A PRELIMINARY INVESTIGATION OF THE EFFECTS OF HIGH AMBIENT TEMPERATURES PRIOR TO BREEDING AND IN EARLY GESTATION IN SWINE

By

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INTRODUCTION

With the increasing popularity of multiple farrowing in swine and the demand for uniform production throughout the year, information as to the importance of heat stress on sow reproduction is urgently needed. The limited data available indicate that embryos are most sensitive to heat stress during early pregnancy. Swine breeders across the country report lowered conception rates and smaller litters from sows bred during the hot summer months. This could be a result of temperature or humidity stress before breeding, at time of breeding or during some stage of gestation.

Heat stress may be postulated to have both direct and indirect effects on reproduction in swine. It can have a direct effect on sperm and ova formation and upon uterine environment in which the embryos must develop. Indirect effects may be by way of lowered feed intake and overall stress of the animal body. Whether the harmful effect on fertilization results directly from hyperthermia or from an endocrine imbalance resulting in an unfavorable environment in the uterine tubes is uncertain.

This study was initiated on June 6, 1966 with the following objectives:

1. To investigate the effect of high ambient temperatures at time of mating on ovulation rate and embryo survival.

2. To investigate the effect of high ambient temperatures during early gestation on embryo survival.

3. To investigate the effects of heat stress with sows maintained under present Ft. Reno sow management facilities during summer months.

4. To investigate the effect of high ambient temperatures prior to breeding on the estrual cycle, conception rate and subsequent embryo survival.

REVIEW OF LITERATURE

The effects of high temperature on pregnancy and embryonic survival vary with the species, temperature, period of exposure, gestation length and stage of pregnancy. These effects have been studied in sheep, dairy cattle, and to a lesser extent in swine and laboratory animals.

Laboratory Animals. Cox *et al*. (1965) studied the response of growing rats to ambient temperature stress. Forty-four of 60 rats living at 4°C. died within 28 days. Rats living at 22°C. consumed more diet and gained more rapidly but less efficiently than those at 33°C.

Macfarlane *et al*. (1957) reported that exposure of pregnant rats to high environmental temperatures increased fetal resorption and reduced litter size.

Fernandez - Cano (1958) suggested a relationship between embryonic degeneration and adrenal-pituitary secretion in heat stressed rats (40°C.). He suggested that embryonic degeneration is induced by a stress condition through the adrenal gland, rather than through the corpus luteum or the ovary. He further stated that high temperatures may have an effect on the development of the fetus at varying stages of gestation. Shah (1956) used a technique of reciprocal transplantation of six-day-old rabbit embryos to study the temperature effects on developing young embryos. Forty-two embryos from does maintained at an environmental temperature of 96°F. were transferred to does maintained at normal room temperature and 15 embryos (35 percent) developed into normal young. When neither the donor nor the recipient was heat-treated, similar results were obtained. However, when embryos from control does were placed in the uteri of heat-treated does, very few survived.

Cattle. While working with a herd of 406 Holstein 2-year-old cows, Stott et al. (1962) concluded that lowered fertility rate and higher embryonic mortality were important factors in lowered breeding efficiency in dairy cows maintained under high environmental stress.

Ragsdale et al. (1948) noted two abortions in twelve Holstein cows when exposed to 100°F. for a period of 27 hours.

Hillin et al. (1960) studied the effect of season on conception rate in Holstein and Jersey cattle. After examining the breeding records of 642 first calf heifers and collecting data on 1,656 conceptions by 593 cows, they found a definite seasonal difference in the number of services required per conception with Holsteins more severly affected than Jerseys. Services required per conception for heifers bred first in the period June through October compared to the seven cooler months were 3.12 and 2.11 for Holsteins and 2.13 and 2.09 for Jerseys, respectively.

Further evidence of a seasonal difference in the reproductive performance of dairy cattle was indicated by an examination of the 10-year breeding records of six herds of dairy cattle by Poston et al. (1960). They reported that the percentage of cows bred which returned for second service within 60-90 days gradually increased from a minimum of 38 percent in January to a maximum of 56 percent in August. Further examination revealed that the month of freshening had an effect on the subsequent calving interval. For cows calving in October, the calving interval was 397 days and for those calving in May the interval was 422 days. This would indicate a seasonal difference in the reproductive performance of dairy cattle.

The effect of hot weather on dairy cattle may be either immediate or delayed, depending on prior adaptation and severity of heat stress (Johnston, 1958). If lactating cows are suddenly exposed to high temperatures, their immediate response is a depression of appetite which is followed by lowered milk production. If cows are allowed to adapt to high temperature gradually, the reduction in milk production is delayed and occurs more gradually.

Sheep. Alliston et al. (1961) demonstrated by means of embryo transfer that temperature had an important effect on early pregnancy loss in ewes. When the donor and recipient were both maintained at 70°F., 56.5 percent of the embryo transfers were successful. However, when donor and recipient were maintained at 70°F. and 90°F., respectively, less than 10 percent of the embryo transfers were successful.

