by postural changes and by increasing drinking frequency (Steinbach, 1987). As was stated earlier, a significant reduction in the feed intake was not observed in the present study, however, reduced motor activity was seen, especially during the day time when the ambient temperatures in RB were high, in fact pigs spent most of the day time at rest. Steinbach (1987) also stated that in the hot climates pigs rest between 63 to 95% of their time, depending on their age, with the older pigs spending more of their time at rest.

In this study the animals in RA behaved differently from those in RB. In the control room (RA), animals kept themselves and their pens clean by defecating and

urinating regularly at the gutter located at the rear part of the pen. In the hot room, animals defecated and urinated indiscriminately over the pen floor and rolled in urine, or any other available water and feces in attempts to increase heat loss. This condition is similar to what was reported earlier in Feeding Standards for Australian Livestock (1987). In natural settings pigs and cattle take advantage of ponds, streams and muddy-wallows to apply moisture in the form of mud to their body surfaces during hot weather(Curtis, 1983). Mud is a very efficient medium for evaporative thermolysis. With this behavioural thermoregulatory trait, heat loss from a pig's mudded side, can reach 800 g h^{-1} m^{-2} which is much greater than that from a cow that is sweating maximally. This can improve pig performance during hot weather (Curtis, 1983). Animals in RB, because of their thermoregulatory behaviour was looked dirty most of the time although regular daily cleaning was similar in both rooms.

Reproductive Performance

Although additional lysine tended to reduce the first proestrus duration, proestrus duration was not affected significantly by treatments. Proestrus is normally distinguished by rapid follicular growth and with elevated estrogens responsible for physical and behavioural characteristics. Although gonadotrophin hormones were not measured in this study, the apparently normal proestrus and estrus would suggest that gonadotrophins, especially FSH were not detrimentally affected by high ambient temperature and supplemental lysine.

Duration of estrus in this study tended to be affected by ambient temperature. Gilts kept under hot ambient temperature had significantly shorter second estrous duration than gilts kept under thermoneutral temperature. This shorter estrous duration which averaged 1.4 days in the hotter room can cause difficulties in mating programs geared to double mating at a 24-h interval. The results of this study were in agreement with data obtained from sows in the tropical countries (Steinbach, 1976) and in Australian summer conditions (Paterson *et al.*,1978). During the hot dry season, estrous duration was significantly shortened and was negatively correlated to the ambient temperature. In addition, the proportion of sows showing no heat symptoms (temporarily anestrus) increased. The same results were also reported by Flowers *et al.*, (1989) with gilts kept at 33.3°C but were attributed to cystic follicles which were not observed in the present study. At 35 °C Steinbach (1976) also reported that the estrous behavior was completely suppressed. Similar results were reported by Madan and Johnson (1973) in dairy heifers subjected to high ambient temperature (35.5 °C, 55%RH) for two consecutive estrous cycles. The estrous duration in these heifers was significantly shorter than in those kept at 18.2°C (16.8h vs 11.9h respectively). One associated factor may be that as in the water buffalo cow (Rao and Pandey, 1983) hotter ambient temperatures may suppress LH and estradiol resulting in poorer manifestation of heat.

Estrous cycle length was not affected by treatments, although some of the laparotomized gilts had slightly longer cycles. All animals that attained puberty cycled normally for the second estrus. This result is in agreement with Steinbach (1976, 1987) in that the length of the cycle was not affected by ambient temperature. As well,

progesterone, which plays an important role for the regulation of estrous cycles was not affected by ambient temperature nor by dietary lysine supplementation.

Progesterone concentrations after the first estrus ($P4^1$) were not affected by treatments and were positively correlated with OR1 (r=0.61). Hoagland and Wettemann(1984) also noted no significant difference in P4 concentrations between heat stressed gilts kept at 32 to 35 °C and the control gilts maintained at 23°C room temperature. The P4 concentrations in the present study were slightly higher than in some previous studies (Tillson, 1970; Robertson and King 1974; Connor *et al* ., 1976; Connor and Van Lunen, 1988). but was similar to that reported by Robertson and King (1974). Robertson and King (1974) noted that the high P4 concentration was related to high ovulation rate. This concurs with the results of the present study in which $P4^1$ and OR1 were positively correlated (r=0.61). $P4^2$ concentration at day 45 of pregnancy was lower than $P4^1$ at the mid-luteal phase, which is consistant with previous reports (Tillson *et al.*, 1970; Robertson and King, 1974; Hoagland and Wettemann, (1984); Tilton *et al* ., 1989). As in the present study, Hoagland and Wettemann, 1984 found no difference in P4 between stressed and non stressed gilts up to day 18 to 20 of the cycle.

Ambient temperature had no effect on OR1, however, lysine supplementation tended to increase OR1. The current study is in agreement with results reported elsewhere that heat stress had little or no effect on the ovulation rate (Warnick *et al.*, 1965; Edwards *et al.*, 1968; Steinbach, 1987). On the average, the OR1 of pigs in this study was in agreement with Young *et al.*, (1974) but was slightly lower than the OR1 reported by Connor and Van Lunen(1988) and was higher than the first ovulation rate

reported by Flowers *et al.*,(1989) or by King (1989). Cystic follicles in heat stressed gilts as reported by Flowers *et al.*, (1989) did not occur in this study. This indicated that ambient temperatures of 26 to 32^0 C had no obvious deleterious effect on the hypothalamo-hypophyseal axis. However, it has been demonstrated in chickens that acute heat stress (24 h at 35^0 C) significantly decreased LHRH content and in turn decreased the LH concentration and ovulation rate in the laying hens (Donoghue *et al.*, 1989). In this study, gilts appeared to have adjusted to the high temperatures before exhibiting their first estrus.

Lysine supplementation tended to increase ovulation rate in both rooms regardless of the ambient temperature. The mechanism of this effect needs to be studied further since this beneficial effect did not occur at the second ovulation. Supplemental lysine at 12 g d^{-1} from puberty to breeding in restricted fed gilts did not improve ovulation rate and embryo survival in a study by Grandhi, (1988).

