EFFECT OF MODIFIED ENVIRONMENT DURING SUMMER ON THE PERFORMANCE OF GROWING PIGS

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled "**EFFECT OF MODIFIED ENVIRONMENT DURING SUMMER ON THE PERFORMANCE OF GROWING PIGS**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that the thesis entitled "**EFFECT OF MODIFIED ENVIRONMENT DURING SUMMER ON THE PERFORMANCE OF GROWING PIGS**" is a record of research work done independently by **Dr. T. Subramanian**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Introduction

1. INTRODUCTION

In developing countries already suffering from widespread malnutrition and indeed facing large scale starvation in the years to come, crucial decisions regarding the orientation of animal protein production must have to be taken. It is inadequately realised that animal products like milk, meat, egg and fish provide nutrients in quality and quantity that can be efficiently utilized by human beings.

Hazel (1963) has stated that pig is an extremely versatile animal, able to adapt to a wide variety of circumstances imposed by man and yet retaining its own peculiar individuality. Pigs are considered to be supreme amongst meat producing livestock and are efficient converters of feed to valuable animal protein. Due to its high prolificacy, short generation interval, fast growth rate, better feed conversion efficiency and other biological advantages pigs can play an important role to make up our animal protein deficiency.

Pigs thrive well in Indian conditions, the mortality rate in the Government farms being low as compared with other farm animals. The basic principles for successful swine production in warm climates are similar to those for cool or temperate climate, namely good systems of breeding, feeding and management. However, tropical conditions demand a different set of requirements in general, mostly due to the constraints on production imposed by the high ambient temperature, humidity and solar radiation.

The environment is of great importance to the livestock producer in obtaining the maximum genetic expression from the domestic animals and birds. Much of time the prevailing temperature and humidity in warm climatic regions impose stress on animals. When this transpires, the animals must expend extra energy if they are to maintain their thermal balance. This results in low input-output efficiency of feed energy for productive processes as compared to that of cooler climate.

Tropical climate is a constraint on efficient livestock production systems particularly for high producing animals whose nutritional needs have to be met. Housing and management technologies are available through which climatic stress on livestock can be reduced. Management practices adopted, in warmer regions have to be different to elicit expression of the full genetic potential of the animals (Sainsbury, 1965; Fuquay, 1981; Gangwar, 1988).

The extent to which the production performance and carcass characteristics are influenced by environmental factors are reported extensively on pigs from western countries but reports of such nature in pigs are scanty and scattered from tropical regions.

Growing and finishing animals grow less rapidly in hot weather. So shelter requirements for growing and finishing pigs need to be suitably modified to get maximum expression of genetic potential of the acclimatized pigs. Under confinement rearing, the most economical means of reducing heat stress for swine would be through evaporative cooling. This can be achieved by use of water as a cooling agent, through direct sprinkling on the animals skin or through providing wallowing tank in pig sties. These are the most feasible techniques for reducing heat stress.

The economic and technical feasibility of modifying livestock environments to narrow the gap between possible and actual production level is largely unproved (Hahn, 1974) and the same is true for the modification of management practices. So it becomes necessary to carry out research work to narrow that gap.

The present investigation is carried out

1. to study the effect of environmental factors on the growth of acclimatized exotic pigs.

2. to recommend suitable housing requirements for the acclimatized exotic pigs in hot-humid climate during dry season to provide maximum comfort within the economic feasibility.

Review of Literature

2. REVIEW OF LITERATURE

The ultimate role of food animals is to convert animal feedstuffs to meat and milk for human consumption. The rate and efficiency of this conversion is determined by many factors including climatic environment. The environment is having a profound influence on the animal's energy expenditure and as this energy is derived from nutrients in the feed, thermal effects of the environment will have direct consequences for energy partition. Energy intake of animal is partitioned into energy that is retained as growth and that is dissipated as heat and lost to production. To maintain optimum production it is necessary to maintain climatic conditions consistent with the requirements of the animal (Clark, 1981).

Manipulation of the physical environment is the potentially important to enhance animal productivity. The physical environment consists of ambient temperature, relative humidity, wind velocity, solar radiation and day length. Report on the effect of these factors on the growth performance of exotic pigs and the means to manipulate the climatic environment in tropical climate for the exotic pigs in tropics are scanty and scattered. The works that were carried out in these aspects are reviewed here.

2.1 Environmental stress factors

2.1.1 Atmospheric temperature

The temperature of the ambient or surrounding air about an animal's body is extremely important to its comfort and normal functioning of physiological processes. Heat normally passes by conduction from the warm skin of most species of livestock to the cooler air around it. But as air temperature rises above the comfort range (13-18°C), the heat loss diminishes and if air temperature exceeds skin temperature, heat will flow in a reverse direction. Then the animals fall into heat stress (McDowell, 1972). The rate and efficiency of growth of animals depends on the level of heat imbalance experienced by it.

Grisdale (1904) reported that air temperature was related to the magnitude of gain in swine.

Heitman *et al.* (1958) reported that significant correlation co-efficients between average daily gain and body weight for air temperature at 10°F intervals were positive at 50° and 60°F and negative at 80°, 90°, 100° and 110°F. At 70°F correlation at weights less than 180 lb was positive and significant while at higher weights it was negative and lacked statistical significance.

Comberg *et al.* (1967) found that for the entire fattening period, the optimum temperature to be 22°C, for the period from 40 to 110 kg and meat type pigs were more affected by environmental changes than the lard type and also recommended 17 to 22°C for individual feeding and 15 to 20°C for group feeding.

McDowell (1972) demonstrated a retardation in growth rate in pigs at high temperature. He has reported an optimum temperature of 21-24°C for swine of 45 kg or larger while that for baby pigs as 27-29°C. The rate of gain for 49-60 kg pigs was reported to be depressed 40-50 per cent at 4-5°C, 25 per cent at 27°C and 40 per cent at 30°C. An environmental temperature of 38°C is reported to decrease gain by 80 per cent.

Morrison *et al.* (1975) had shown that, when mean air temperature were optimal, diurnal temperature cycle upto 20°C do not affect growth rate and efficiency of food conversion compared with a constant temperature equal to the mean of the cycle.

Morrison *et al.* (1975) concluded from American studies that the optimal temperature for feed conversion is about 22°C in pigs weighing 30-65 kg and 15°C for heavier animals.

Staub *et al.* (1976) reported that feed intake was significantly lower at 35°C than 15°C but feed conversion ratio was same at both temperature.

Close and Mount (1978) reported that the partial efficiency of energy retention decreased with increase in environmental temperature from 0.79 at 10°C to 0.63 at 30°C and was 0.67 at the thermally neutral temperature of 25°C.

Verstegen *et al.* (1978) reported that feed intake was lowest at 25°C. Rate of gain was maximal and feed conversion ratio (feed intake: live weight gain) was maximal at 20°C. The lower and upper critical temperatures for individually fed pigs weighing 25 to 50 kg are in the range of 14 to 17°C and 28 to 32°C respectively.

Le Dividich (1981) observed that the growth rate of piglets reared in a high ambient temperature (28 then 26°C) was lower ($P<0.10$) than in a temperature environment decreasing from 28 to 20°C. Piglet gain were lower ($P<0.05$) and food: gain was higher ($P<0.05$) in the 20°C environment than in the temperature environment decreasing from 32, 28 or 24 to 20°C. Maximum growth rate was obtained between 20 and 25°C in weaned piglets kept individually in metabolism cages (Fuller, 1965).

Jensen *et al.* (1983) reported that average daily intake (kg), gain (kg) and efficiency (kg feed/kg gain) were lower ($P<0.04$) in pigs exposed to constant 35°C when compared to constant 20°C treatment.

Kamada *et al.* (1985) demonstrated that the simple correlation of daily gain and daily feed intake with air temperature, were -0.824 and -0.828 respectively. The partial correlation of daily gain with daily feed intake (air temperature held constant) was 0.484.

Rinaldo and LeDividich (1991) showed that above the lower critical temperature i.e., between 25.0 and 31.5°C feed intake was decreased by 18 per cent ($P<0.05$) energy retension by (19%). Growth rate 15 per cent and feed to gains ratio remained constant and minimal.

Becker *et al.* (1992) observed that pigs in the hot environment grew more slowly ($P<0.01$) than pigs at thermoneutrality.

Korthals *et al.* (1994) reported that the reduction of daily feed intake by 64 g from every 1° rise in temperature to increase of 4°, 6°, 8° above a base condition of 23°C constant ambient temperature for 2 days.

2.1.2 Relative humidity

As the pig relies to a greater extent on evaporative heat loss in the hot than in cold, vapor pressure is much more important under hot conditions than in cool (Curtis, 1983).

Heitman and Hughes (1949) found that at 90°F (35°C) there was not much difference in the response of hogs weighing over 200 lbs to an increase from 30 per cent to 95 per cent relative humidity.

The respiratory rate is increased at the higher humidity level and evaporative losses from swine at 22.8°C (73°F) are about 25 per cent of the total (Bond *et al.*, 1952).

Hale and Coey (1961) reported that the practical observation in Northern Ireland have suggested that very high air humidity is advantageous for fattening pig and that low humidity is disadvantageous. When two comparable groups of pigs were kept in an experimental piggery at relative humidity levels of 85 per cent and 50-60 per cent respectively there was no significant effect of humidity level on live weight gain to 200 lb or on amount of meal consumed per lb gain.

Ingram (1965) reported that when pigs aged 2 months were exposed to 25° DB, an increase of humidity from 19°C to 24° WB had no effect on body temperature or respiratory frequency, but animals aged 4 months experienced a slight rise in respiratory frequency. An increase in humidity from 23°C to 32° WB at 35°DB caused an increase in the rate of breathing to 400/min and steady rise in deep body temperature. The rate of increase of body temperature was even greater when humidity was increased to 40°DB.

Comberg *et al.* (1967) reported that for the fattening period the optimum relative humidity was 80 per cent period from 40 to 70 kg and 60 per cent from 70 to 100 kg.

Morrison *et al.* (1967) developed a temperature humidity relationship to the weight gain of swine. It was based on the assumption that the fractional decrease in gain due to increased humidity at a given temperature is equal to the fractional decrease in heat loss due to this same humidity.

Morrison *et al.* (1967) have shown that as relative humidity increased from 30 to 90 per cent at an environmental temperature of 30°C, the animal become more dependent on cutaneous water loss, eventhough respiration rate had almost doubled.

As mean daily temperature fall outside 13-18°C range, other climatic variable assume greater significance in the homeostasis of animal. The water vapour content or humidity of the air offsets importantly the animal's rate of heat loss. If the humidity is high as occurs in warm, humid areas, evaporation takes place slowly, restricting heat loss and thereby endangering the animal's thermal balance (McDowell, 1972). The level of relative humidity is a critical factor in the growth rate in summer particularly at 27°C or above (McDowell, 1972). Greorgiev *et al.* (1972) showed that an air temperature at a relative humidity of 70 per cent imposes a higher degree of heat stress on the miniature Gottingen pigs than does this air temperature at relative humidity of 50 per cent.

In hot, wet conditions some animals sweat, some pant and some spread saliva on their bodies (Hales, 1974). Pigs do none of these effectively. They do, however, wallow in moisture, mud, urine or faeces. Very high rate of heat loss are achieved in this way provided that the humidity of the ambient air is not very high (Ingram, 1965).

Bresk (1984) reported that high relative humidity at low environmental temperature had no effect on energy metabolism or growth, except when excessive condensation placed a burden on thermoregulation. High humidity at high temperature lead to heat stress and impaired appetite and growth.

The relative humidity is not normally a biologically important feature of the climatic environment for pigs, mainly because the pig has no sweating response and is also not a good panter. The dry-bulb temperature is therefore far more important than the wet-bulb temperature in dry conditions (Ingram, 1965; Roller and Goldman, 1969). In hot, wet conditions wet bulb temperature would, of course, be very important.

When considering heat loss, it has been suggested that at 30°C an increase of 18 per cent in relative humidity value is equivalent to an increase in air temperature of 1°C. At 22.8°C, an increase from 45 to 95 per cent was comparable in its effect on the pigs' heat balance to a 2.2°C temperature increase (Curtis, 1983).