In a study involving 120 Northwestern ewes, Dutt et al. (1959) found that 92.6 percent of the ova from control ewes were cleaved three days post breeding compared to only 51.9 percent cleaved ova from ewes exposed to heat stress (90^{o}F.). These ewes were exposed to heat stress from 12 days after onset of the last estrual period to 3 days post-breeding. They observed 64 percent fertilized ova for sheared ewes maintained at 90^{o}F. compared to only 40.7 percent fertilization rate for unsheared ewes subjected to the same heat stress. Embryo loss for the control group was 4 percent compared to 91.7 percent embryo loss from ewes exposed to heat before breeding. Abnormal ova for the control group was 3.7 percent compared to 32 percent and 55.6 percent, respectively, for sheared and unsheared ewes maintained at 90^{o}F. Shearing before heat stress reduced embryo loss and percent abnormal ova. Dutt concluded that fertilization rate and early embryo survival appear to be more susceptible to heat damage than is the 8-day embryo.

Further work by Dutt (1963) showed that the critical period for early embryo mortality in ewes was at the time of breeding. Control ewes had 3.7 percent abnormal ova while those exposed to heat stress (90^{o}F.) on the day of breeding and one day post breeding had 46.2 and 30.8 percent abnormal ova, respectively.

Shelton et al. (1965) studied the ovulation rate and lambing ability of 539 aged ewes. Four mating periods of

6-week durations were used. These periods started on March 21, June 21, September 21 and December 21. Highest ovulation rate was at the September mating, but highest percentage of lambs born followed the December mating. Lambing results from the June and September mating periods were significantly altered by high environmental temperatures.

A significant increase in ewes exhibiting estrus and a higher percentage of ewes lambing was reported by Godley et al. (1966) when ewes were maintained in a control chamber to simulate October light and temperature conditions. This experiment was conducted during the months of April, May and June and results were compared to controls maintained outside.

Aldred et al. (1961) found a consistent increase in embryo loss from ewes as thermal stress was prolonged. Ewes were exposed to temperature stress (104°F.) for 1, 3, or 5 hours on the day following mating. Embryonic mortality was greatest after 5 hours of exposure (19.3 percent). Rectal temperatures increased an average of 3.0°F. following 5 hours of exposure.

The effect of high temperature on fetal dwarfism in sheep was studied by Yeates (1958). Seven Merino ewes were exposed to temperatures of 112°F. for seven hours a day. The temperature was dropped gradually to a minimum of 90°F. the remainder of the time. Ewes were placed in the chamber following service and were maintained there until lambing was imminent, at which time they were transferred to lambing pens. Three of the seven ewes failed to lamb, and those that did lamb had lambs weighing an average of 2 pounds 13 ounces less than that of unheated ewes. The mechanism of dwarfing in sheep is not clear and it may be due to placental defect, reduced blood supply, pituitary insufficiency or adrenal steroid excess.

Swine. Heitman et al. (1951) concluded that the pregnant sow was more susceptible to high temperatures than the non-pregnant female. An open sow showed a respiration rate of 64 per minute when exposed to 98°F., while a pregnant sow of similar weight and condition showed a respiration rate as high as 186 per minute. They concluded, however, that heat stress may kill the sow before causing death of the litter and subsequent abortion.

A study by Wallace and Combs (1962) involving 224 sows showed a consistent advantage in conception rate, number of pigs weaned, and average weaning weights when breeding occurred during the cooler months of the year.

Ahlschwede and Robison (1966) analyzed the litter records for 937 sows over a 5-year period to study the effect of climatic conditions on litter size. Within the limitations of their study, there was little association between climatic conditions at time of breeding and size of the subsequent litter.

Warnick et al. (1965) stated that cooling sows during periods of stress, particularly soon after breeding, may increase embryo survival and subsequent litter size. Their data showed 14.6 corpora lutea from gilts maintained at 60°F. compared to 13.6 corpora lutea from gilts maintained at 90°F. Live embryos at 25 days gestation were 11.7 and 10.4 for gilts maintained at 60° and 90° F., respectively. Based on the relatively limited data available, they concluded that 90° F. seemed to have less detrimental effect on fertility and embryo survival in gilts than in ewes.

Whatley et al. (1957) found that sprinkling pregnant sows during the hot summer months resulted in an increase of 2.35 more pigs farrowed per litter compared to non-sprinkled sows. The gestation test period covered 90 days; 77 of which the air temperature exceeded 90° F. Rectal temperatures averaged 2.8 °F. higher for the non-sprinkled sows. Number of pigs weaned per litter and pig weight at weaning were significantly higher for the sprinkled sows.

Ulberg (1966) suggested that increased temperature stress may have a detrimental effect on embryo survival in late pregnancy as well as in early stages of gestation. Ulberg also found a high association between body temperature at mating and embryo survival.

In a study of Duroc gilts exposed to 27°, 30° or 33° C. for one estrous cycle before breeding, Teague et al. (1966) found a lowered number of corpora lutea present after 25 days gestation for the gilts at 33° C. Rectal temperatures were significantly increased with an increase in dry bulb temperature.

MATERIALS AND METHODS

Trial I

<u>General</u> <u>Procedure</u>. This study utilized two temperature control chambers at the Ft.Reno Experiment Station. These chambers were located inside a closed building, were approximately 12' x 12' x 8' in dimensions, had five inch double wall insulation in both walls and ceilings, and were equipped with slatted floors and automatic watering systems. Each chamber was equipped with two 20,000 BTU room air conditioners capable of maintaining the chamber at 72^{o}F. Heat source for the hot chamber was supplied by means of a duct system from an overhead gas heater located outside the chamber. In each chamber, thermostats were located on the wall opposite the air conditioning units at approximately 48 inches above the floor. In the heat chamber, the thermostats were set to elevate the temperature to 102^{o}F. (95^{o}F. at floor level) during the heat stress period and to maintain the chamber at 72^{o}F. the remainder of the time. In the cool chamber the thermostats were set at 72^{o}F. Although hygrothermographs recorded both temperature and humidity, it was not possible to control humidity in the chambers. However, the relative humidity stabilized at 75 percent in

the cool chamber for the duration of the study and at approximately 50 percent in the heat chamber during the heat stress period. Heat chamber humidity stabilized at 75 percent the remainder of the time.