There was also a significant relationship between OR1 and body weight at puberty found in this study. Pigs with high body weight at puberty had higher ovulation rates. A similar relationship between body weight and ovulation rates has been reported elsewhere (King, 1989). In relation to feed intake, Dyck and Strain (1979) demonstrated that increasing feed intake from 1.5 kg to 3 kg pig^{-1} day^{-1} dramatically increased the ovulation rate. In the present study, feed was offered *ad libitum* for the entire trial which allowed the animals to produce high body weight. Therefore, their OR was relatively high with no substantial increase for either first (OR1) or second OR (OR2). Similar results were reported earlier by Connor and Van Lunen (1988) in that well fed gilts

showed no significant increase of OR up to third estrus. It was noted also that well fed gilts exposed to extreme heat stress had 15 to 18 CL when slaughtered at day 30 post mating (Steinbach, 1987), but at a lower protein intake, OR was reduced. Chronic high ambient temperature can also affect gonadotrophins which are necessary for follicle maturation (FSH) and for ovulation to occur (LH) (Paterson *et al*, 1978). In the present study, second ovulation rates tended to be lowered by high ambient temperature (14.05 ± 0.4 vs 13.04 ± 0.4 ova), but was not affected by lysine supplementation.

Early Pregnancy

The pregnancy rate (%), defined as the number of females pregnant of the number of mated females X 100% (Pond *et al.*, 1991), was satisfactorily high in the present study at 92% in control room vs 100% in room B. High ambient temperature and supplemental lysine had no effect on pregnancy rate. These are within industry standards and are comparable to the 88% pregnancy rate reported by King (1989) under conditions of *ad libitum* feeding and presumably non stressful temperatures. However, the pregnancy rate reported by King (1989) was based on mating at first estrus while in this study mating occurred on the second estrus.

Fetal number at day 45 of gestation was not affected by room ambient temperature, but was significantly reduced by supplemental lysine. A significant and positive correlation ($r=0.39$) was found between fetal number and the second ovulation rate (OR2), which means that those pigs with high ovulation rate at second estrus

produced more fetuses than gilts with lower OR2, according to this study. Similar results were reported previously by Young *et al,* (1974) who found a similar correlation (r=0.48). However, no significant relationship was found between OR1 and OR2 under these treatments conditions. Fetal survival rate tended to be lower in the hot room.

Significant and positive correlations existed between body weight at various stages in the present study. Pigs that had high body weight at puberty, had high body weight at mating and at day 45 of gestation. These data are in agreement with results found by Young *et al,* (1974).

High ambient temperature that began during the prepubertal period had no effect on fetal development. From the earlier studies, high ambient temperature was detrimental to embryo survival when applied during the preimplantation period (Warnick *et al.*,(1965), but had no deleterious effect when applied at the end of the gestation period. However, Steinbach (1987) observed the most sensitive period to heat stress in the tropical climate was the first two weeks after mating and the last two weeks of gestation. Exposure to heat stress at this time caused high embryonic loss and high numbers of stillborn. In the current study, the physiological measurements indicated the gilts adjusted to the high temperature quite easily and it did not appear to be a major stressor.

Heitman *et al.*, (1984) reported that in boars, low (17 to 33°C) and medium diurnal temperature stress (19.5 to 35.5°C) had no effect on boar sperm quality. The deleterious effects of high diurnal temperature stress (22 to 38°C) on boars' sperm quality occurred at two to three weeks after the high temperature was applied to the

boars. The diurnal ambient temperature used as treatment in the present study would fall between low and medium temperature stress.

Lysine supplementation did have a suppressive effect on the fetal growth and reduced fetal number. Recent studies by Grandhi(1992) and Stahly *et al.*,(1992) reported that lysine significantly improved reproductive performance in lactating sows by reducing the sows' body weight loss during lactation, increasing the piglets weaning weight, increasing the % sows in estrus by day 14 *postpartum* and reducing weaning to estrus interval. These studies indicated that lysine direcly improved the lactating sows' body condition by reducing weight loss, and thereby indirectly improving reproductive performance by producing more viable piglets at birth and at weaning. Lysine is usually the first limiting amino acid in most pig diets while arginine is an amino acid present in great excess (Southern and Baker, 1982). This excess leads to the possibility that excess arginine could interfere with lysine utilization and as such, adversely affect pig performance (Southern and Baker, 1982). This is especially true in younger animals.

Harper *et al.*, (1970) reviewed the effects of age on amino acid disproportions and indicated that younger animals were more susceptible to amino acid imbalances than older, more mature animals. Edmonds *et al.*, (1987) studied the effects of excesses of 4% for the amino acids methionine, tryptophan, arginine, lysine or threonine in young growing pigs for a 16 days feeding trial. They found that excess lysine had less and threonine had no growth depression and no effect on feed efficiency when compared with the other three amino acids in their study.

High ambient temperature and lysine supplementation on the present study had

no effect on ovarian or uterine weight at day 45 postbreeding. However, there was a significant interaction between feed and room by which additional LYS decreased gravid uterine weight for pigs in the hot room but not in the control room. It is surprising that lysine decreased uterine weight for pigs in the hot room since there was no significant reduction in the feed intake. This may have reflected fewer , smaller fetuses in LYS supplemented gilts in the hot room. Ovarian weight and function as well as uterine weight has been related to the feed intake. Howland, (1972) noted that in rats subjected to restricted feed intake (50% *ad libitum*) there was a significant reduction of their ovarian weight and function. The results of reduced feed intake and consequent effect on ovarian weight were attributed to impaired release of gonadotrophins. Dyck and Strain (1979) observed similar results with ovarian and uterine weights of feed restricted gilts. As well, the restricted fed gilts tended to have a higher incidence of anestrus and lower conception rates. However, in the current study, no effect on feed intake or estrous characteristics were noted.

Decreased uterine weight as related to heat stress was reported by Collier *et al.*, (1982)and attributed to a decrease in uterine blood flow. This in turn may alter the endocrine dynamics during pregnancy and may have significant implications for the maternal system. Decreased uterine weight in LYS supplemented gilts in the hot room may have resulted in decreased room in the uterus for the fetuses to grow which in turn caused less fetal growth in terms of weight and length.