2.1.3 Air movement

In assessing the suitability of a pig house, the effect of air flow on the animals' comfort is atleast equally as important as temperature and humidity. The rate at which air moves over the skin of an animal affects the rate of heat loss from the body surface. In hot, humid environments, low air movement is characteristic; consequently, air movement below 5 kmph and even the small irregular movements should be of concern.

The provision of the shade for livestock is of questionable value in the real humid regions because the congregation of animals may so reduce air circulation and thus restrict heat loss by evaporation and convection that the net effects of shade will be nil (McDowell, 1972). The local topography frequently dominates wind pattern. So the topography can be useful in the placing of animal shelters.

Sainsbury and Dunkin (1953) considered that air velocities between 30 and 40 ft/min were reasonable, but that in poorly constructed piggeries velocities upto 300 ft/min. might be encountered.

The extent to which air movement causes an increase in heat loss is dependent upon an animals' body weight, the temperature exposure and whether it is kept individually or in a group. Younger animals are more susceptible to changes in air movement than older animals (Mount and Ingram, 1965; Holmes and Mount, 1967). Similarly, low air velocity changes are proportionately more effective in increasing heat loss than similar changes at high wind speed (Mount, 1966). The effect of air movement is also temperature dependent, with the higher losses occurring at lower environmental temperatures (Mount and Ingram, 1965).

Linton (1965) suggested that 250-500 air flow in cubic feet per hour for fattening pigs and 700 air flow in cubic feet per hour for sows and boars whereas requisite air space in cubic feet 50-100 for fattening pigs and 250-500 air space in cubic feet for sows and boars.

The air velocity in the vicinity of pigs affect their energy balance and is affected by the ventilation rate and position, shape and size of inlets. Considerable effort has gone into defining how these variables interact (Randell, 1975; Boon, 1978).

Morrison *et al.* (1976) reported that growth rate and food conversion were not affected by ventilation rate, but food intake was significantly lower at the lower ventilation rate (0.14 m^3/min) compared with the other two rate (0.42 and 0.71 m^3/min/pig) at the hot temperature 31°C for light weight, at 29°C for heavy weight pigs.

Sallvik (1979) has pointed out that, although ventilation in livestock building is used primarily to control temperature and humidity, other environmental factors within the building are affected. Of high importance are the air velocity and dust concentration.

Increasing air speed from 8 to 100 cm sec^{-1} caused the temperature of the trunk skin on a young pig to drop but there was no such reduction when environmental temperature was 30°C or higher (Curtis, 1983).

Kamada and Notsuki (1987) concluded that heat loss was to be significantly affected by air movement at high temperature and air movement was effective to alleviate heat stress in the pig. Air humidity has little effect on heat loss.

2.2 Physiological norms

The pigs' responses to climate and its thermal environment are complex, varied and can be acute. The lack of a significant hair coat makes the pig very susceptible to cold and its inability to sweat in response to thermal stimulus (Ingram, 1967) means that it is readily heat-stressed in the absence of a wallow. The pigs' responses to its environment are complex and it is difficult to assess the importance and effect of individual components of the environment (Baxter, 1969).

2.2.1 Body temperature

The body surface temperature of hogs was found by Kelly *et al.* (1948) to vary with hog weight as well as the environmental air temperature. Dukes (1955) noticed that rectal temperature of pigs begin to increase at an environmental temperature of 85-90°F (29.4 to 32.2°C). The pigs could not tolerate prolonged exposure (seven hours) to an environmental temperature of 95°F if the relative humidity was 65 percentage or above. At an environmental temperature of 105°F (40.5°C) the pigs was unable to stand an atmosphere of any humidity. A rectal temperature of 107°F (41.7°C) was near the danger point for pig.

Garrett *et al*. (1960) reported the mean value for rectal temperature for shaded wallow 103.4°F (range 102.40 to 104.0°F); sun wallow 104.4°F (range 102.6 to 105.8°F) when the ambient temperature were between 102.4° to 104.0°F).

Sutherland (1967) observed that as ambient temperature rose above the upper critical temperature, the temperature of animals may began to increase. According to Martin (1970) the rectal temperature of pigs began to show a sharp increase when the environmental temperature from 60°F to 80°F (15.6 to 26.7°C). The magnitude of the change was related to body size and was greater for heavier pigs.

Georgiev *et al*. (1972) reported that at 35°C and 70-90 per cent relative humidity the rectal temperature rose gradually and animals salivated profusely as soon as a rectal temperature of 40.5°C was reached. Campbell and Lasley (1977) have reported that rectal temperature of swine as 102.5°F (39.2°C). The normal fluctuation range in rectal temperature is very narrow in domestic animals ie. not more than about 2.5°C. Rectal temperature is usually taken as an index of body temperature (Herz and Steinhauf, 1978). According to West (1985) pigs show a variation in body temperature between 100.9° to 104.9°F (38.2°C to 40.5°C) with an average of 103.5°F (39.7°C). They have also reported that diurnal variation in body temperature exist and is normal. The temperature according to them, is usually at its lowest in early hours of morning and it is at its highest in the late afternoon. According to Mathur (1990) the average temperature of pig vary from 101.7°F to 105.6°F (38.6°C to 40.9°C).

Becker and Misfeldt (1994) reported that rectal temperature were higher in sows maintained for 28 days following farrowing in a cycling hot environment (27-32°C) (50-90% RH) than in sows in a cool environment (21°C, 50% RH).

Korthals *et al.* (1994) reported that peak body temperature occurred between 12.30 and 22.45 h during the days when environmental temperature were increased starting at (8.30) with an average peak temperature occurring near 16.00 h. It was concluded that a producer has 1 to 5 h to take action after severe heat stressors occur in order to reduce its effect on growing-finishing pigs.

2.2.2 Respiration

Pigs respond to high air temperature by an increase in respiratory frequency, but they are believed to lose very little water through their skin, even under hot conditions (Moritz and Henriques, 1947). The significance of increase of respiration rate under heat stress is that it enables the animals to dissipate the excess of body heat by vaporizing more moisture in the expired air, which accounts for about 30 per cent of the total heat dissipation (McLean, 1963).

Kibler *et al.* (1949) reported that the respiration rate was increased with an increase in air temperature and humidity.

Tidwell and Fletcher (1951) reported that the exposure of pigs to sunlight under naturally occurring temperature and humidity condition in summer environment, the average rise in respiration of the Poland China pigs was 61.6 for 15 min exposure and 84.9 for 30 min exposure V. 36.4 and 76.4 for Duroc pigs. The breed difference as regard to respiration was statistically significant.

Heitman *et al.* (1959) observed that pigs were breathing at the rate of 130-170 per minute when air temperature varied from 90-97°F in the house or fabric shade without wallow. The respiratory rate of wallow groups was about 45-75 per minute while under fabric shade. Pigs in the water shaded wallow breathed 25-45 times per minute while the rate of pigs in the water of wallows in the sun was 60-80 per minute. In the air conditioned house and in the indoor pen the respiratory rate was approximately 60-90 per minute.

Garrett *et al.* (1960) reported the mean respiratory rate were in shaded wallow, 49 per minute (range 22 to 94) in sun wallow 124 per minute (range 70 to 184) when the ambient temperature were between 104 and 107°F.

A high respiration rate can be an efficient means of increasing heat loss for short periods (Bianca, 1965), but if high rates continue for several hours or longer, serious problems are likely to arise for the animal, with increasing environmental temperature, respiration rate continues to rise linearly until a certain temperature, where the rate of increase in respiration rate slows, then it almost levels off or slightly decreases (Kibler, 1962; Bianca, 1963).

Butchbacker and Shanklin (1965) found that the respiration rate for newly born pigs remains relatively constant at approximately 20 breaths per minute for various environmental temperatures as low as 75°F (23.9°C). However at 105°F (40.6°C) environmental temperature, the pig holds this rate of approximately 20 per minute for less than an hour and then it suddenly increases and continues to rise for a while.

Fraser (1970) reported that the exposure of pigs to direct solar radiation 30, 60, 90 and 115 minutes showed changes in respiration rate 115, 260, 258, 228 per minute respectively.

Herz and Steinhauf (1978) found that in pigs exposed for six weeks to a heat stress of 33°C, respiratory rate first of all rose sharply and then to fall within the first week to lower values, which were however, still higher than the original values.

Nicholas *et al.* (1983) reported that sprinkled sows had lower ($P<0.05$) respiration rates than control (16.5 Vs 34.7 breath/minute).

Kamada and Notsuki (1987) reported that respiration rate was increased with temperature rise and in still air, more respiration rate was observed.

Joseph (1997) reported that a significantly higher respiration rate in LWY pigs reared in open sties without facility for wallowing or water sprinkling and in open sties without facility for wallowing and water sprinkling, but are left out to a shaded range during day time. But this has not reached the level of growth impairment.

2.2.3 Cardiac rate

Herz and Steinhauf (1978) reported that results on the effect of heat stress on cardiac rate are inconsistent. These findings can be partially explained by the fact that there is a positive correlation between cardiac rate and metabolic speed and that high heat levels consequently cause a rise in pulse rate, while moderate heat levels over a long period cause a drop.

The pulse rate reflects primarily the homeostasis of circulation along with the general metabolic level. It increase on exposure to high environmental temperature (Salem, 1980; Aboul Naga, 1987). This increase blood flow from core to surface to give a chance for more heat to be lost by sensible and insensible ways. At very high temperature, it may decrease (Yousef and Johnson, 1966) due to decrease in metabolic rate of animals under heat stress. However, some studies showed that pulse rate does not always change appreciably under high environmental temperatures (Marai *et al.*, 1991).

Joseph (1997) reported that higher pulse rate in pigs housed in open sties without facility for wallowing or water sprinkling than pigs housed in open sties with facility for wallowing and water sprinkling at hot hours of the dry.

2.3 Body weight and body measurements

Since the major influence of the environment on the growth of pig is energy exchange, providing artificial means of efficient thermal exchanges will help to attain the maximum weight gain.

Jackson (1938) and Bray and Singletary (1948) demonstrated that in some areas additional cooling devices such as water spray wallow etc. under or in conjunction with shades, have enhanced the performance of swine during hot weather.

Hietman and Hughes (1949) reported that one of the best known cooling device to growers was the wallow, which makes use of the natural instinct of swine to cool themselves. Rapid cooling effected by evaporation of water from pig's surface. An increase in daily gain of 0.41 lb due to use of a summer wallow has been reported by Bray and Singletary (1948). Spray have been compared with and found as effective as wallow (Andrews *et al.*, 1956).

Kelly *et al.* (1965) reported that at ambient temperature upto 110°F the surface of 7x9 ft concrete slab was shaded and lying with 20 per cent of their body surface in contact with slab for 22 hrs daily were compared with those of pigs having access to an unshaded water wallow. Heat transfer was most efficient when the slab was cooled to 80°F.

Hale *et al.* (1966) observed that pigs with access to shades equipped with sprinklers gained weight ($P<0.01$) rapidly than pigs without sprinklers. Average daily feed consumption per pig was 2.64 and 2.33 kg for sprinkled and non-sprinkled pigs, respectively. There was a difference ($P<0.01$) of 0.11 kg in average daily gain in favour of sprinkled pigs. This difference in gain is within the range of 0.09 to 0.18 kg reported by McCormick *et al.* (1956) in favour of sprinkled pigs.

In high environmental temperature, the most effective means of relieving heat stress is by increasing the animals' evaporative heat loss. Although virtually unable to sweat (Mount, 1968), the pigs can evaporate large quantities of water if its skin is wetted (Ingram, 1965).

Morrison *et al.* (1968) developed a growth response function for finishing hogs based on combined effects of temperature and humidity.

Morrison *et al.* (1970) found that although all sprinkling treatments significantly improved performance, an interval between wettings of 60 minutes was more effective than one of 30 minutes. They also obtained better performance when the sprinklers were operated at temperatures above 21°C then when they operated only above 29°C.

Hsia *et al.* (1974) reported that periodic sprinkling of water on growing and finishing pigs for 2 minutes at the approximate rate of 50 ml per pig significantly improved their average, daily gain and feed conversion. There was little change in feed intake. Sprinkling every 45 minutes gave better results than sprinkling every 90 minutes. If the sprinklers were operated when the temperature was above 25°C in the growing stage and above 21°C in the finishing stage performance was better than it was if they were operated only above 29 and 25°C. The improvement in body weight gain was almost entirely attributable to an improved feed utilization with little or no change in intake.