Sows were removed from the chambers for approximately thirty minutes each morning and evening to be fed and allow time for the chambers to be cleaned. Each sow in the study was fed in a separate stall to insure uniform consumption of feed. The ration fed during the study is given in Table I.

TABLE I

BREEDING HERD RATION[a]

Ingredient		Amount, lbs.
Molasses		50
Wheat		727
Milo		728
Ground alfalfa hay		300
Soybean meal (44%)		150
Dicalcium phosphate		30
Trace mineral salt		10
Vitamin-mineral premix		5
	Total	2,000

[a]200 pounds of wheat bran was added to ration for sows in the chambers.

Five days before the beginning of this study, all sows were started on eight pounds of the above ration per day. As each sow was bred, feed consumption was reduced to five pounds per day. The sows were maintained at this level until the 85th day of pregnancy at which time the level was increased to six and one-half pounds per day.

Forty-six second-litter Beltsville No. 1-Duroc crossbred sows that had weaned their first litters in the spring of 1966 were used for this study. Table II gives the distribution and description of the treatments.

TABLE II

DISTRIBUTION AND DESCRIPTION OF TREATMENTS FOR TRIAL I

Treat-ment	Number of Sows	Description of Treatment	Destination
1	10	Outside Control Lot	slaughtered[a]
2	8	Heat Chamber (1-10 days post-breeding)	slaughtered[a]
3	9	Heat Chamber (11-20 days post-breeding)	slaughtered[a]
4	9	Outside Control Lot	farrowed
5	10	Cool Chamber (1-109 days post-breeding)	farrowed

[a]All sows were slaughtered 30-35 days post-breeding.

The sows on Treatment 5 were randomly selected from the group prior to start of the trial and placed in the cool chamber before the start of the breeding period. To insure uniform distribution of breeding dates, the remaining sows were alloted to the other treatments at the time of breeding as follows:

Order in which sows were bred	Treatment assignment
1st	1
2nd	2
3rd	3
4th	4
5th	4
6th	3
7th	2
8th	1
9th	1
etc.	etc.

Sows alloted to Treatments 2 and 3 were maintained in the heat chamber for the 10 day periods indicated in Table II. Temperatures in the chamber were maintained at 102° F. (95° F. at floor level) from 9 a.m. to 4 p.m. and at 72° F. the remainder of the time each day.

The other three treatment groups were not exposed to the heat chamber in this trial. Treatment 5 sows were maintained from time of breeding to the 109th day of gestation in the cool chamber at 72° F. Sows in Treatments 1 and 4 were maintained under the conventional management system at Ft. Reno in 2 acre open lots equipped with sprinkler shades. Treatment 1 sows (outside control) were slaughtered at weekly intervals at 30-35 days gestation and their reproductive tracts obtained and examined. The sows in Treatment 4 remained in the outside lots from the start of the study to the 109th day of gestation, at which time they were moved to the farrowing barn. With the exception of Treatment 5 sows, all sows were maintained in the regular sow lots when they were not exposed to their respective heat treatments.

Five yearling Hampshire boars were used in this study with each boar mated to no more than two sows within each treatment to equalize possible sire effects.

Evaluation of Reproductive Tracts and Sow Productivity. All sows in Treatments 1, 2 and 3 were slaughtered at Wilson & Co., Oklahoma City between the 30th and 35th day of gestation. Intact reproductive tracts were obtained and taken to the physiology laboratory at Oklahoma State University for detailed examination.

The uterine horns were dissected and the embryos examined. Crown-rump measurements were made with embryos still enclosed in the amnionic sac. Hemorrhagic and partially decomposed embryos were noted but such embryos were not measured. Ovaries were removed and corpora lutea were counted and verified by dissection.

Sows in Treatments 4 and 5 were carried full term. These sows were brought into the farrowing barn at 109 days post-breeding and each sow and litter was maintained in individual pens until weaning. Pigs were not given access to creep feed through the first 21 days. All pigs were weighed at birth and at 21 days.

Rectal Temperatures. Rectal temperatures were obtained from four sows at random in the outside pasture lots each day at 2 p.m. Rectal temperatures were taken three times daily from four sows chosen at random in the cool chamber and on each sow in the heat chamber. The first reading was taken at 7 a.m. before elevating the temperature in the chamber, the second at noon and the third at 4 p.m. before the temperature in the chamber was reduced.

Ambient Temperature Data. Hygrothermographs were located in both chambers and at the outside pasture lots to record temperature and humidity for the duration of this study. The instruments were installed, calibrated and checked periodically by personnel of the Oklahoma State University Agriculture Engineering Department.

Trial II

Trial II was designed to study the effects of high ambient temperature on the estrous cycle, conception rate and embryonic development. These investigations were conducted during the first three months of 1967.

The two chambers used in Trial I were also used in Trial II, but slight modifications were made to maintain stress conditions when the outside temperatures were greatly reduced during winter. Heat from the overhead gas heater was directed under the chamber and the hygrothermograph was moved to floor level to insure accurate temperature recordings.