Cortisol concentrations have been used as a tool to judge if an animal is under stress or to assess its welfare status (Stott, 1981; Shutt *et al*, 1988). Most researchers

agree that cortisol concentration increases under various types of stress conditions (Riad-Fahmy, *et al.*, (1979); Riad-Fahmy *et al.*, (1982); Vining *et al.*, (1983)). However, measuring cortisol itself by sampling the blood from the animal can be stressful. Recently, a nonstressful method using saliva has been developed to asses steroid concentrations including cortisol in humans and animals (Riad-Fahmy *et al,* 1979; Riad-Fahmy *et al,* 1982). Salivary cortisol was collected in this study to compare with blood cortisol concentrations at the time of laparotomy.

During the prolonged high ambient temperature in room B serum and saliva cortisol concentrations were similar to the control room regardless of lysine supplementation. The same result was reported in the dairy cow (Fuquay *et al.*, 1980) subjected to heat stress. There was no cortisol response to heat stress during the 10-day heat stress treatment. The lack of responsiveness of cortisol to heat stress may have been due to habituation to high ambient temperature. The result reported by Fuquay *et al.*, (1980) may be similar to the pigs in the present study due to prolonged high ambient temperature. Salivary cortisol concentrations were between 14 and 21% of the serum cortisol levels. This is somewhat higher than the 10% of the total protein bound plasma cortisol reported elsewhere (Parrott and Misson (1989), Riad-Fahmy *et al,* 1982, Fell and Shutt, 1986). Parrott and Misson (1989) found that the baseline of saliva cortisol in prepubertal pigs was between 1 - 2 nmol L^{-1}. Blackshaw and Blackshaw (1989) observed the plasma cortisol concentration of resting and exercised sows was 9.2 ± 1.9 ng ml^{-1} while in the saliva the concentration was 3.2 ± 0.7ng ml^{-1}.

Various types of stressors may cause an increase in saliva cortisol including

practices such as routine mixing of animals. Saliva cortisol concentration tended to be higher in pigs from the hot room. This increase was of a magnitude similar to that stimulated by maximal adrenocorticotrophin (ACTH) hormone (Becker *et al.*, 1985). The same results were demonstrated in calves during transport stress (Fell and Shutt, 1986). It was therefore concluded that this unrestrained method of salivary cortisol measurement seemed to be a practical proposition, since the animals did not have to be handled or subjected to venepuncture for sampling, which in itself is an intrinsically stressful activity to the animal. However, Blackshaw and Blackshaw(1989) found a poor correlation between salivary and plasma cortisol in pigs. In the present study, prolonged high ambient temperature did not have a major effect on blood and saliva cortisol. This may not be surprising since the elevated ambient temperature had caused very little increase in the RT (very mild stress). There was no correlation between salivary and serum cortisol concentrations in this study, possibly due to the conditions underwhich the saliva and blood were collected under anaesthetic.

High Ambient Temperature and Overall Animal Performance

Although cortisol concentrations were not elevated it is not an indicator that heat stress did not occur in the gilts kept at high diurnal ambient temperature (Room B). In the hot room, there was one pig that did not reach puberty within the scheduled time frame and there were two pigs from that treatment room which died during the course of this study. This would suggest that to some extent this diurnal ambient temperature

had some effect on the pigs. Aberle *et al* ., (1974) as well as Ellersieck *et al.*, (1979) demonstrated, there were some pigs within the same breed that could be stress susceptible while some could be stress resistant. Estrus duration was the parameter most affected among the reproductive parameters in this study of temperature effects.

The behavior of these two groups of pigs was quite different during the course of this study. Although not all reproductive performance was affected significantly, the shortened estrous duration may influence the overall reproductive performance since short estrous duration may result in problems in the breeding program if estrus cannot be detected after the first 24 h.

CONCLUSION

High diurnal ambient temperature (32^0C,12h: 26^0C,12h) and lysine supplementation had no significant effect on the mean rectal temperature, feed intake, body weight gain and feed conversion rate in this trial. However,pigs kept in high temperatures showed significantly increased respiratory rate and daily water usage, but maintained normal rectal temperature (RT) after the initial adjustment period.

Pubertal onset characteristics were not significantly affected by ambient temperature and lysine supplementation, however, there was a trend that high ambient temperature reduced estrus duration. Lysine tended to increase first ovulation rates but not second ovulation rate. Long term supplementation of dietary lysine by 50% above control decreased fetal number and fetal development and tended to decrease fetal survival rate.

The results of this study indicate that pigs raised in the high temperature were able to adjust to the diurnal ambient temperature and thereby avoid most of the adverse effects reported with continuous exposure to temperatures above thermoneutrality.

Further investigations are required to clarify the effects of supplemental lysine on fetal development.