Straub *et al.* (1970) observed that body length and bone length measurements were significantly greater under the hot than under cool conditions.

Ho and Khoo (1977) reported that the advantage of fogger cooling in daily gain (592 Vs 546 g) and reduction of time period to reach 90 kg weight from 25 kg (110 Vs 120 days).

Joshi *et al.* (1977) reported that amelioration of high ambient temperature stress of hot dry season, by keeping 20 large White Yorkshire weaners under artificially cooled chamber environment (18.5°C with 10 mm Hg vapor pressure) for 8 hr daily caused an almost two fold increase in body weight gain during 7 weeks of experimental trail.

Jensen *et al.* (1983) reported daily cooling to 20°C for 4, 8 or 16 h also resulted in better ($P<0.04$) growth performance and feed efficiency than that of pigs housed in constant hot temperature while assessing the influence of diurnal changes in hot temperatures on growth performance.

Dede (1983) found that weekly body weight gains was not significantly affected by heat stress in without wallow facility, wallow and air conditioned room from the time of weaning to further 7-10 weeks.

Heath (1984) reported that the external surface area, surface area of the nasal cavity, length of extremities and the mass of skin with subcutaneous fat were greater at 35°C. The mass of the heart, liver, kidneys, stomach and small intestine was greater at 10°C.

Kolącz and Hilliger (1985) found that of all the cooling methods to sows in 4-5th week and in 14-15th week of pregnancy in summer sprinkling with cold water was the most effective while shading was less effective. Use of a fan was not effective.

Arganosa *et al.* (1988) reported that a relatively higher body weight, average daily gain and feed conversion efficiency in growing pigs reared in shaded range without the provision of wallowing facility than the pigs reared in wallowing facility.

Machado and Ouwerkerk ENJ Van (1989) reported that pigs that were showered for 1 minute per hour at ambient temperature above 25°C had 22 g higher average weight gains per day and 4 per cent better average food conversion non-showered pigs.

Becker *et al.* (1992) observed that pigs in the hot environment had a lower ($P<0.01$) final body weight and less leaf fat and back fat than pigs at thermoneutrality.

Panagakis *et al.* (1992) found that spray cooling did not significantly improve piglets' weight gain, feed intake and feed conversion in early weaned piglets of 3-4 weeks old. However when mean weekly pen level air temperature exceeded 28.5°C, spray cooling did send to improve piglets' growth performance.

Leena (1992) found a progressive increase of body measurements such as body length, chest girth, body height from the period of weaning to market age in growing pigs. The similar trend of progressing nature of body measurements were also made by Pradhan (1993).

Sebastian (1992) found that the fortnightly rate of gain ranged from 0.7 kg to 10.2 kg with inconsistant progress in different fortnights from weaning to twelfth fortnight in grower pigs. Similar findings of fluctuating fortnightly rate of gain were also observed by Manju (1997).

McArthur and Ousey (1994) reported that the rate of heat loss from fully wet model increased linearly with decreasing air temperature when air temperature exceeded above 26°C, the evaporation rate from fully wet model was sufficient to cool the surface below air temperature. Heat loss from the fully wet model remained almost constant for a period of about 2 h. Drying was almost complete after about 3 h at each air temperature. Surface wetness can raise the lower critical temperature of poorly insulated animal from 20 to 40°C when its resting metabolic rate is 150 $w\ m^{-2}$.

Kuriahara *et al.* (1996) found that growth and daily gain in piglets were affected by variation in environmental temperature, but feed conversion efficiency (FCE) and digestability were not significantly affected.

Material and Methods

3. MATERIALS AND METHODS

Location

The Kerala Agricultural University Pig breeding Farm, Mannuthy, Thrissur District, Kerala State is the location of the present study. Mannuthy is geographically situated

at longitude 76,16"E

at latitude 10,32"N and

at an altitude of 22.25 meters MSL

Experimental animals

Twenty four weaned Large White Yorkshire female piglets similar in body weight belonging to Centre for Pig Production and Research, Kerala Agricultural University, Mannuthy were selected for the study. These animals have been grouped into four groups of six each and have been allotted at random to the following four treatments.

1. Treatment T_1 - without wallowing and sprinklers
2. Treatment T_2 - with wallowing facility only
3. Treatment T_3 - with sprinkler only
4. Treatment T_4 - with both sprinkler and wallowing facility

Each treatment group was considered as independent trial model for housing and management for grower pigs.

Housing

The pigs were housed in open sties which had concrete flooring and corrugated asbestos roof. The height of the roof at the ridge 4.24 m and at the eave 2.56 m. Four pens of equal size measuring 10.60x2.72 m were taken for the treatment T_1, T_2, T_3 and T_4 respectively, of which 4.17x2.72 m laid within the roofed area. Each pen was having a wallowing tank measuring 1.92x1.17x0.20 m. The wallowing tanks for treatment T_2 and treatment T_4 were only filled with water for cooling purpose and the pens of treatment T_3 and treatment T_4 were having a sprinkler which was fixed at a height of 2 m from the concrete floor at the central position of the eave end of the pen roof. The sprinkler would have the operation from 12.00 noon to 3 p.m. in such a way that each 10 min operation followed by 20 min interval to the next operation in the peak hours of heat stress. The sprinkler had the capacity of spraying 250 ml water/min.

Feeding

The pigs were fed concentrate mixture which contained 18 per cent crude protein for the period of four months from the starting of experiment thereafter a ration having 14 per cent crude protein upto eight months of age. Every day at 10.30 a.m. and 2.30 p.m. hours animals were provided with measured quantity of concentrate in the feed trough as per the farm feeding schedule. Drinking water was provided at all the time in sties.

Composition of ration fed

Rations :	Ration I	Ration II
CP per cent :	CP	CP
Age group fed :	18 per cent <6 months	14 per cent >6 months
Ingredients (parts/1000)		
Yellow maize	500	470
Groundnut cake expeller	160	70
Rice polish	155	130
Wheat bran	70	245
Dried unsalted fish	100	70
Common salt	5	5
Mineral mixture	10	10
Vitamin A B_2 D_3 (Indomix)	0.1	0.1

Management

The pens and pigs were cleaned in every day. Butox sprayed once in a month on pigs and premises to prevent ectoparasitic infestation. The animals were dewormed during the first week of weaning and at monthly intervals. The other management practices were as per routine management in the farm.

Observations

Environmental stress factors

The meteriological data over a period from November 1997 to May 1998 obtained from the meteriological observatory unit attached to the College of Horticulture, Vellanikkara. Fortnightly average maximum temperature, fortnightly average minimum temperature, relative humidity (%), wind velocity (km/hr) were collected to study the effect of macro-climatological influence on the growth of pigs. The relative humidity was recroded at 7.25 am (RH1) and at 2.25 pm (RH2). The daily mean relative humidity was calculated as an average of these two observations.

Physiological norms

Body temperature, respiration rate and cardiac rate of the individual pig were recorded twice on a day at 7.30 a.m. and 2.30 p.m. on every Saturday and Sunday in a week throughout the experimental period.

Growth parameters

Growth parameters in terms of live weight, body length, chest girth and height were recorded at fortnightly intervals. The body weight were recorded using a platform balance having a built in cage. Body length, chest girth and height were recorded using a measuring tape in centimeter.

Feed consumption, feed conversion, efficiency and average daily gain were also recorded.

The data collected were statistically analysed as per methods described by Snedecor and Cochran (1985) and results interpretted.

Results

4. RESULTS

The results and data obtained during the course of study are summarised in Table 4.1 to 4.9 and Fig.4.1 to 4.7.

4.1 Environmental variables

Fortnightly mean of environmental variables such as maximum and minimum temperature, mean temperature, relative humidity 1 at 7.25 am, relative humidity 2 at 2.25 pm, mean relatively humidity, wind speed are presented in Table 4.1 and the effect of the mean temperature on the average daily gain in T_1, T_2, T_3 and T_4 treatment groups are depicted graphically in Fig.4.1 and Fig.4.2.

4.2 Physiological norms

4.2.1 Body temperature

The mean ± SE of body temperature of pigs both in forenoon and afternoon for T_1, T_2, T_3 and T_4 treatment groups are furnished in Table 4.2 and it is depicted graphically in Fig.4.3. There was significant ($P<0.05$) difference between T_1 and other three treatments in forenoon observations. But there was no significant difference between T_3 and T_4. Other treatments T_1 and T_2 varied significantly ($P<0.05$) in afternoon observations.

4.2.2 Respiration

The mean ± SE of respiration rate of pigs both in forenoon and afternoon for T_1, T_2, T_3 and T_4 treatment groups are presented in Table 4.2. There was significant ($P<0.05$) difference between treatment groups except T_2 and T_3 in the forenoon but in afternoon each treatment group vary significantly ($P<0.05$). The mean respiration rate of four treatment groups both in forenoon and afternoon are shown in graphical form in Fig.4.4.

4.2.3 Cardiac rate

The mean ± SE of cardiac rate of T_1, T_2, T_3 and T_4 treatment groups in forenoon and afternoon are furnished in Table 4.2. There was significant ($P<0.05$) difference between treatment groups both in forenoon and afternoon except T_2 and T_3. The mean of cardiac rate of four treatment groups graphically presented in Fig.4.5.

4.3 Growth performance

4.3.1 Body weight

The fortnightly body weight (mean ± SE) of pigs reared under treatments T_1, T_2, T_3 and T_4 are furnished in Table 4.3.

The body weight of pigs at different stages of growth under different treatments found to be nonsignificant.

4.3.2 Body length

The fortnightly body length (mean ± SE) of pigs of treatments T_1, T_2, T_3 and T_4 are presented in Table 4.4. There was no significant difference between body length of pigs at different stages of growth under different treatments.

4.3.3 Chest girth

The fortnightly chest girth (mean ± SE) of pigs reared under treatments T_1, T_2, T_3 and T_4 are tabulated in Table 4.5. The chest girth of pigs at different stages of growth under different treatments found to be nonsignificant.

4.3.4 Body height

The fortnightly body height (mean ± SE) of pigs of treatments T_1, T_2, T_3 and T_4 are presented in Table 4.6. There was no significant difference between body height of pigs at different stages of growth under different treatments.

4.3.5 Rate of gain

Fortnightly rate of gain of pigs of treatment groups T_1, T_2, T_3 and T_4 are tabulated in Table 4.7. There was no significant difference in overall fortnightly rate of gain.

4.3.6 Average daily gain

Average daily gain of pigs of treatment groups T_1, T_2, T_3 and T_4 at fortnightly interval are presented in Table 4.8 and is shown graphically in Fig.4.6. There was no significant difference among treatment groups in overall average daily gain.

4.3.7 Feed consumption, feed efficiency and cost of production

The total feed consumption of pigs in each treatment, total body weight gain of pigs in each treatment, average daily feed intake per animal, average daily gain, feed efficiency and cost for per kg live weight production are furnished in Table 4.9. Feed efficiency of treatment groups T_1, T_2, T_3 and T_4 are depicted graphically in Fig.4.7.