The cool chamber was maintained at 74°F. with no attempt made to regulate humidity which stabilized at approximately 35 percent for the entire period. In the heat chamber the temperature was elevated to 102°F. for 17 hours daily (from 4 p.m. to 9 a.m.) and lowered to 90°F. for the remaining 7 hours. Humidity in the heat chamber averaged 35 percent and ranged from 30-42 percent throughout the trial.

Eighteen Poland-Beltsville No. 1 crossbred gilts were used in this trial. Only gilts that had gone through two normal estrous cycles just prior to the start of the experiment were used. At the onset of the third estrus, gilts were randomly allotted to either the heat chamber or the cool chamber where they were maintained until their next observed estrus. The gilts were then removed from the chambers, bred and maintained in outside lots until 30-35 days post-breeding. At this time they were slaughtered and their reproductive tracts were obtained and examined using the same procedures as in Trial I.

Rectal temperatures were routinely obtained from each gilt in each chamber at 9 a.m. and again at 4 p.m. Rectal temperatures were also obtained from each gilt in the heat chamber several times during the daily period of elevated heat to determine their high temperature for each day. The reading obtained at 11 p.m. (about 7 hours after elevation of ambient temperature) was usually their highest for the day.

Gilts were fed 5 pounds of feed per day before the trial began and this level was maintained throughout the trial. Other feeding and management practices were similar to those in Trial I with all gilts given access to feed twice daily during the seven-hour reduced heat period.

RESULTS AND DISCUSSION

Trial I

<u>Ambient Temperatures</u>. The daily maximum and minimum temperatures for the pasture lot were averaged for 3-week periods and compared to the cool chamber temperature in Figure 1.

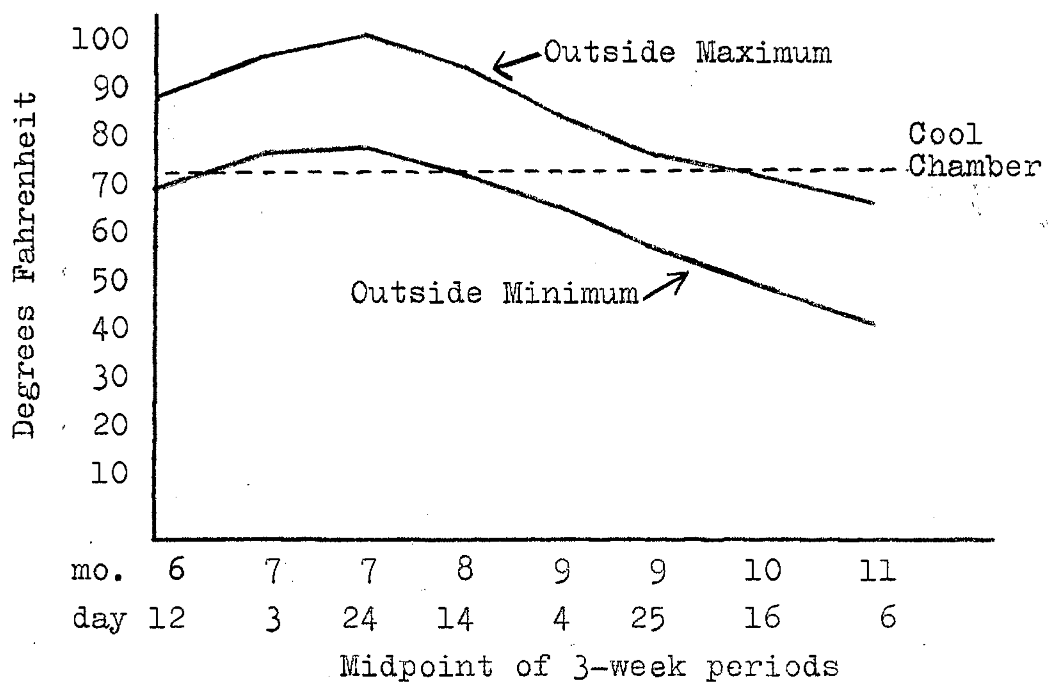

Figure 1. Average Maximum and Minimum Daily Temperatures for 3-Week Periods at Outside Control Lot as Compared to the Cool Chamber

A study of this graph shows that most of the trial was conducted when outside temperatures were above those in the cool chamber (72°F.).

Several studies have been made dealing with the optimum temperature for normal growth and development of swine (Heitman _et_ _al_., 1954; Heitman _et_ _al_., 1958; and Heitman and Hughes, 1949). In view of these studies, the outside temperatures experienced during this trial would be considered above the "comfort zone" suggested by these workers.

It is apparent from review of Figure 1 that Treatment 4 sows (outside control) were exposed to high environmental temperatures during the first half of gestation, but the environmental temperatures during the last half of gestation would not be considered as stress conditions.

Because of the unseasonably high temperatures experienced during July at the Ft. Reno Station, the sows maintained in the outside lots were probably under as much stress, if not more, than those exposed to the heat chamber. Also, the sows exposed to the heat chamber were forced into a cool environment (72°F.) at 4 p.m. each day while the outside temperatures normally did not drop until the early hours of the morning.