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APPENDICES

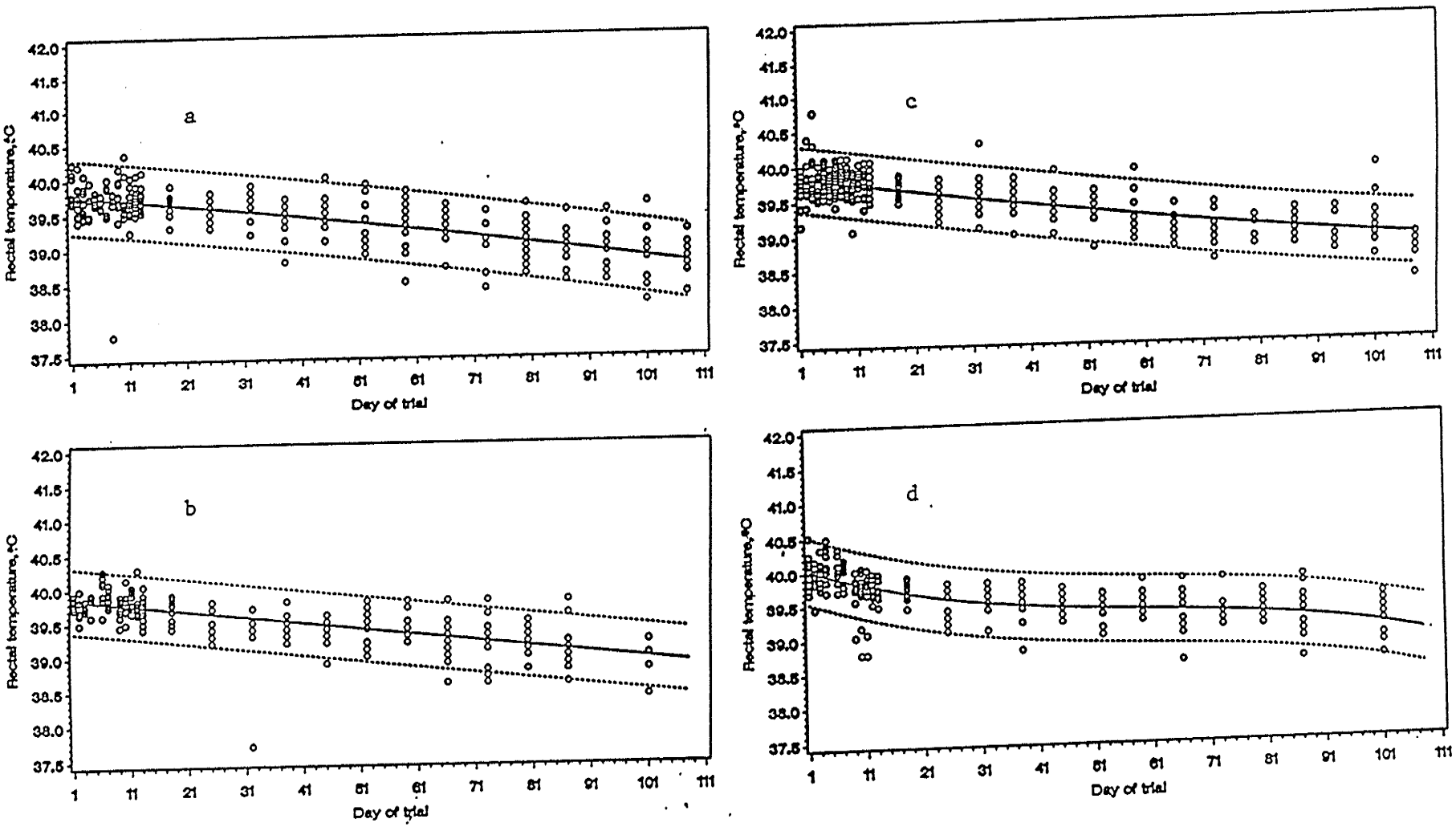

Figure 1. Change in rectal temperature of gilts in room A (control, 20^0 C) on two feed types (REG,LYS) in morning (AM) and afternoon (PM) during the trial Regression lines are shown (solid lines) with their 95% upper and lower confidence limits. a) REG, AM; b) REG, PM; c) LYS, AM; d) LYS,PM.

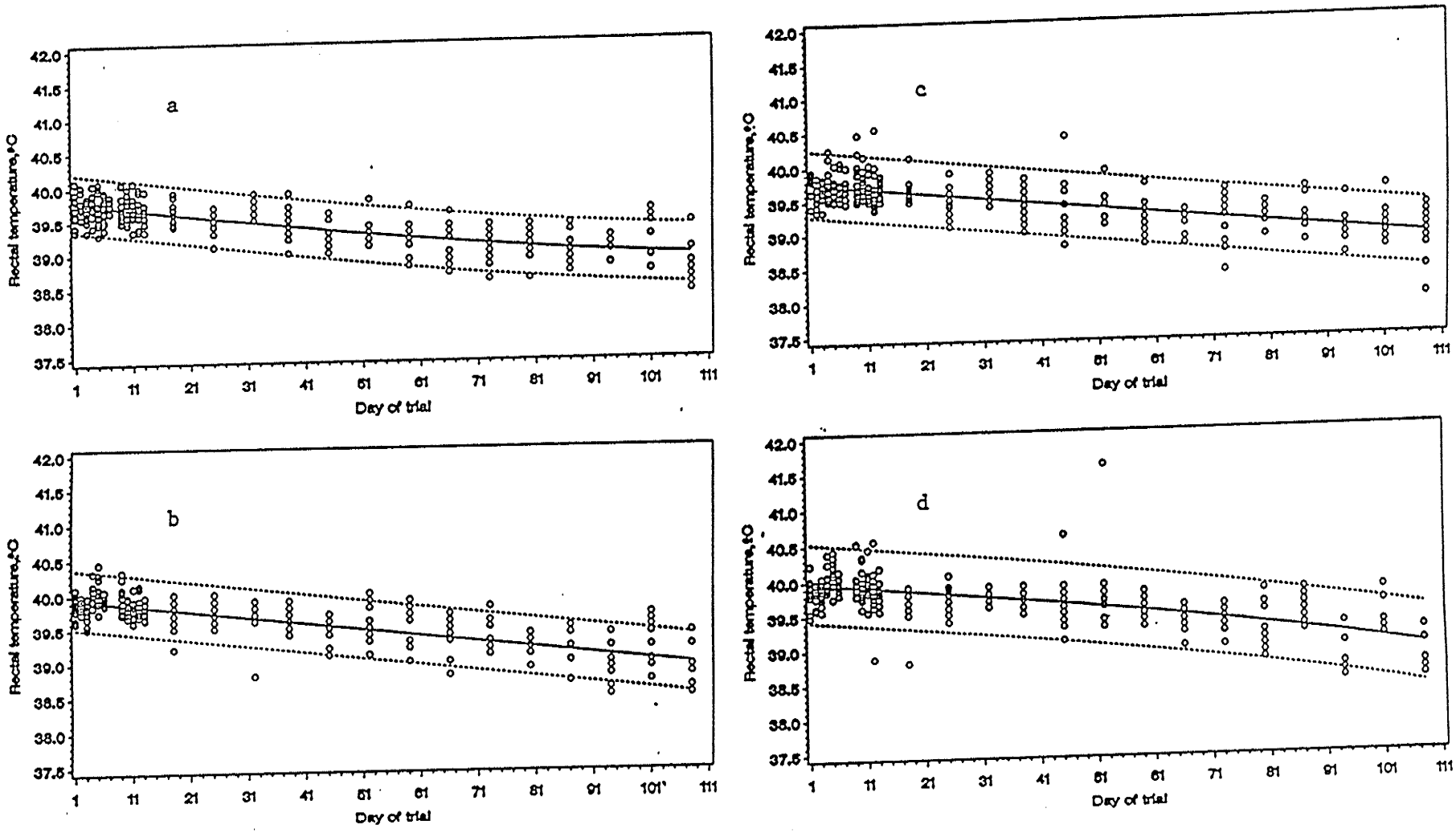

Figure 2. Change in rectal temperature of gilts in room B (hot, 32° C 12 h : 26°C 12 h) on two types of feeds (REG, LYS) in morning (AM) and afternoon (PM) during the trial. Regression lines are shown (solid lines) with their 95% upper and lower confidence limits. a) REG,AM; b) REG, PM c)LYS,AM d) LYS,PM.