Table 4.1 Environmental variables (mean) of fortnightly interval during the period of experiment

Fort-nights	Maximum temp °C	Minimum temp °C	Mean temp °C	RH 1(%) 7.25 am	RH2(%) 2.25 pm	Mean RH(%)	Wind speed km/h
1	31.5	23.3	27.4	84.1	65.5	74.8	6.2
2	31.8	23.9	27.9	86.8	64.6	75.7	4.0
3	31.9	23.5	27.7	77.5	51.5	64.6	7.8
4	32.2	22.8	27.5	76.7	49.7	63.2	6.9
5	34.5	24.7	29.6	82.5	48.8	65.7	5.8
6	34.8	23.6	29.2	78.0	50.8	64.4	7.0
7	34.1	23.6	28.8	89.7	55.9	72.8	2.8
8	35.6	23.8	29.7	88.6	49.3	68.9	3.3
9	36.9	23.5	30.2	83.0	43.9	63.4	3.7
10	37.0	25.1	31.0	85.3	44.6	64.9	3.1
11	36.4	26.1	31.3	86.1	53.3	69.7	3.2
12	35.6	25.4	30.5	88.6	55.1	71.9	2.3

Table 4.2 Mean and S.E. of physiological norms of treatment groups

Treatment groups / Physiological norms		Without wallow and sprinkler T_1	Wallow only T_2	Sprinkler only T_3	Wallow and sprinkler T_4
Body temperature °C	FN	38.700± 0.020^{a}	38.533± 0.020^{b}	38.450± 0.040^{b}	38.433± 0.040^{b}
	AN	39.483± 0.040^{a}	39.283± 0.081^{b}	39.100± 0.036^{c}	39.000± 0.036^{c}
Respiration rate	FN	31.800± 0.718^{a}	28.183± 0.563^{b}	26.433± 0.836^{bc}	25.200± 0.836^{c}
	AN	68.867± 1.689^{a}	59.583± 1.591^{b}	54.300± 1.093^{c}	46.917± 0.918^{d}
Cardiac rate	FN	68.333± 0.371^{a}	66.667± 0.489^{b}	65.550± 0.253^{b}	63.467± 0.828^{c}
	AN	88.233± 0.877^{a}	80.083± 0.746^{b}	80.333± 0.779^{b}	77.183± 0.648^{c}

FN - Forenoon 7.30 AM
AN - Afternoon 2.30 PM

Figures having different superscript in the row varies significantly ($P<0.05$)

Table 4.3 Mean and S.E. of fortnightly body weight (kg) of pigs

Fortnights	Treatment groups			
	T_1	T_2	T_3	T_4
1	11.867 ± 0.624^{a}	11.567 ± 1.093^{a}	11.933 ± 1.404^{a}	11.783 ± 0.616^{a}
2	13.483 ± 0.734^{a}	13.167 ± 1.257^{a}	15.350 ± 2.224^{a}	14.533 ± 1.089^{a}
3	18.833 ± 1.114^{a}	18.083 ± 1.636^{a}	21.500 ± 3.012^{a}	20.850 ± 1.546^{a}
4	24.000 ± 1.314^{a}	22.833 ± 1.951^{a}	26.500 ± 3.314^{a}	25.583 ± 2.159^{a}
5	28.750 ± 1.493^{a}	29.083 ± 2.877^{a}	33.167 ± 4.077^{a}	33.950 ± 2.751^{a}
6	34.167 ± 1.583^{a}	34.083 ± 3.440^{a}	38.500 ± 4.453^{a}	37.333 ± 3.228^{a}
7	40.167 ± 1.697^{a}	39.917 ± 3.767^{a}	44.333 ± 5.167^{a}	43.750 ± 3.424^{a}
8	46.583 ± 1.800^{a}	45.250 ± 3.767^{a}	51.500 ± 5.163^{a}	49.000 ± 3.746^{a}
9	52.883 ± 1.563^{a}	50.417 ± 3.714^{a}	55.083 ± 4.718^{a}	54.583 ± 3.718^{a}
10	55.750 ± 1.604^{a}	53.917 ± 4.175^{a}	58.333 ± 5.191^{a}	57.583 ± 4.853^{a}
11	62.083 ± 1.514^{a}	61.500 ± 4.918^{a}	64.500 ± 4.546^{a}	63.250 ± 5.195^{a}
12	70.833 ± 2.114^{a}	69.333 ± 5.816^{a}	73.333 ± 5.681^{a}	71.667 ± 5.975^{a}

Figures having the same superscript in a row do not vary significantly ($P<0.05$)

Table 4.4 Mean and S.E. of fortnightly body length (cm) of pigs

Fortnights	Treatment groups			
	T_1	T_2	T_3	T_4
1	$53.16^{a}\pm0.60$	$50.60^{a}\pm1.64$	$50.00^{a}\pm2.40$	$50.33^{a}\pm0.71$
2	$54.83^{a}\pm0.70$	$53.33^{a}\pm1.89$	$52.83^{a}\pm2.45$	$52.83^{a}\pm0.95$
3	$56.67^{a}\pm0.80$	$56.50^{a}\pm2.20$	$56.00^{a}\pm2.56$	$56.00^{a}\pm1.44$
4	$59.67^{a}\pm1.38$	$59.83^{a}\pm2.70$	$60.67^{a}\pm2.18$	$59.83^{a}\pm1.96$
5	$64.67^{a}\pm1.54$	$66.00^{a}\pm1.57$	$66.07^{a}\pm2.23$	$65.67^{a}\pm2.03$
6	$68.00^{a}\pm1.65$	$66.33^{a}\pm1.54$	$70.83^{a}\pm1.82$	$69.83^{a}\pm1.82$
7	$72.00^{a}\pm1.51$	$74.50^{a}\pm2.78$	$76.50^{a}\pm1.75$	$75.83^{a}\pm1.70$
8	$75.17^{a}\pm1.51$	$76.50^{a}\pm2.74$	$80.33^{a}\pm1.56$	$80.17^{a}\pm1.56$
9	$78.17^{a}\pm2.26$	$81.00^{a}\pm2.42$	$82.00^{a}\pm1.93$	$81.00^{a}\pm1.75$
10	$83.67^{a}\pm0.76$	$82.83^{a}\pm2.60$	$84.00^{a}\pm1.84$	$82.83^{a}\pm1.91$
11	$86.00^{a}\pm0.63$	$86.50^{a}\pm1.48$	$88.33^{a}\pm1.60$	$87.00^{a}\pm2.19$
12	$89.00^{a}\pm1.34$	$89.33^{a}\pm1.64$	$90.67^{a}\pm1.38$	$89.00^{a}\pm1.48$

Figures having the same superscript in a row do not vary significantly ($P<0.05$)

11	$61.00^{a}\pm0.51$	$59.50^{a}\pm1.43$	$61.50^{a}\pm1.59$	$61.00^{a}\pm1.77$
12	$62.33^{a}\pm$[illegible]	$60.17^{a}\pm$[illegible]	$62.33^{a}\pm$[illegible]	$61.83^{a}\pm$[illegible]

Table 4.5 Mean and S.E. of fortnightly chest girth (cm) of pigs

Fortnights	Treatment groups			
	T_1	T_2	T_3	T_4
1	51.00±1.67 [a]	50.00±1.86 [a]	50.17±1.87 [a]	51.17±0.95 [a]
2	53.17±0.95 [a]	52.50±0.84 [a]	54.17±2.24 [a]	54.83±1.20 [a]
3	56.83±1.08 [a]	55.83±2.18 [a]	59.00±2.91 [a]	59.00±1.61 [a]
4	59.67±0.88 [a]	59.67±1.96 [a]	63.92±3.07 [a]	62.33±1.71 [a]
5	65.00±1.13 [a]	65.17±2.93 [a]	68.33±1.84 [a]	68.00±1.88 [a]
6	71.00±1.29 [a]	71.67±2.94 [a]	73.50±2.69 [a]	71.00±2.41 [a]
7	75.83±1.14 [a]	74.16±3.11 [a]	78.17±3.09 [a]	78.00±2.35 [a]
8	78.17±1.17 [a]	77.00±2.76 [a]	82.83±3.10 [a]	81.00±2.07 [a]
9	84.00±0.36 [a]	82.50±2.90 [a]	85.00±2.22 [a]	84.83±2.26 [a]
10	84.67±0.80 [a]	87.17±3.76 [a]	87.67±1.98 [a]	86.50±2.55 [a]
11	86.67±0.67 [a]	90.33±3.13 [a]	90.50±1.33 [a]	89.17±3.00 [a]
12	92.83±0.47 [a]	92.00±3.31 [a]	92.83±1.40 [a]	92.67±3.56 [a]

Figures having the same superscript in a row do not vary significantly (P<0.05)

Table 4.6 Mean and S.E. of fortnightly body height (cm) of pigs

Fortnights	Treatment groups			
	T_1	T_2	T_3	T_4
1	36.66±0.21 [a]	35.00±0.73 [a]	35.20±0.87 [a]	33.20±0.76 [a]
2	38.33±0.21 [a]	36.50±0.67 [a]	37.50±0.84 [a]	35.83±0.60 [a]
3	40.50±0.62 [a]	38.17±0.95 [a]	40.33±1.20 [a]	38.80±0.86 [a]
4	43.00±0.73 [a]	41.00±1.41 [a]	44.00±1.69 [a]	42.17±1.14 [a]
5	47.17±0.54 [a]	45.50±1.63 [a]	47.33±1.43 [a]	48.17±1.35 [a]
6	50.33±0.62 [a]	49.00±1.18 [a]	52.17±1.76 [a]	51.50±0.92 [a]
7	53.67±1.05 [a]	52.00±1.44 [a]	54.67±1.78 [a]	54.50±1.26 [a]
8	56.00±1.48 [a]	54.50±1.49 [a]	57.50±2.26 [a]	56.17±1.33 [a]
9	57.83±0.83 [a]	57.17±1.44 [a]	59.83±1.35 [a]	57.33±1.36 [a]
10	59.83±0.54 [a]	58.00±1.51 [a]	60.83±1.53 [a]	60.00±1.59 [a]
11	61.00±0.51 [a]	59.50±1.43 [a]	61.50±1.59 [a]	61.00±1.77 [a]
12	62.33±0.33 [a]	60.17±1.66 [a]	62.33±1.71 [a]	61.83±1.78 [a]

Figures having the same superscript in a row do not vary significantly (P<0.05)

Table 4.7 Fortnightly rate of gain (kg) of pigs

Fortnights	Treatment groups			
	T_1	T_2	T_3	T_4
1	2.03	1.81	1.93	2.11
2	1.62	2.04	3.42	2.72
3	5.35	4.40	6.15	6.35
4	5.17	4.83	5.00	4.73
5	4.75	6.25	6.67	6.37
6	5.41	5.00	5.33	5.38
7	5.17	5.84	5.83	6.42
8	7.17	5.33	7.17	5.25
9	6.33	5.17	3.58	5.58
10	2.92	3.52	3.25	2.92
11	6.33	7.58	6.17	5.73
12	8.75	7.83	8.83	8.42
Average rate of gain	$5.08^{a} \pm 0.60$	$4.97^{a} \pm 0.54$	$5.28^{a} \pm 0.56$	$5.17^{a} \pm 0.60$

Figures having the same superscript in the row do not vary significantly ($P<0.05$)

Table 4.8 Average daily gain (g) of pigs

Fortnights	Treatment groups			
	T_1	T_2	T_3	T_4
1	135	121	128	141
2	108	136	228	181
3	357	293	410	423
4	345	322	333	315
5	317	417	445	425
6	361	333	355	359
7	345	389	388	428
8	478	355	478	350
9	422	343	238	372
10	195	235	217	195
11	422	505	411	377
12	583	522	589	561
Overall average daily gain	339.0 ± 39.9^{a}	330.9 ± 36.1^{a}	351.7 ± 37.6^{a}	343.9 ± 36.0^{a}

Figures having the same superscript in the row do not vary significantly (P<0.05)

Table 4.9 Feed consumption, feed conversion efficiency and cost per kg of live body weight production of pigs

Sl. No.	Particulars	Treatment groups			
		T_1	T_2	T_3	T_4
1.	Total feed consumption (kg) of pigs during the experiment period (170 days)	1484	1484	1484	1484
2.	Total body weight (kg) gain of pigs during experiment period	366	357.5	380	372
3.	Average daily feed intake/animal (kg)	1.45	1.45	1.45	1.45
4.	Average daily gain (g)	339	330.9	351.7	343.9
5.	Feed conversion efficiency (kg feed/kg gain)	4.05	4.15	3.91	3.99
6.	Cost per kg of live body weight production (Rs.)	36.16	37.03	35.05	35.81

Assumption

1. 80% of total cost of production is accounted for feed
2. Sprinkler cost/kg of meat Rs.0.17