Rectal Temperatures. When rectal temperatures from Treatment 2 were compared to those for Treatment 3 for the 10-day heat stress period, a definite pattern was obtained. These temperatures are presented graphically in Figure 2. This graph indicates that the sows showed definite response to the elevated temperatures during the first 6 days of exposure. This is even more apparent in Figure 3 which represents Treatments 2 and 3 combined. It appeared that

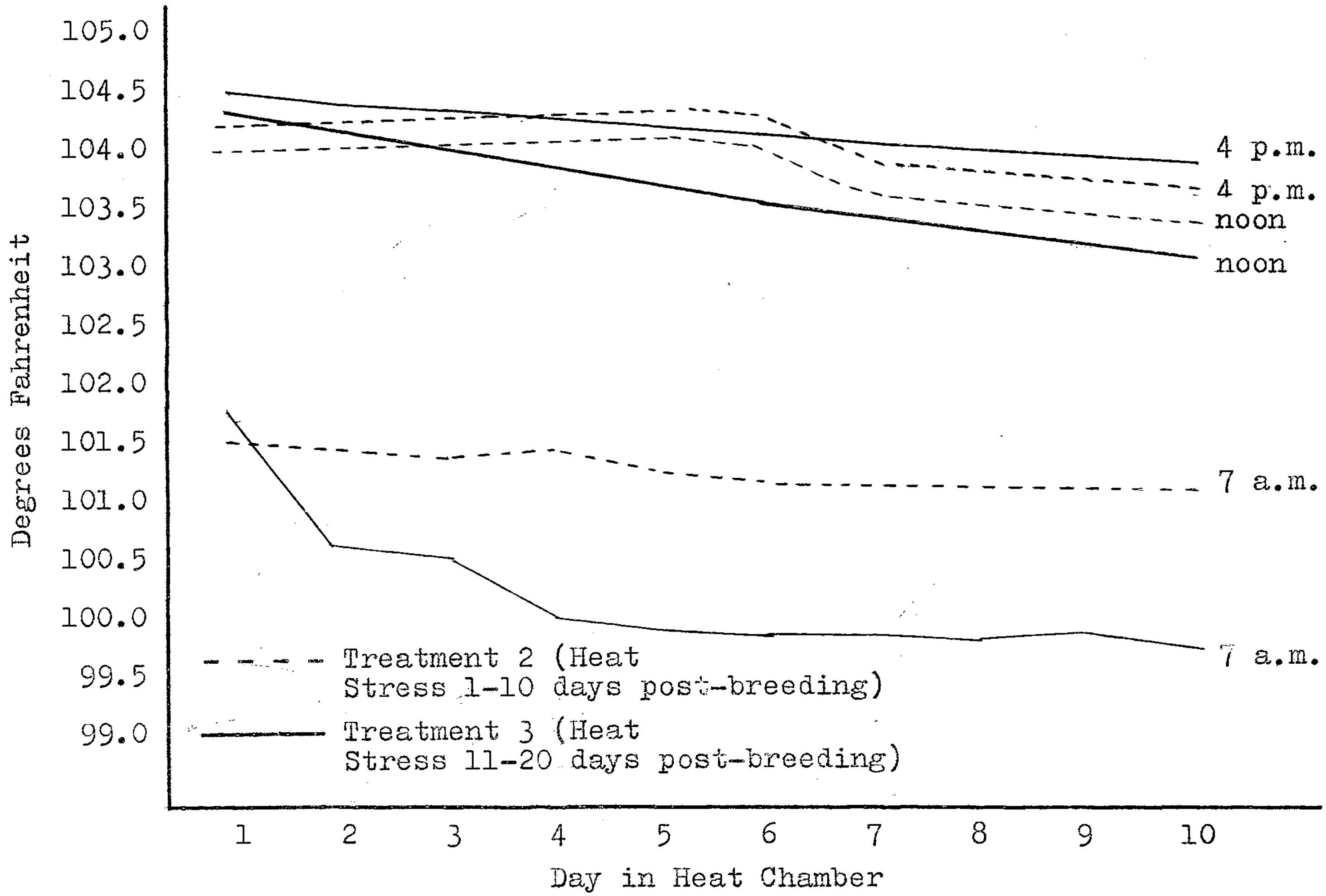

Figure 2. Average Rectal Temperatures for Treatments 2 and 3 During Heat Stress Period