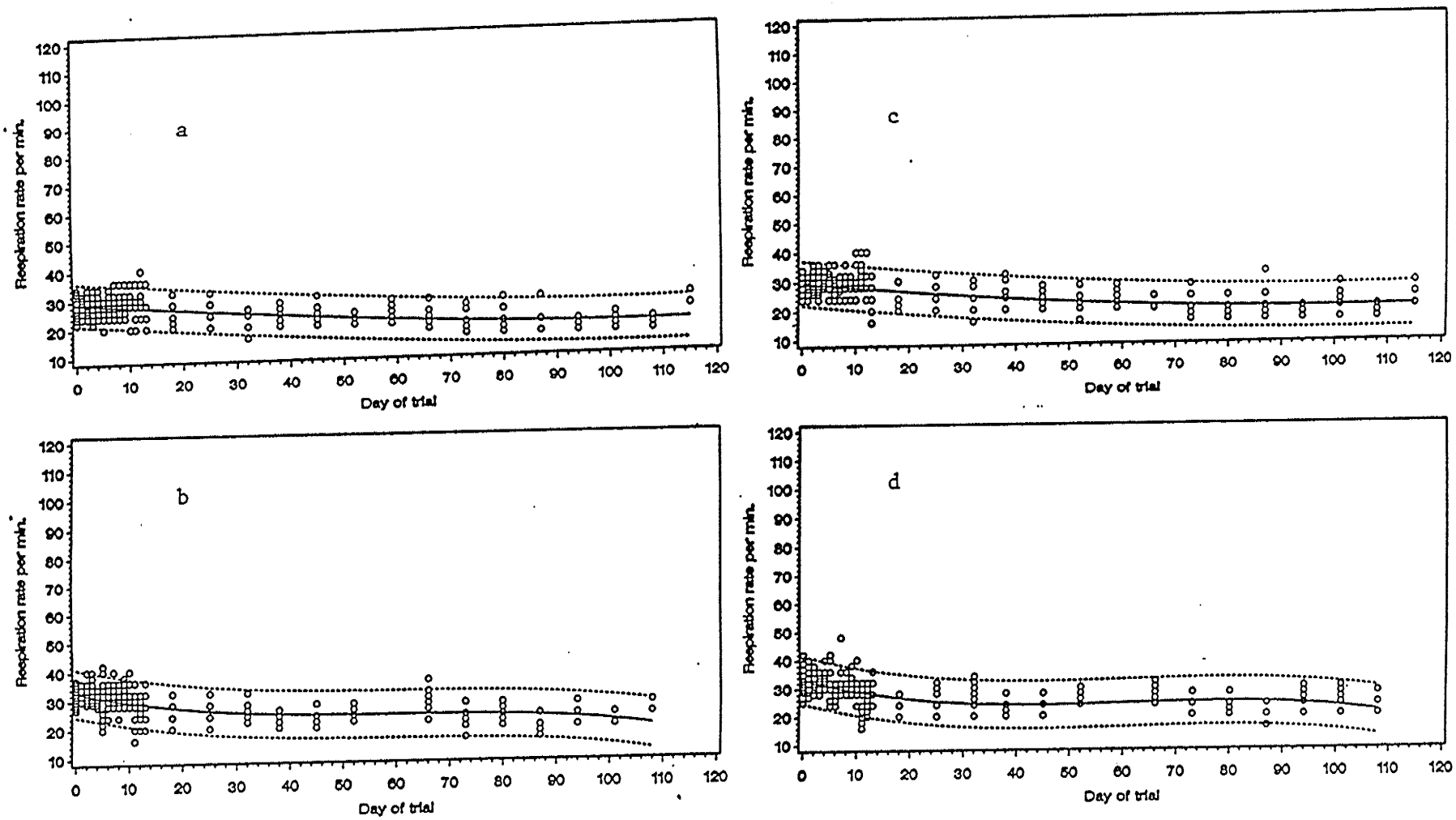

Figure 3. Change in respiration rate of gilts in room A(control, 20°C) on two types of feed (REG,LYS) in morning (AM) and afternoon (PM) during the trial. Regression lines are shown (solid lines) with their 95% upper and lower confidence limits. a) REG,AM; b)REG,PM; c)LYS,AM; d)LYS,PM.