Fig.4.1 EFFECT OF TEMPERATURE ON AVERAGE DAILY GAIN OF PIGS

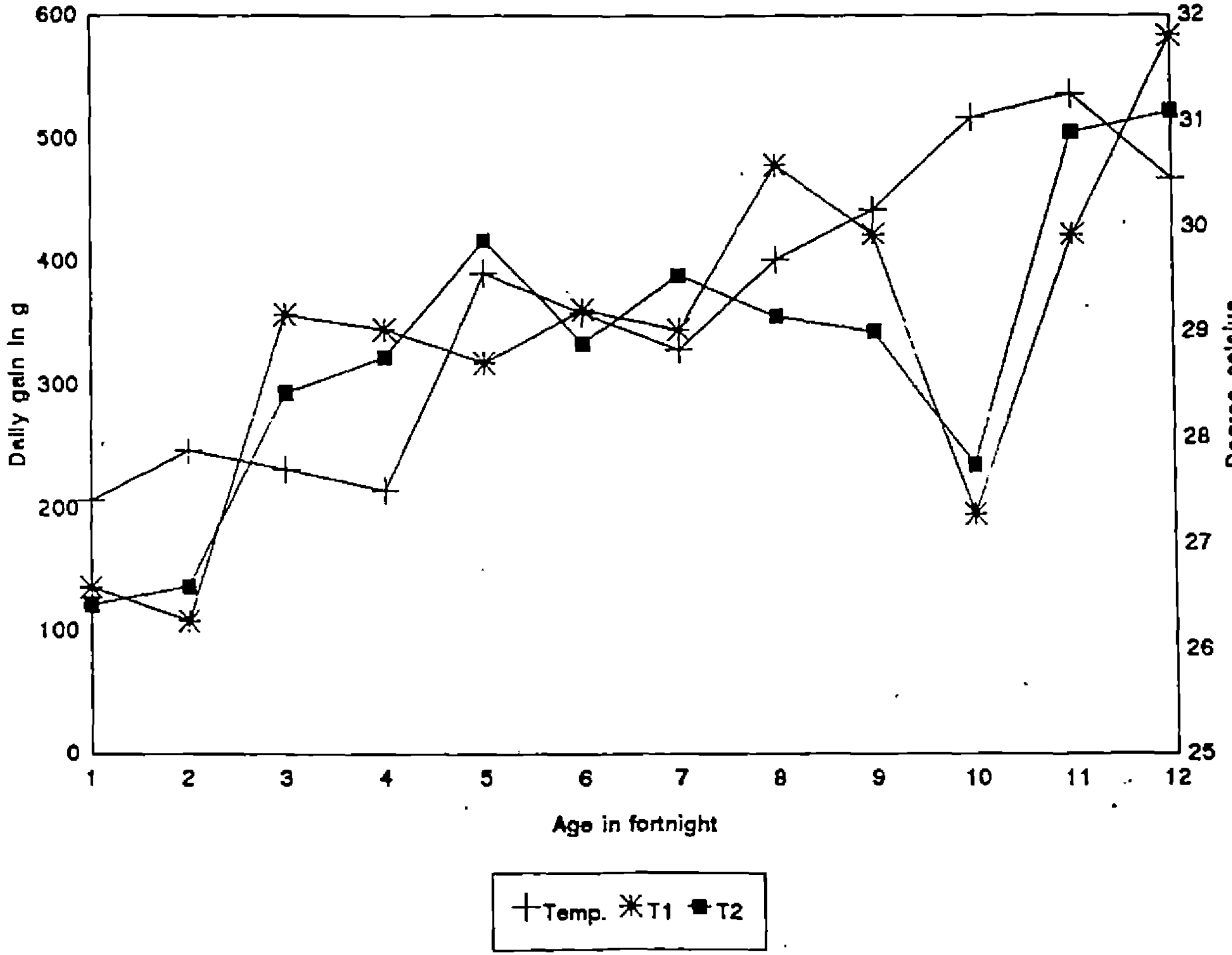


Fig 4.2 EFFECT OF TEMPERATURE ON AVERAGE DAILY GAIN OF PIGS

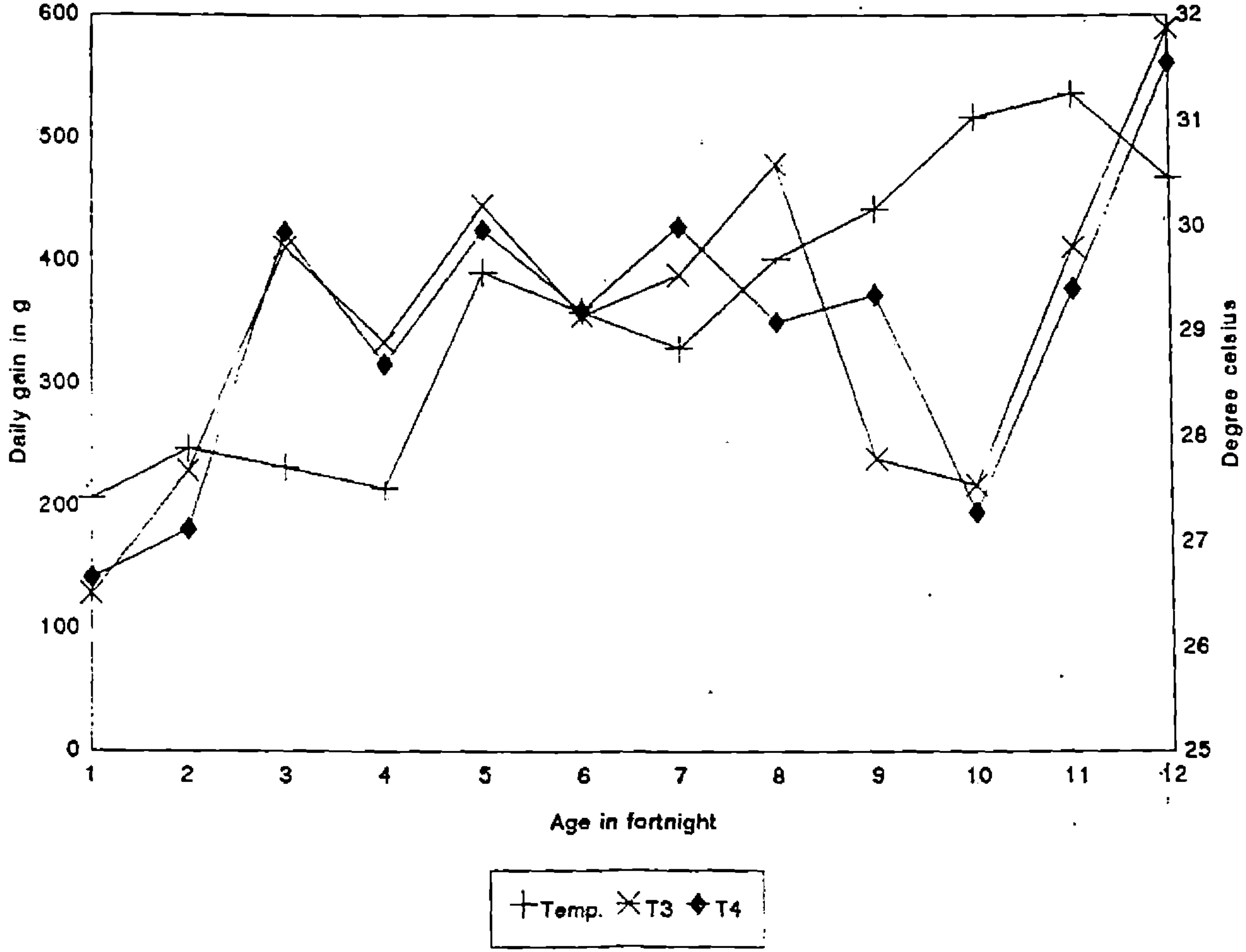


Fig.4.3 BODY TEMPERATURE OF PIGS (FORENOON AND AFTERNOON)

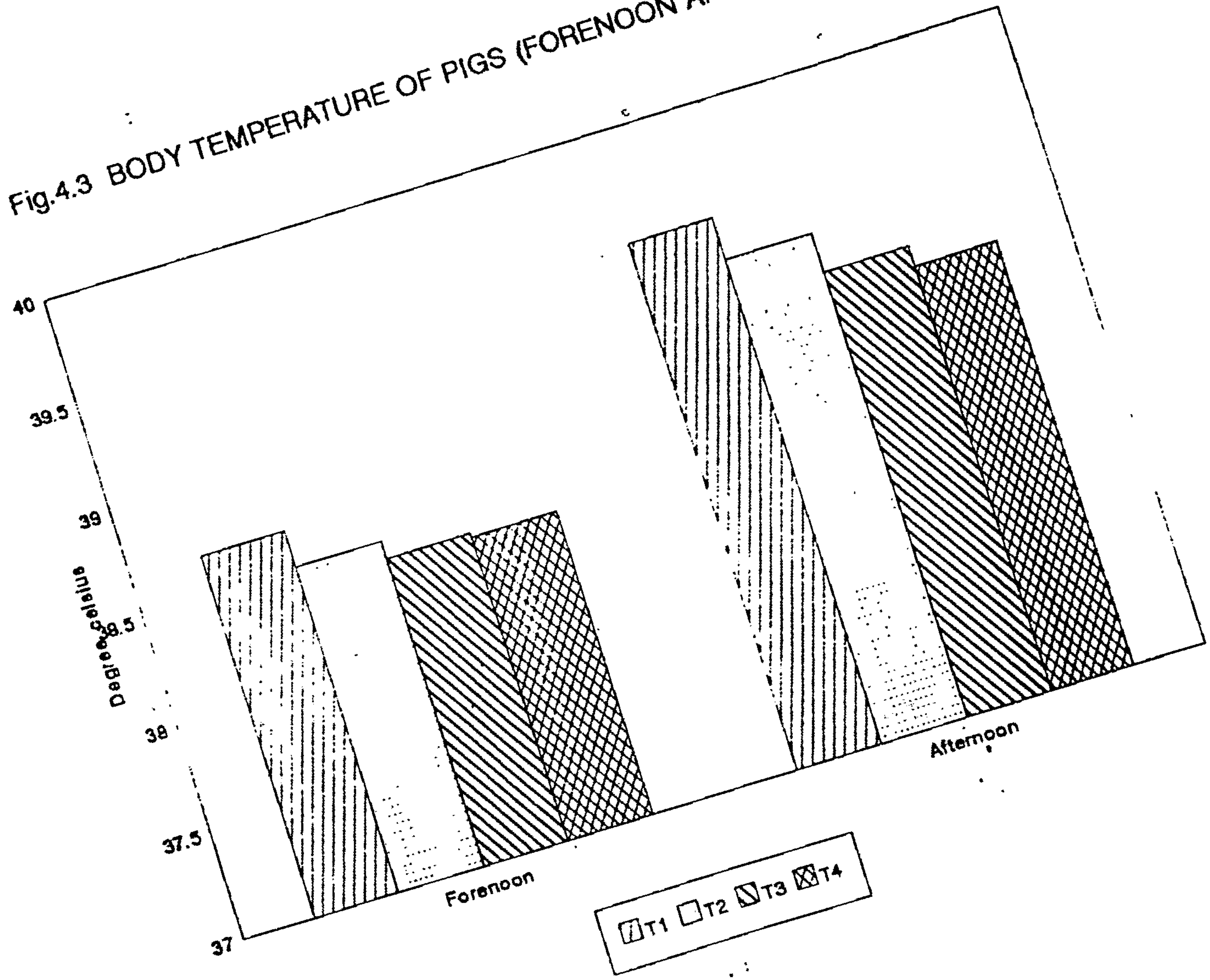


Fig.4.4 RESPIRATION RATE OF PIGS (FORENOON AND AFTERNOON)