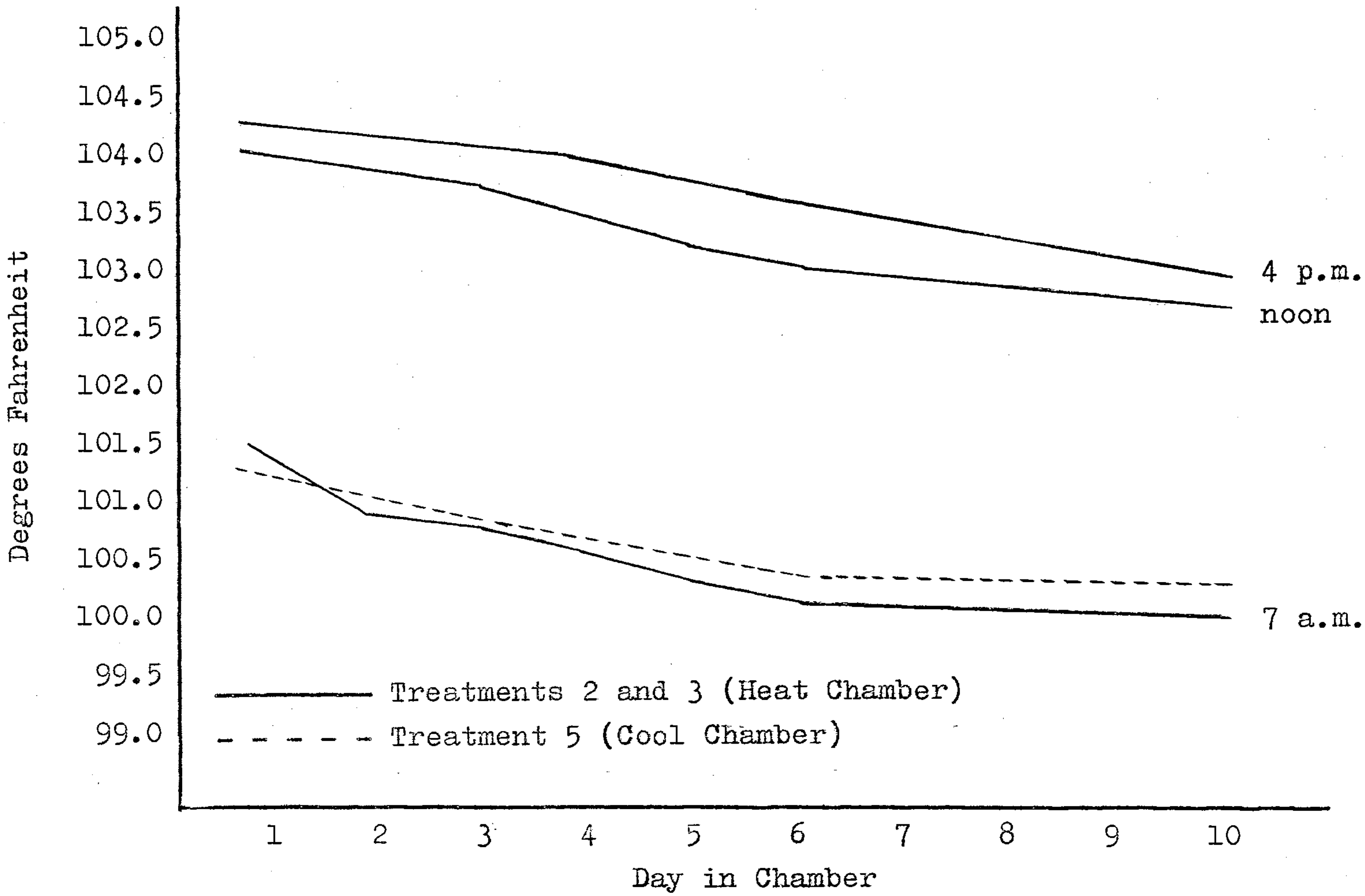

Figure 3. Average Rectal Temperatures for Treatments 2 and 3 Combined During Heat Stress Period and for Treatment 5 first 10 days Post-breeding

sows tended to become adapted to their environment after about 6 days of exposure to the high temperatures.

Rectal temperatures from Treatment 5 sows (cool chamber) for the first 10 days post-breeding are also presented in Figure 3. These temperatures dropped to approximately 100.5°F. within 5 days after being placed in the chamber and tended to stabilize at this point for the remainder of the time the sows were confined. This temperature is somewhat below the considered normal of 102.5°F. quoted by Dukes (1955). In this study, rectal temperatures for Treatment 4 (outside control) were significantly higher ($P<.05$) then those for Treatment 5 (cool chamber). Consequently, one might question whether the sows maintained in the cool chamber were under normal conditions.

Embryo Development and Survival to 30 days Post-breeding. The number of corpora lutea and normal embryos per sow and percent survival for Treatments 1, 2 and 3 are given in Table III.

In comparing the number of normal embryos at 30 days post-breeding, no significant differences between treatments were detected when number of corpora lutea were held constant by use of covariance analysis. Therefore, the differences in number of normal embryos noted in Table III are a result of differences in number of corpora lutea rather than a result of the various treatments imposed. Likewise, an analysis of variance revealed no significant difference in survival percentage.

TABLE III

AVERAGE NUMBER OF CORPORA LUTEA, NORMAL EMBRYOS PER SOW AND PERCENT SURVIVAL FOR SOWS SLAUGHTERED 30 DAYS POST-BREEDING

Treatment	Number of Sows	Number of Corpora Lutea	Normal Embryos per Sow[a]	Percent Survival
1	10	18.50±1.20	12.40±1.06	67.0±3.2
2	8	19.00±1.36	13.03±0.78	73.0±3.1
3	9	17.55±1.00	12.88±1.06	73.4±2.7

[a]Adjusted number of embryos holding corpora lutea constant.

The average number of corpora lutea for Treatments 1, 2 and 3 was 18.3. This mean was used to establish average ovulation rate for sow groups that farrowed in this trial.

The means and standard errors for embryo length are given in Table IV.

All normal embryos were measured before removal from the amnionic cavity. While the embryos in Treatment 1 averaged 37.97 mm. compared to 33.90 mm. for Treatment 2 and 36.47 mm. for Treatment 3, these differences were not significant when day of pregnancy was held constant.

Means and standard errors for number of dead embryos at time of slaughter are given in Table V. There was a tendency for fewer dead embryos in the control sows (Treatment 1) than in Treatment 2 or 3, but these differences were not significant.

TABLE IV

MEANS AND STANDARD ERRORS FOR EMBRYO LENGTH OBSERVED 30 DAYS POST-BREEDING

Treatment	Number of Embryos	Embryo Length, mm.[a]
1	124	35.21 ± 1.43
2	111	34.29 ± 2.16
3	116	34.76 ± 2.63

[a]Adjusted embryo length holding days pregnant constant.