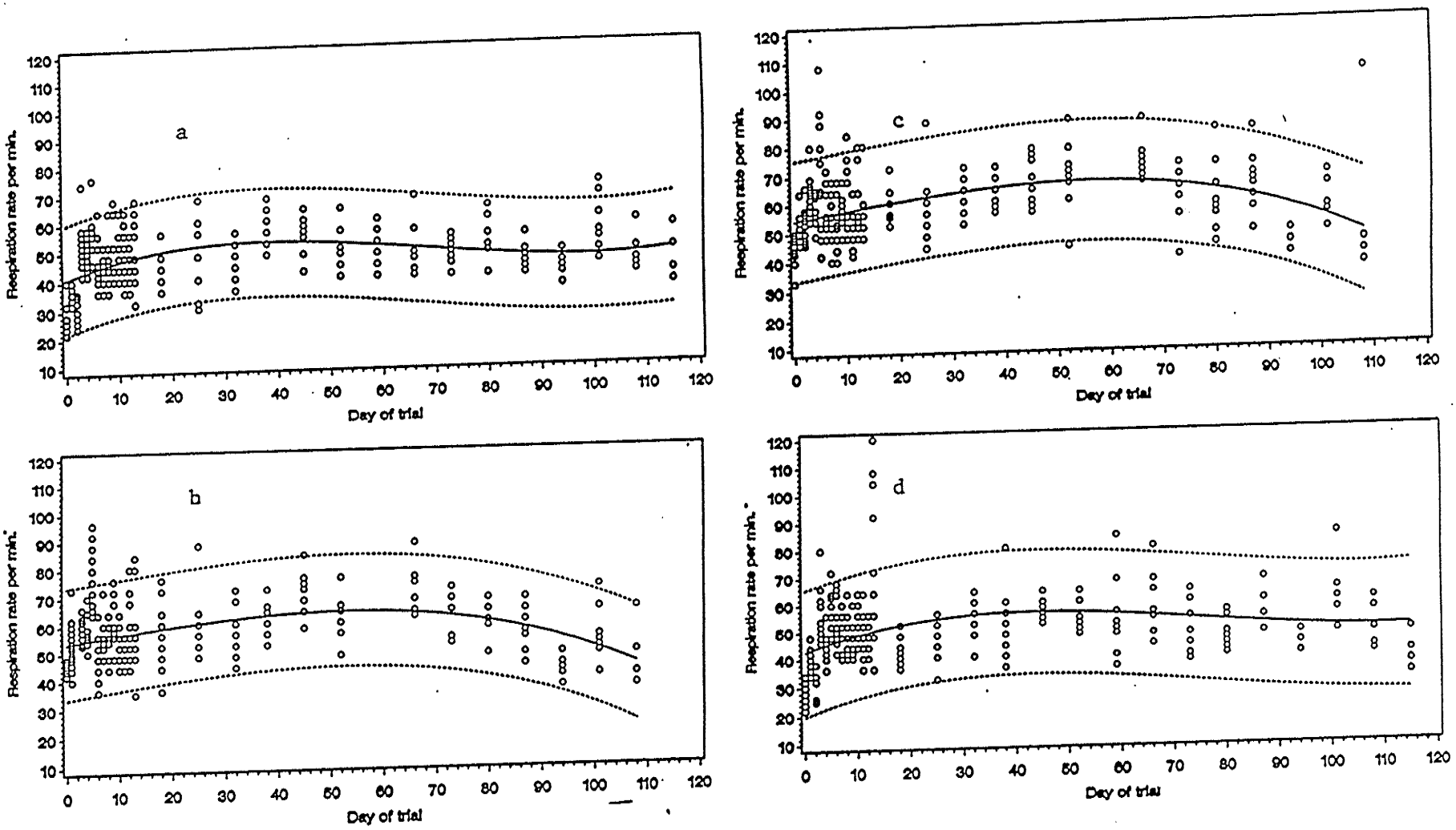

Figure 4. Change in respiration rate of gilts in room B(hot, 32° C 12 h : 26° C 12 h) on two types of feed (REG, LYS) in morning (AM) and afternoon (PM) during the trial. Regression lines are shown (solid lines) with their 95% upper and lower confidence limits.a) REG,AM; b) REG,PM; c) LYS,AM; d) LYS,PM.