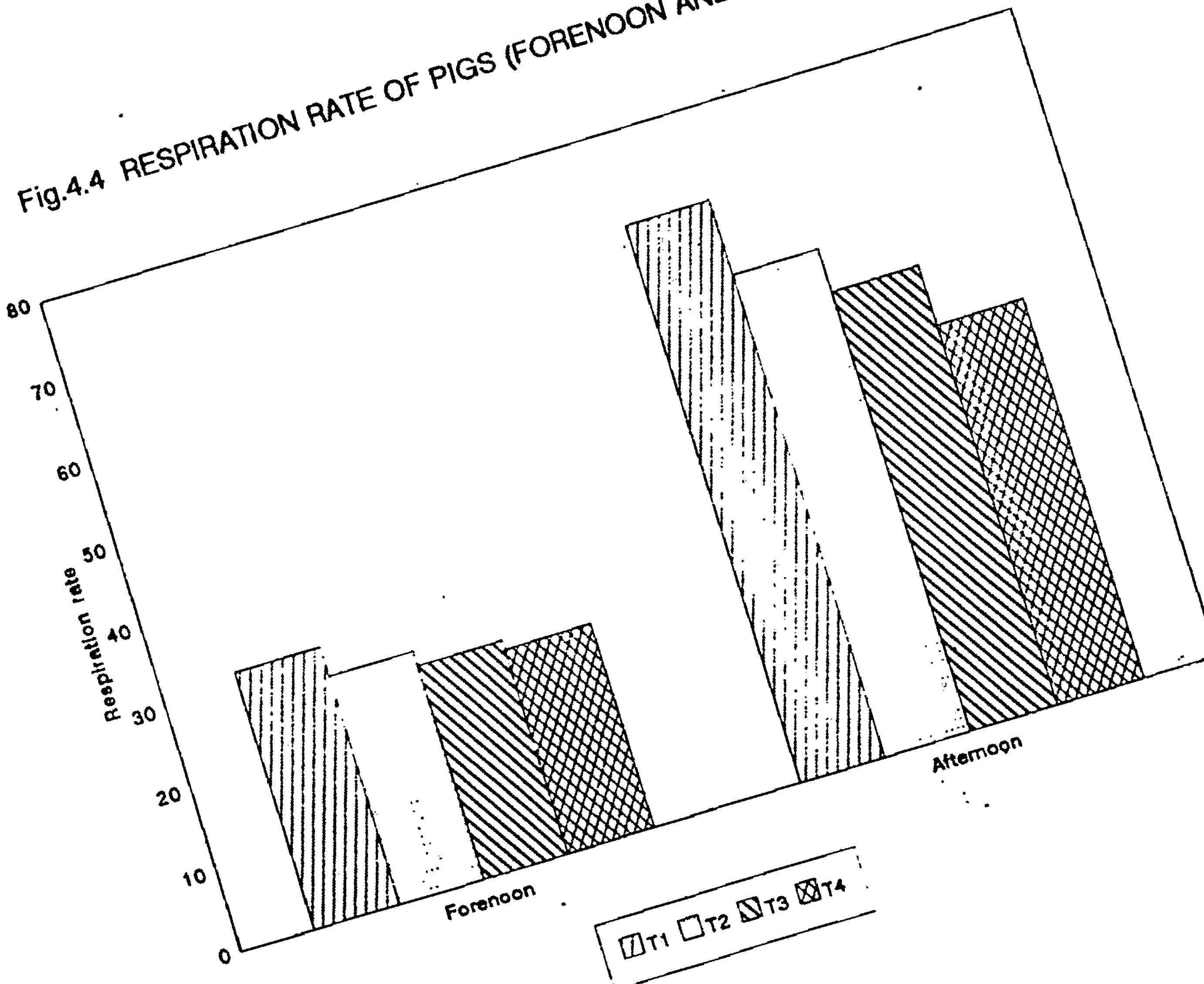


Fig. 4.5 CARDIAC RATE OF PIGS (FORENOON AND AFTERNOON)

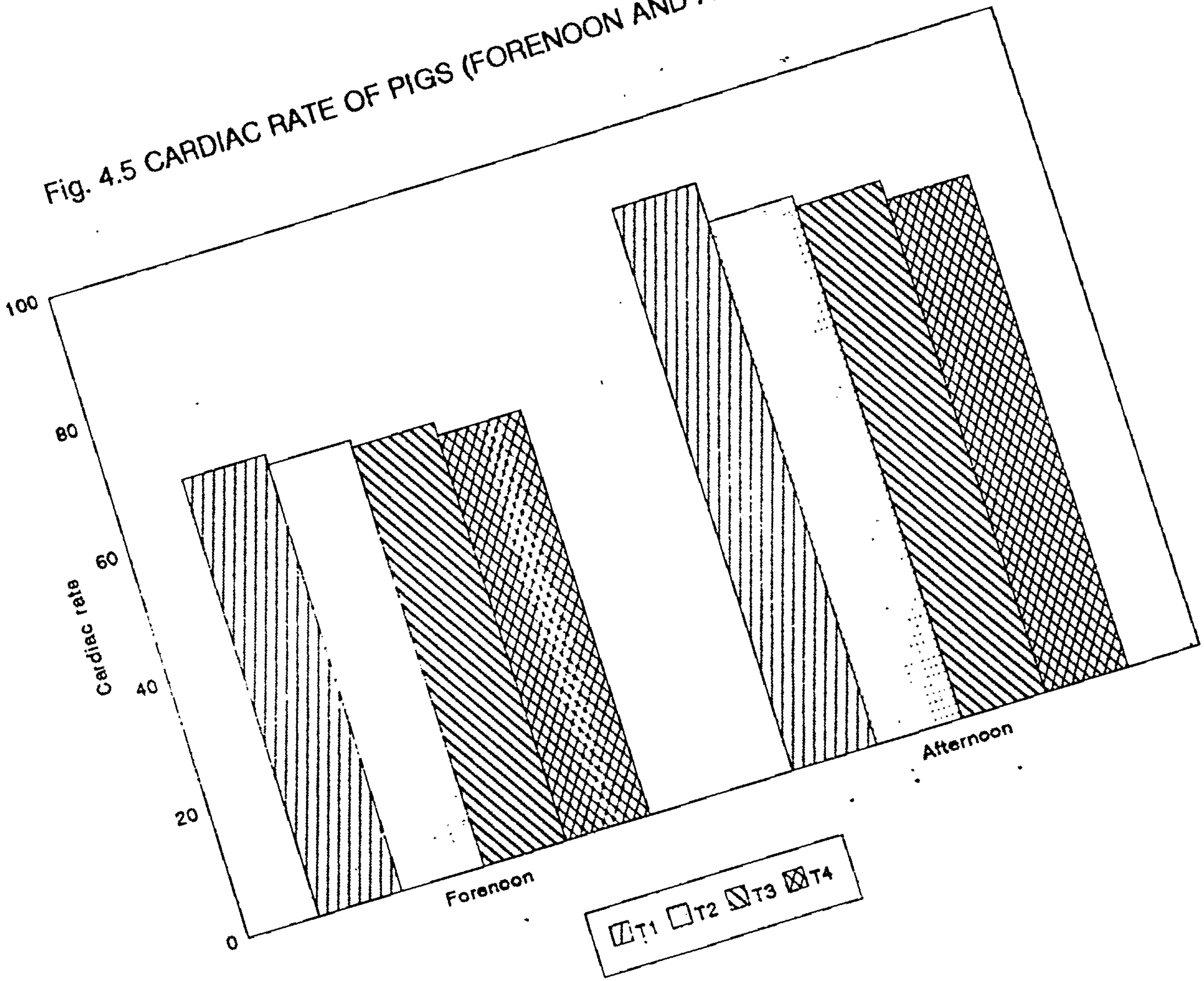


Fig 4.6 AVERAGE DAILY GAIN OF PIGS

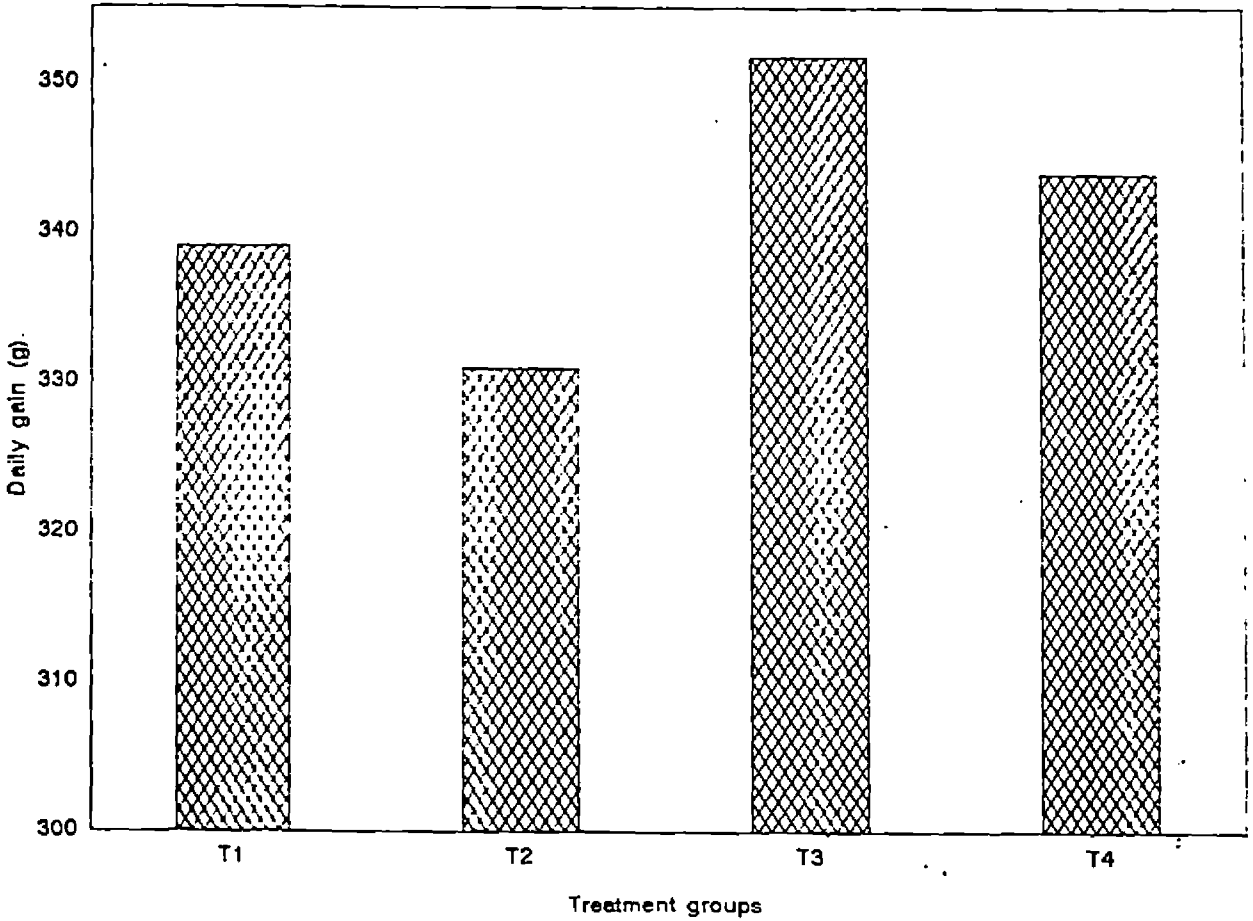
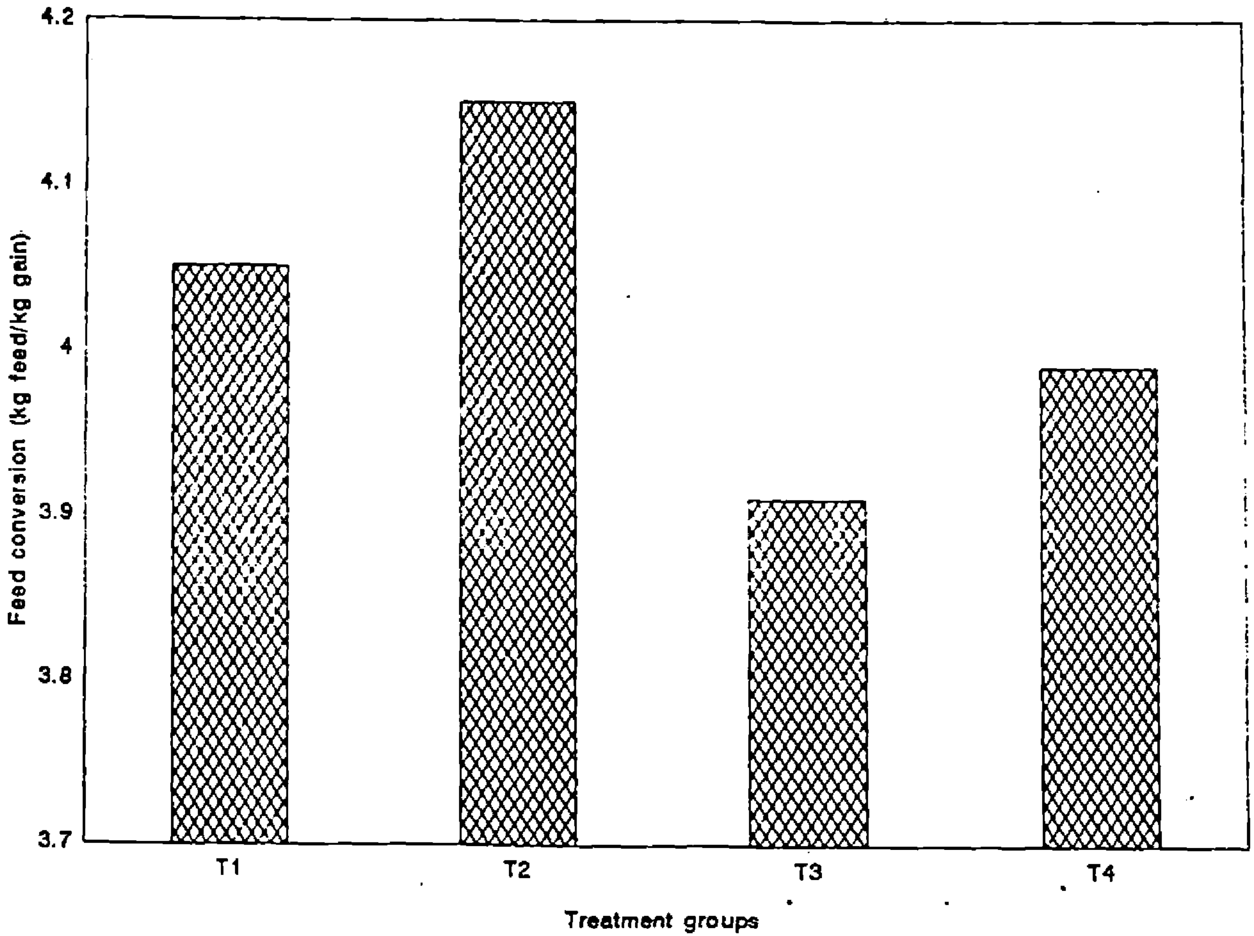