TABLE V

MEANS AND STANDARD ERRORS FOR NUMBER OF DEAD EMBRYOS AT 30 DAYS POST-BREEDING

Treatment	No. Litters	Total No. Dead Embryos	Dead Embryos Per Sow
1	10	6	0.60 ± 0.34
2	8	16	2.00 ± 1.26
3	9	12	1.33 ± 0.74

Based on these very limited data, the degree of heat stress supplied during the first 30 days of gestation in this trial appeared to have no effect on ovulation rate, embryo development or survival rate.

Results for Sows Carried Full Term. The primary purpose of this section of the trial was to study the influence of total confinement and the adequacy of present Ft. Reno sow management facilities during the hot summer months in terms of sow productivity. Results for gestation gains and sow productivity are summarized in Table VI.

TABLE VI

GESTATION GAINS AND SOW PRODUCTIVITY DATA FOR TREATMENT 4 AND 5 SOWS

Comparison	Treatment 4 (outside)	Treatment 5 (cool chamber)
No. of litters	9	10
Sow gestation gains, lbs.	154.33 ± 6.28	118.60 ± 5.96
Pigs farrowed per litter	12.00 ± 0.82	12.20 ± 0.78
Pig birth wt., lbs.	3.04 ± 0.88	3.07 ± 1.00
Litter birth wt., lbs.	38.47 ± 2.37	39.01 ± 2.21
21-day pig wt., lbs.	14.44 ± 3.47	13.54 ± 3.26

Although both groups of sows were limited to the same daily intake of ration during gestation, gestation gains were significantly ($P<.01$) lower for the sows maintained in the cool chamber throughout gestation. The reason for this difference is not clearly understood but may be due to the fact that the sows maintained in the outside lots had access to very limited amounts of vegetative growth and to soil throughout the trial.

Number of pigs born alive in Treatment 4 (outside control) and Treatment 5 (confinement) were 12.00 and 12.20, respectively. Using the average number of corpora lutea (18.3) for the sows that were slaughtered as the expected ovulation rate for the sows that farrowed, survival rates of 65.6% for Treatment 4 and 66.7% for Treatment 5 were calculated. These figures closely parallel those obtained from the slaughtered groups. Fifteen mummified fetuses were observed in each of the two groups.

No significant differences in litter size, pig birth weight, litter birth weight or 21-day pig weight were obtained. This would indicate two things: First, the sows maintained in the outside lots equipped with sprinkler shades during the unseasonably high environmental temperatures obtained during the first half of the trial were equally as productive as the cool chamber sows. Second, sows could be confined to the cool chamber throughout gestation without hindrance to their reproductive performance.

Trial II

General Comments. Three of the ten gilts assigned to the heat chamber died during the heat stress period, presumably as the result of heat prostration. It was not possible to obtain accurate counts of respiration rate but estimates ran as high as 180 per minute just prior to death. It was evident that a more severe heat stress was imposed in Trial II than in Trial I.

Reproductive tracts were removed from the gilts immediately after death and the ovaries examined. All ovaries appeared to be normal and the average number of corpora hemorrhagicum for the three sows was 13.7.

One gilt, exposed to the heat chamber for one estrous cycle, returned to estrus 23 days post-breeding. She was rebred and slaughtered 30 days post-breeding but was not included in the analysis of this trial.

Rectal Temperatures. Average rectal temperatures for the eight gilts in the cool chamber and the remaining seven gilts in the heat chamber are presented graphically in Figure 4. The response observed in this trial was similar to that reported in Trial I. The gilts showed definite response to the high temperatures for the first 6-8 days of exposure and then apparently became somewhat adjusted to