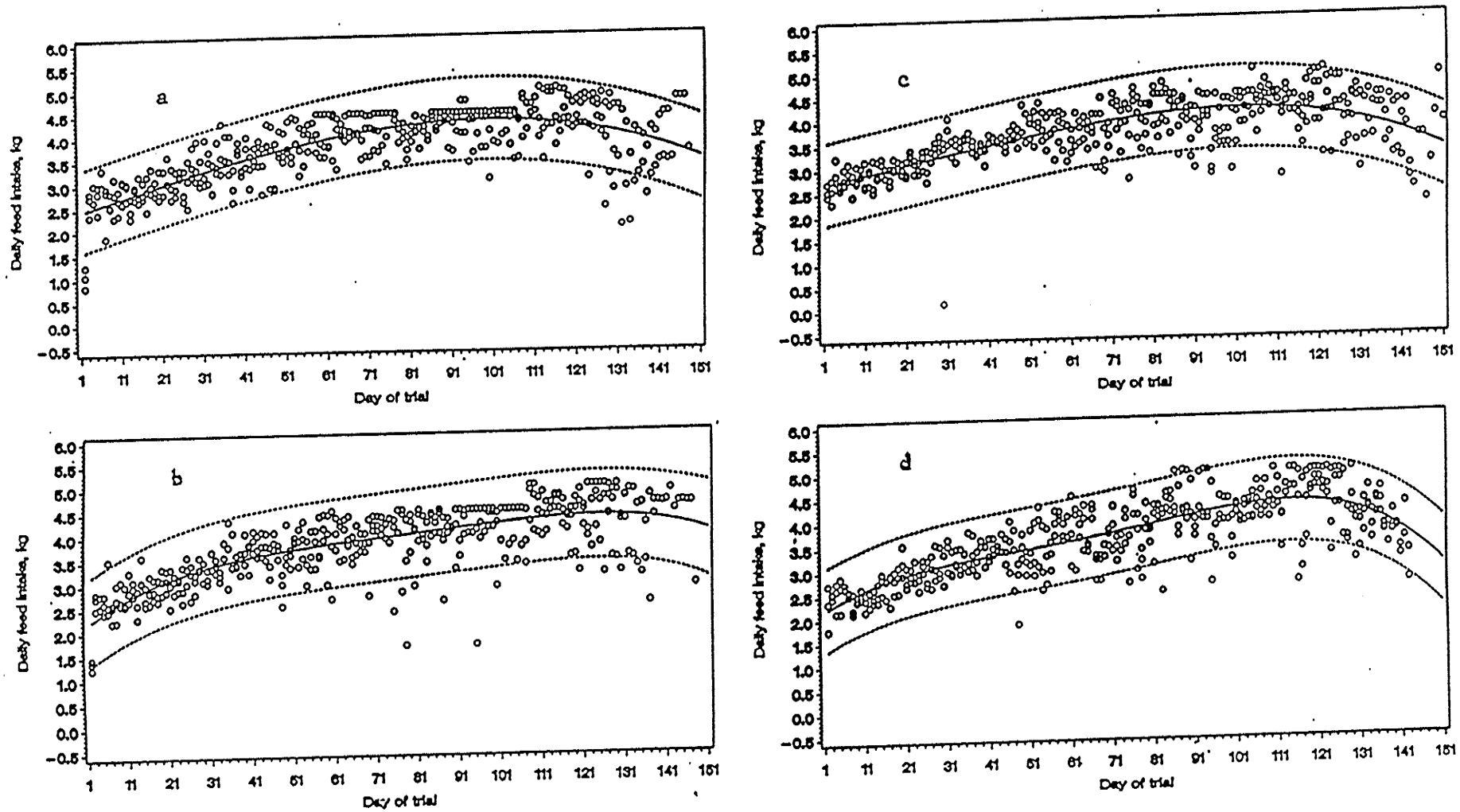

Figure 5. Change in feed intake of gilts in rooms A(control, 20° C) and B (hot, 32°C 12h : 26° C 12 h) on two types of feed (REG, LYS) during the trial. Regression lines are shown (solid lines) with their 95% upper and lower confidence limits.a) RA,REG; b)RA,LYS; c) RB,REG; d) RB,LYS.

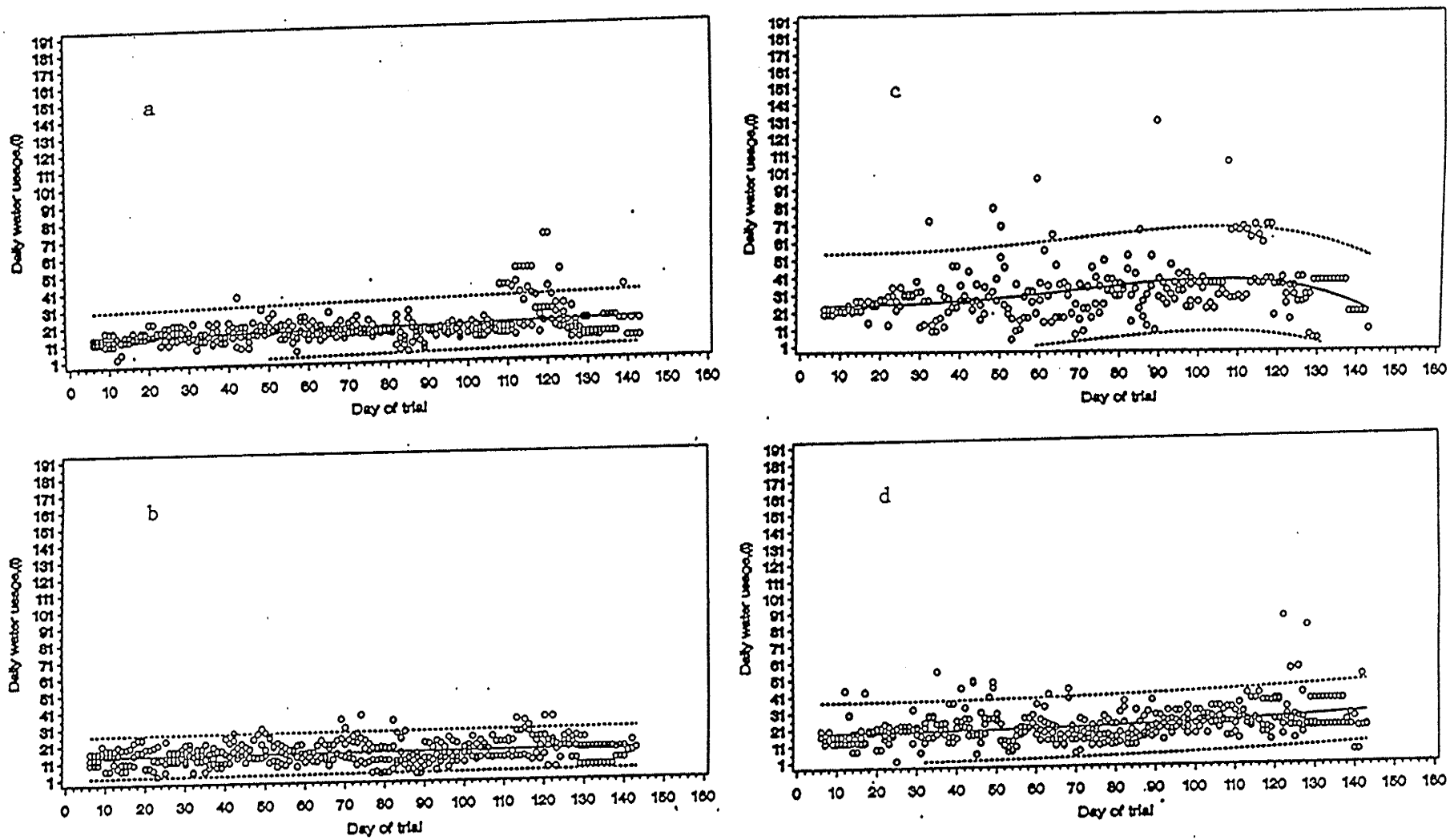

Figure 6. Change in water usage of gilts in rooms A(control, 20°C) and B(32° C 12 h : 26° C 12 h) on two types of feed (REG,LYS) during the trial. Regression lines are shown (solid lines) with their 95% upper and lower confidence limits. a) RA,REG; b) RA,LYS; c) RB,REG; d)RB,LYS