Fig. 4.7 FEED EFFICIENCY OF PIGS



Discussion

5. DISCUSSION

5.1 Environmental variables

According to the classification of Somanathan (1980) the study period falls in the hot-dry season which include the months of December, January, February, March and April. Dry season is characterised by high ambient temperature, long hours of sunshine, high wind velocity and comparatively low relative humidity and vapour pressure. Dry season was further subdivided into two groups based on the prevailing ambient temperature.

The dry season is divided into:

a. Warm and dry - where the maximum temperature did not exceed 32°C (December and January)

b. Hot and dry - where the maximum temperature was above 32°C (February to April)

The findings of the environmental variables in this study were in accordance with the classification by Somanathan (1980). The initial four fortnights in the months of December and January (warm and dry season) wherein the maximum temperature was in the range of 31.5°C to 32.2°C. From the fifth to eleventh fortnight has fallen in hot and dry season wherein the maximum temperature was in the range of 34.5 to 37°C. The peak maximum temperature was recorded at tenth fortnight (37°C). The minimum temperature recorded in the experiment period was in the range of 23.3 to 26.1°C and there was a drastic rise in minimum temperature during the tenth and eleventh fortnights (25.1°C and 26.1°C). The fortnightly daily mean temperature had ranged from 27.4°C in the first fortnight to 31°C in the tenth fortnight. There were two sharp rise in the mean temperature from fourth fortnight (27.5°C) to fifth fortnight (29.6°C) and from eighth fortnight (30.1°C) to eleventh fortnight (31.0°C).

The RH1 in the forenoon observations has ranged from 76.7 per cent to 89.7 per cent while the RH2 in the afternoon observation has fallen within the range of 43.9 per cent to 65.5 per cent. The fortnightly daily mean relative humidity ranged between 63.2 per cent to 75.7 per cent. A trend of higher level of relative humidity was recorded in the initial two fortnights than the further period of study. The observed level of the relative humidity in this range might not play major stress factor in that dry season in comparison with that of ambient temperature. This can be substantiated based on the literature reviewed in 2.1.2.

In hot, humid environment low air movement is the characteristic. The dry season had recorded highest wind velocity at the same station in an earlier study (Somanathan, 1980).

The wind speed recorded in the experimental period ranged from 2.3 to 7 km/h. A trend of higher air movement was observed upto sixth fortnights and thereafter lower wind speed below 3.7 km/h. The low air movement associated with higher ambient temperature might have played more stress in the finishing period of the study.

It is reported that ambient temperature, relative humidity and wind speed are the important climatic elements which effect the growth performance in pigs (Heitman *et al.*, 1958; Comberg *et al.*, 1967; McDowel, 1972; Morrison *et al.*, 1975; Kamada *et al.*, 1985; Korthals *et al.*, 1994; Hale, and Coey, 1961; Morrison *et al.*, 1967; Greorgiev *et al.*, 1972; Bresk, 1984; Sainsbury and Dunkin, 1953; Holmes and Mount, 1967; Randell, 1975; Curtis, 1983 and Kamada and Notsuki, 1987).

5.2 Physiological norms

5.2.1 Body temperature

The body temperature of pigs of T_1, T_2, T_3 and T_4 in the forenoon were 38.700 ± 0.02, 38.533 ± 0.02, 38.453 ± 0.04 and 38.433 ± 0.04 and in the afternoon 39.483 ± 0.04, 39.283 ±

0.081, 39.1 ± 0.036 and 39 ± 0.036 respectively (Table 4.2). In the forenoon T_1 was having significantly ($P<0.05$) higher temperature than T_2, T_3 and T_4 while in the afternoon T_1 and T_2 were having significantly ($P<0.05$) higher temperature from T_3 and T_4 (Table 4.2). The rise in body temperature in the four treatments in the afternoon from the forenoon was in between 0.6 to 0.7°C.

The diurnal variation of body temperature in pigs and rise of body temperature during high environmental temperature were in agreement with Dukes (1955), Sutherland (1967), Martin (1970), Georgiev *et al.* (1972), Mathur (1990) and Korthals *et al.* (1994). The peak rise of body temperature in T_1 without wallow and sprinkler facility might be due to the absence of facilities for evaporative cooling in the peak hours of heat stress. It is supported by the observation made by Joseph (1997). The minimisation in the rise of body temperature in the peak hours of heat stress by the provision of wallows and sprinklers was reported by Garrett *et al.* (1960), Kelley *et al.* (1965), Morrison *et al* (1968) and Mc Arthur and Ousey (1994).

5.2.2 Respiration rate

The recorded observations of respiration rate of pigs of four treatment groups in the forenoon were 31.8 ± 0.718, 28.183 ± 0.563, 26.433 ± 0.836 and 25.200 ± 0.836 for T_1, T_2,

T_3 and T_4 respectively. The afternoon respiration rate of treatment groups of T_1, T_2, T_3 and T_4 were 68.867 ± 1.689, 59.583 ± 1.591, 54.300 ± 1.093 and 46.917 ± 0.918 respectively. In the forenoon observations T_1 significantly ($P<0.05$) varied from T_2, T_3 and T_4 while treatment groups T_2 and T_3, T_3 and T_4 did not have significant difference. But in the afternoon each treatment group had a significant ($P<0.05$) difference from other treatments. This points to the added advantage of providing sprinklers and wallows in pig sties for facilitating thermolysis in growing pigs.

The above findings are in agreement with . Heitman *et al.* (1959), Garrett *et al.* (1960), Morrison *et al.* (1968), Nicholas *et al.* (1983) and Joseph (1997).

The significance of increase of respiration rate under heat stress is that it enable the animals to dissipate the excess body heat by vaporising more moisture in the expired air. This was proved in the T_1 group which did not have the provision of wallow and sprinkler for surface wetting to exploit the evaporative cooling. The lower respiration rate in T_2, T_3 and T_4 was possible due to evaporative heat loss through the channel of wallow, sprinkler and sprinkler and wallow wetting of the body surface of pigs.

5.2.3 Cardiac rate

The recorded cardiac rate in the forenoon for T_1, T_2, T_3 and T_4 were 68.333 ± 0.371, 66.67 ± 0.489. 65.550 ± 0.253 and 63.467 ± 0.828 respectively while the values for afternoon were 88.233 ± 0.877, 80.083 ± 0.746, 80.333 ± 0.779 and 77.183 ± 0.648. There was significantly ($P<0.05$) lower cardiac rate in T_4 from T_1, T_2 and T_3 in the forenoon. T_2 and T_3 did not vary significantly in the forenoon observations but these vary significantly from T_1. In the afternoon, T_2 and T_3 did not vary significantly but both vary significantly ($P<0.05$) from T_1 and T_4. The higher trend of cardiac rate in T_1 was similar to the observations of Joseph (1997) who recorded higher pulse rate in pigs housed in open without wallow and sprinkler.

In the present study, exposure of pigs to high ambient temperature in dry season without the provision of evaporative cooling in the form of wallow and sprinkler has been found to increase cardiac rate significantly in comparison to the treatment groups which were provided with wallow or sprinkler or both. The picture was slightly different in the forenoon observation but was highly different in the afternoon observations. The cardiac rate reflects the reaction of the circulatory system of the animals in which more blood is brought to the periphery and lungs to facilitate thermolysis.

5.3 Growth performance

5.3.1 Fortnightly body weight

Fortnightly body weight of pigs of treatment groups T_1, T_2, T_3 and T_4 can be seen in Table 4.3. The following were the mean of body weight of the treatment groups T_1, T_2, T_3 and T_4 in the first fortnight 11.867 ± 0.624, 11.567 ± 1.093, 11.933 ± 1.404 and 11.783 ± 0.616 respectively. The body weight of pigs in all treatment groups have increased progressively from weaning to twelfth fortnight indicating that as age advanced the body weight also increased. The twelfth fortnight body weight of the treatment groups T_1, T_2, T_3 and T_4 were 70.833 ± 2.114, 69.335 ± 5.816, 73.335 ± 5.681 and 71.667 ± 5.975 respectively. These did not vary significantly between them.

A trend for higher body weight were observed in T_3 and T_4 groups which might be the beneficial effect of environmental enrichment during the hot hours of day time during the dry season. These observations are in accordance with McCormick *et al.* (1956), Hale *et al.* (1966), Morrison *et al.* (1968), Morrison *et al.* (1970) and Hsia *et al.* (1974).

A relatively lower trend although non-significant in the body weight of T_2 group compared to T_1, T_3 and T_4 group raise the questionable value of the wallow as the enrichment to reduce heat stress for fattener pigs in dry season. The lower trend in body weight of T_2 were in contrast with Heitman and Huges (1949), Bray and Singletary (1948), Andrews *et al.* (1956). But these observation were supported by Arganosa *et al.* (1988) and Joseph (1997). The lower trend in the T_2 in comparison with T_3 may be due to the fact that habitual wallowing (wallowing for the sake of wallowing even at cold hours of the day) might have lead to certain degree of body depletion for maintenance of body temperature resulting in less body weight in the group (Joseph, 1997).

The poor growth performance of T_2 vis a vis T_3 and T_4 and even T_1 indicates that the current recommendation of the use of wallow to relieve summer stress for fattening pigs need to be reconsidered based on the above findings. Although T_1 group showed more of physiological stress reactions like rise of body temperature, rise of respiration rate and rise of cardiac rate during the peak hot hours of day time that might not have reached severity enough to reduce the growth performance. It necessitates a better understanding of the long term acclimatization process through several generations on the exotic pigs in the humid tropics. This point of view was substantiated by Ames and Ray (1983). They had stated that too often, most of the research and field observations have focused on the short term, acute responses to unfavourable environments and have failed to recognize longer term responses of the important role played by adaptation and compensation. Future research should place much more emphasis on the adaptation and compensation of animal response when assessing environmental impacts on animal productivity.

5.3.2 Body length

Fortnightly body length of pigs maintained in various treatment groups can be seen Table 4.4 Body length of pigs of treatment group T_1, T_2, T_3 and T_4 were 53.0 ± 0.60, 50.60 ± 1.64, 50.0 ± 2.40 and 50.33 ± 0.71 respectively in the first fortnight. There was progressive increase in the body length of the pigs in all the treatment groups while age advances upto twelfth fortnight. There was no significant ($P<0.05$) variation between the treatment groups in the first fortnight body length and at subsequent fortnightly body length upto the twelfth fortnight. The twelfth fortnight's is observation of body length of T_1, T_2, T_3 and T_4 were 89.0 ± 1.34, 89.33 ± 1.64, 90.67 ± 1.38 and 89.00 ± 1.48 respectively.