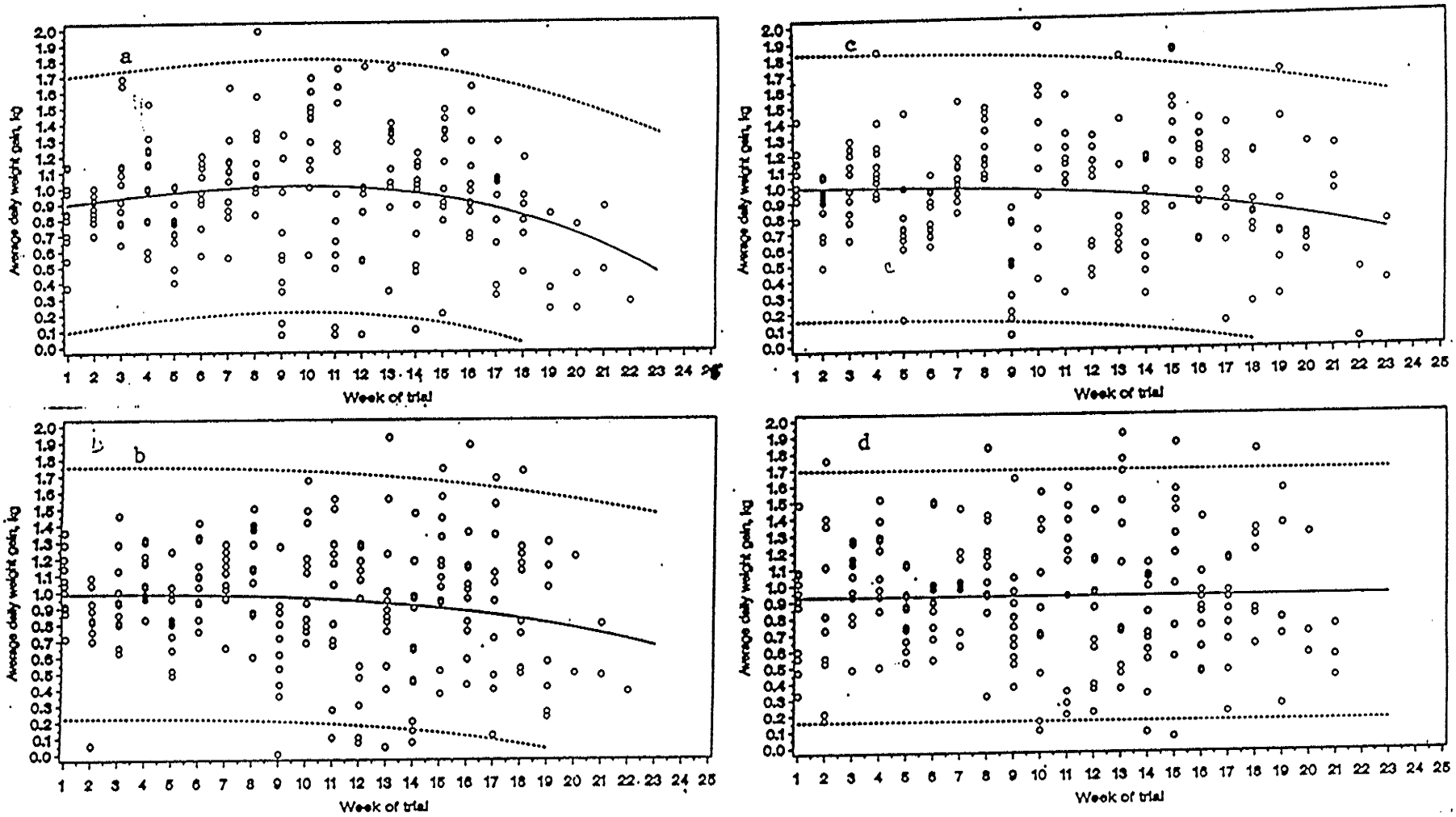

Figure 7. Change in body weight gain of gilts in rooms A(control,20° C) and B(32° C 12 h : 26° C 12 h) on two types of feed (REG,LYS) during the trial. Regression lines are shown (solid lines) with their 95% upper and lower confidence limits. a) RA,REG; b)RA,LYS; c)RB,REG; d)RB,LYS.

Effect of Laparotomy on reproductive performance.

Room	Lap	Room A		Room B		P=		
Feed		REG	LYS	REG	LYS	R	F	R*F
TFW,g	L	264.3±43.9	213.4±34.1	225.1±37.1	110.3±37.6			
	N	238.3±33.3	204.1±34.7	257.9±33.8	174.9±37.7			
	LN	251.3±25.2	208.8±21.3	241.5±22.8	142.6±25.0	0.12	0.008	0.24
AvFW,g	L	24.04±2.7	21.7±2.1	24.0±2.3	19.2±2.3			
	N	22.3±2.0	20.0±2.1	24.6±2.1	20.7±2.3			
	LN	23.0±1.4	20.8±1.2	24.3±1.3	20.1±1.4	0.82	0.03	0.46
FL,cm	L	7.3±0.3	7.0±0.2	7.2±0.2	6.5±0.2			
	N	7.1±0.2	6.8±0.2	7.3±0.2	7.0±0.2			
	LN	7.1±0.1	6.9±0.1	7.2±0.1	6.8±0.2	0.95	0.03	0.48
Fetuses	L	11.3±1.8	9.5±1.4	9.9±1.5	6.1±1.6			
	N	10.6±1.4	10.2±1.4	10.8±1.4	8.7±1.6			
	LN	10.8±0.9	9.8±0.8	10.4±0.9	7.5±0.9	0.12	0.04	0.29
Fesur,%	L	80.6±12.5	60.6±9.7	77.4±10.6	51.3±12.2			
	N	76.5±9.5	80.4±9.9	71.4±9.8	69.5±10.7			
	LN	77.7±6.6	70.6±6.0	73.1±6.2	62.2±7.1	0.31	0.17	0.76
OW, g	L	17.9±0.9	18.7±1.0	20.0†11.0	20.0±1.2			
	N	17.8±0.9	17.4±1.0	17.4±1.0	17.9±1.0			

	LN	17.9±0.6	18.1±0.6	18.6±0.6	18.8±0.6	0.26	0.77	0.98
OR2	L	12.5±0.9	15.1±0.9	12.3±1.0	11.5±1.2			
	N	14.3±0.9	13.1±1.0	15.1±0.9	12.3±1.0			
	LN	14.1±0.5	14.1±0.5	13.8±0.5	12.5±0.8	0.08	0.15	0.16
UW,kg	L	2.2±0.4	3.3±0.4	3.3±0.5	2.4±0.5			
	N	3.5±0.4	3.4±0.4	3.7±0.4	3.0±0.5			
	LN	2.8±0.3	3.4±0.3	3.5±0.3	2.7±0.3	0.95	0.77	0.03
EUW,k	L	1.9±0.3	2.8±0.3	2.6±0.3	2.1±0.3			
	N	2.8±0.3	2.7±0.3	2.9±0.3	2.6±0.3			
	LN	2.4±0.2	2.7±0.2	2.7±0.2	2.3±0.2	0.99	0.94	0.08