The progressive nature of increasing body length as the age advances was in accordance with Brody (1945), Leena (1992), Pradhan (1993) and Joseph (1997).

5.3.3 Chest girth

Fortnightly chest girth of pigs of four treatment groups can be seen in Table 4.5. The initial fortnightly chest girth of pigs of treatment groups T_1, T_2, T_3 and T_4 were 51.00 ± 1.67, 50.00 ± 1.86, 50.17 ± 1.67 and 51.17 ± 0.95 respectively. There was no significant variation in between treatment groups in the initial observations. The growth inturn of girth showed a progressive increasing tendency from initial stage to final stage in all the treatment groups as that of growth expressed in terms of weight, length and height. There were no significant difference between treatment groups from the initial observation to twelfth observation. The final chest girth of the treatment groups T_1, T_2, T_3 and T_4 were 92.83 ± 1.47. 92.00 ± 3.31, 92.83 ± 1.40 and 92.67 ± 3.56.

Similar reports of chest girth of pigs were reported by Leena (1992), Pradhan (1993) and Joseph (1997).

5.3.4 Body height

Fortnightly body height of pigs of treatment groups T_1, T_2, T_3 and T_4 is given in Table 4.6. The first fortnight body height of pigs of treatment groups T_1, T_2, T_3 and T_4 were 36.66 ± 0.21, 35.00 ± 0.73, 35.2 ± 0.87 and 33.20 ± 0.76. There was non-significant variation between the body height between treatment groups in the first fortnight. The body height of pigs of all the treatment groups increases progressively as age advances. There were no significant difference between treatment groups in the subsequent fortnightly body height of pigs upto twelfth fortnight. The twelfth fortnight body height of pigs of T_1, T_2, T_3 and T_4 were 62.33 ± 0.33, 60.17 ± 1.66, 62.33 ± 1.71 and 61.83 ± 1.78.

The present observation of the body height of pigs during growth were similar to that of Leena (1992), Pradhan (1993) and Joseph (1997).

5.3.5 Fortnightly rate of gain

Fortnightly rate of gain in weight of pigs of treatment groups T_1, T_2, T_3 and T_4 are given in Table 4.7. In the T_1 the rate of gain ranged from 1.62 kg in the second fortnight to 8.75 kg in twelfth fortnight. The ranges for T_2, T_3 and T_4 were 1.81 kg, 1.93 kg and 2.11 kg in the first fortnight to peak rate at twelfth fortnight 7.83, 8.83 and 8.42 respectively. In the present study, there were no consistant progressive trends in any one of the treatment groups in the rate of gain. There were sharp fall in the rate of gain in the tenth fortnight which might be the effect of sharp rise of the mean temperature in that particular fortnight (Fig.4.1 and Fig.4.2). The overall average rate of gain for T_1, T_2, T_3 and T_4 were 5.08 ± 0.60, 4.97 ± 0.54, 5.28 ± 0.56 and 5.17 ± 0.60.

Growth is never a smooth rising curve. It occurs in irregular spurts interposed with relative quiscent periods. Similar findings have been reported by Sebastian (1992) and Manju (1997).

5.3.6 Average daily gain

Average daily gain of pigs of treatment groups T_1, T_2, T_3 and T_4 can be seen in Table 4.8. The average daily gain ranged from 108 g in the second fortnight to the peak of 583 g in twelfth fortnight in the T_1 group. In case of T_2, T_3 and T_4 the range starting from 121 g, 128 g, 141 g respectively in the first fortnight to 522 g, 589 g and 561 g in the twelfth fortnight respectively. There were no consistant trend of progressive nature in the average daily gain among the treatment groups. The overall average daily gain for T_1, T_2, T_3 and T_4 were 339 ± 39.9, 330.9 ± 36.1, 351.7 ± 376 and 343.9 ± 36.0. There were no significant ($P<0.05$) variation in the average daily gain between the treatment groups. T_3 group is having relatively higher average daily gain than T_1, T_2 and T_4 groups. In the tenth fortnight the average daily gain was lower in all the treatment groups.

The higher average daily gain for sprinkled pigs were supported by Hale *et al.* (1966), Hsia *et al.* (1974) and Machado and Ouwerkerk ENJ Van (1989). The lower average daily gain of wallowing group T_2 was in contrast with Heitman *et al.*

(1959), Bray and Singletary (1948). But the lower daily gain in T_2 was supported by Arganosa *et al.* (1988) and Joseph (1997).

5.3.7 Feed consumption, feed conversion efficiency and cost of production

As measured quantity of feed was given to the treatment groups as per the recommendation of farm schedule ie the restricted feeding the animals of each treatment consumed the same quantity of feed during the period of trial. The better feed intake in the sprinkled pigs were reported by Hale *et al.* (1966) and Hsia *et al.* (1974).

Feed conversion efficiency was taken as a whole for the experimental period based on the observation of total feed intake during the experimental period and total weight gain in each treatment groups. The feed conversion efficiency of T_1, T_2, T_3 and T_4 were 4.05, 4.15, 3.91 and 3.99. The T_3 group was found to have highest efficiency 3.91 and T_2 had lowest efficiency 4.15. The higher efficiency of feed conversion for sprinkling treatment was in agreement with Hale *et al.* (1966), Hsia *et al.* (1974) and Machado and Ouwerkerk ENJ Van (1989). The lowest efficiency of T_2 was in contrast to Heitman *et al.* (1959), Bray and Singletary (1948) but in agreement with Arganosa *et al.* (1988) and Joseph (1997).

The cost of production of one kg live weight in T_1, T_2, T_3 and T_4 treatment groups were calculated. The cost of production of one kg live weight in T_1, T_2, T_3 and T_4 were Rs.36.16, Rs.37.03, Rs.35.05 and Rs.35.81. The lowest cost for per kg live weight producti on was in T_3 due to the better conversion efficiency of sprinkled pigs than others.

5.4 Overall discussion

Provision of wallowing and sprinkling reduced the ambient temperature in the pig sties during the dry season. This was reflected in the physiological reactions like respiratory and heart rates and rectal temperature. However, the heat stress was not severe enough to produce any significant effect on growth. There was a trend against wallowing and favouring sprinklers. Similar negative influence of wallowing facility was also observed in an earlier study at the same station (Joseph, 1997). This was in spite of beneficial effects on physiological reactions. As reported by Joseph (1997) earlier this might be the result of habitual wallowing resulting in energy loss.

The finding points to the necessity of rethinking over the present practice of providing wallowing tanks in pig sties. Instead it may be advantageous to provide sprinklers which are operated only when the environment is hot.

Summary

6. SUMMARY

A study was conducted in the Centre for Pig Production and Research, Kerala Agricultural University (CPPR), Mannuthy to assess the effect of modified environments during summer (dry season) on the performance of grower pigs.

Twenty four weaned female piglets similar in body weight were randomly assigned to four treatment of groups as T_1, T_2, T_3 and T_4 each consisting of six animals. All the groups were maintained in the open sties of Centre for Pig Production and Research, Mannuthy with following modified housing environment during the dry season. The modified housing environment included T_1 - without wallowing and sprinkler, T_2 - with wallowing facility only, T_3 - with sprinkler only and T_4 - with both sprinkler and wallowing facility.

Environmental variables during the period of the study was collected to find out the role of these variables on the performance on the treatment groups. The physiological norms of pigs of these treatment groups such as body temperature, respiration rate and cardiac rate were recorded weekly twice in the forenoon and afternoon.

Growth performance in terms of live weight, body length, chest girth and body height were recorded at fortnightly

intervals. Feed consumption, feed conversion efficiency, average daily gain, fortnightly rate of gain and cost per kg of live weight production were estimated.

As the period of study falls in dry season which is characterised by higher ambient temperature (maximum temperature 31.5 to 37.0°C, mean temperature 27.4 to 31.3°C, comparatively lower relative humidity (mean relative humidity 63.15 per cent to 75.68 per cent) and wind speed (2.75 to 7.8 km/h). The high ambient temperature observed was sufficient to cause stress in growing pigs.

There were significant ($P<0.05$) difference in the physiological norms between the treatment groups both in the forenoon and afternoon. T_1 was having significantly ($P<0.05$) higher trend of body temperature, respiration rate and cardiac rate than T_2, T_3 and T_4 both in forenoon as well as afternoon observations. T_2 and T_3 were found to have lesser variation in the physiological norms. T_4 appeared to be more benefited in thermolysis as reflected in their physiological norms.

Growth performance in terms of fortnightly gains in body weight, body length, chest girth and body height between treatment groups T_1, T_2, T_3 and T_4 did not have significant variation from the first fortnight to twelfth fortnight. Though the observation of fortnightly body weight were not statistically significant, T_3 and T_4 showed numerically higher values and T_2 lower trend than the T_1.

Average daily gain, fortnightly rate of gain of the treatment groups showed that T_3 has numerically higher though statistically non significant than T_1, T_2 and T_4 groups. The descending order of average daily gain and feed conversion efficiency were T_3, T_4, T_1 and T_2.

The T_3 has shown better feed conversion efficiency and lower cost per kg of live weight production. The ascending order of feed conversion efficiency and descending order of cost per kg of live body weight production were T_2, T_1, T_4 and T_3.

From the point of view of efficient production, the sprinklers can be advised in the period of dry season to reduce the heat stress in grower pigs. The feasibility of this enrichment can be substantiated based on the size of the farm. But wallow as the enrichment for the grower pigs in the current recommendations need to be reconsidered. The wallow and sprinkler treatment group can not be substantiated as the enrichment mean in terms of economical point of view.

Provision of sprinklers which are operated only during the hot hours in summer appear to be a financially viable system.

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EFFECT OF MODIFIED ENVIRONMENT DURING SUMMER ON THE PERFORMANCE OF GROWING PIGS

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ABSTRACT OF A THESIS

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ABSTRACT

An investigation was carried out to study the environment variables and the effect of modified housing conditions on the physiological norms and growth performance during the dry season on the large white Yorkshire grower pigs. The modified housing include, T_1 - without wallow and sprinkler, T_2 - with wallow only, T_3 - with sprinkler only and T_4 - with wallow and sprinkler as the four treatment groups.

The dry season (summer) characterised by higher ambient temperature (maximum temperature - 31.5° to 37°C, minimum temperature 22.8 to 26.1°C, mean temperature - 27.4°C to 31.3°C), comparatively lower relative humidity (mean RH 63.15 to 75.68%) and wind speed (2.75 to 7.8 km/h). The higher range of temperature was sufficient to cause stress on the performance of the grower pigs as per the literatures.

The treatment (T_1) without wallow and sprinkler varies significantly ($P<0.05$) in the body temperature, respiration rate, cardiac rate both in the forenoon and afternoon from the T_2, T_3 and T_4 groups, i.e., T_1 has shown more of physiological stress reaction than other treatment groups. T_4 was found to be more comfortable than T_1. T_2 and T_3 were having no significant difference except in afternoon body temperature and respiration rate.

There were no statistically significant (P<0.05) difference between treatment groups in the fortnightly body weight gain from the first fortnight to upto twelfth fortnight. The twelfth fortnight body weight of the treatments T_1, T_2, T_3 and T_4 were 70.833 ± 2.114, 69.333 ± 5.816, 73.333 ± 5.681 and 71.667 ± 5.975. There were also no significant difference in the body length, chest girth and body height among the treatment groups in the fortnightly observations. Though T_1 had shown significant (P<0.05) rise of physiological norms that had not reached upto the level of growth retardation.

The overall fortnightly rate of gain (kg) and average daily gain (g) of the treatment groups of T_1, T_2, T_3 and T_4 were 5.08 ± 0.60, 4.97 ± 0.54, 5.28 ± 0.56 and 5.17 ± 0.60 and 339 ± 39.9, 330.9 ± 36.1, 351.7 ± 37.6 and 343.9 ± 36.0. Under restricted feeding regime, T_3 was having relatively better feed conversion efficiency and lower cost per kg of live weight production than T_4, T_1 and T_2. The conversion efficiency of T_1, T_2, T_3 and T_4 were 4.05, 4.15, 3.91 and 3.99 and cost per kg of live weight production 36.16, 37.03, 35.05 and 35.81.

Based on the observations and the results suitable method of environment modification during the dry season for grower pigs can be recommended.