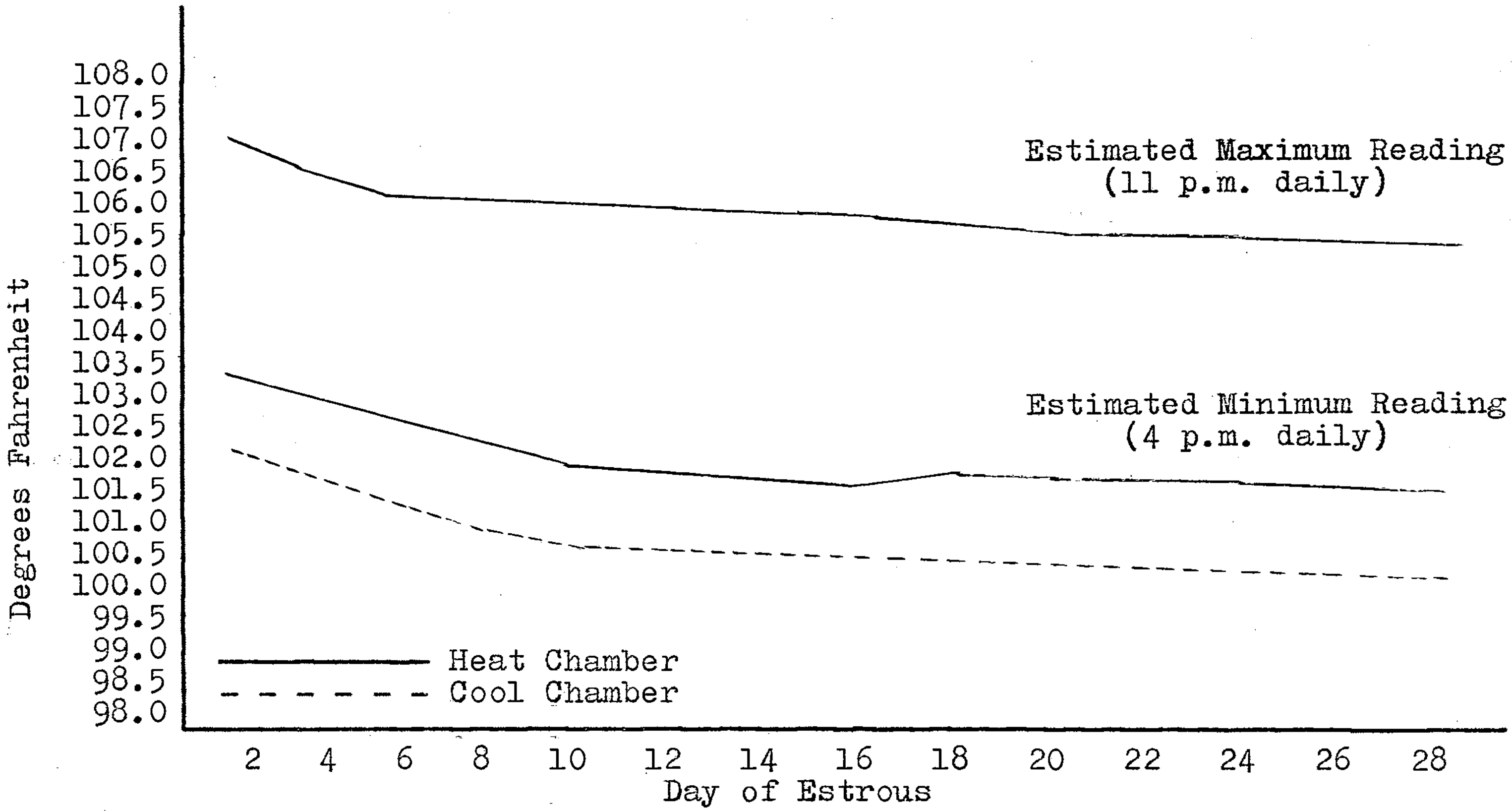

Figure 4. Average Rectal Temperatures for Cool Chamber and Heat Chamber Gilts During Estrous Cycle

the stress conditions. However, rectal temperatures for the gilts exposed to the heat chamber remained well above what is the considered normal (102.5°F.) for the entire time of exposure.

In contrast, rectal temperatures for gilts maintained in the cool chamber were slightly below normal. This was also the case with sows in Trial I.

Length of Estrous Cycle. The average length of the estrous cycles for gilts prior to and during chamber confinement are summarized for each treatment in Table VII.

Although gilts were alloted to the two chambers at random, there was a significant ($P<.05$) difference in the average length of the estrous cycles of the two groups prior to confinement. However, no significant differences were found in length of estrous cycles during confinement between the gilts in the cool chamber and those in the heat chamber when length of cycle prior to confinement was held constant.

Among gilts alloted to the cool chamber, no significant differences were found between the estrous cycle lengths during confinement and the average of the two cycles prior to confinement, but the cycle lengths were increased ($P<.05$) for the gilts alloted to the heat chamber.

Feed Consumption and Weight Changes. Feed consumption and weight change data for gilts in Trial II are presented in Table VII. The gilts maintained in the cool chamber had no loss of appetite and consumed their alloted five

TABLE VII

AVERAGE LENGTH OF ESTROUS CYCLE PRIOR TO AND DURING CHAMBER CONFINEMENT, FEED CONSUMPTION AND WEIGHT CHANGES FOR GILTS IN TRIAL II

Comparison	Heat Chamber	Cool Chamber
Number of gilts	6	8
Estrous cycle length prior to confinement, days	19.50±0.67[a]	22.44±0.69
Estrous cycle length during[b] confinement, days	24.37±0.67[a]	22.72±0.69
Approximate daily feed consumption per gilt during confinement, lbs.	3.4	5.0
Average weight change per[c] gilt during confinement, lbs.	-29.50±6.52	- 1.62±5.64
Average weight change per[d] gilt post-breeding, lbs.	+55.67±3.19	+45.75±2.76

[a]Significant difference ($P<.05$) in estrous cycle length prior to confinement and during confinement.
[b]Adjusted length during confinement holding length prior to confinement constant.
[c]Difference between heat chamber and cool chamber highly significant ($P<.01$).
[d]Difference between heat chamber and cool chamber significant ($P<.05$).

pounds of feed daily. However, those maintained under heat stress conditions suffered a severe loss of appetite, particularly at the morning feeding, and consumed an average of only 3.4 pounds of feed per day. This partially explains the reason that heat chamber gilts lost significantly ($P<.01$) more weight during confinement than did the cool chamber gilts. The reverse was true after confinement, with the heat chamber gilts gaining significantly ($P<.05$) more than those confined to the cool chamber.

The reduction in feed consumption by the heat chamber gilts must be kept in mind when interpreting the results of this trial. Heat stress could have affected ovulation rate, and possibly other aspects of reproductive performance, indirectly through reduced feed consumption. Self et al. (1955) reported significantly ($P<.01$) more ova shed for full-fed gilts as compared to those limited-fed.

Post-breeding Performance. The performance data for Trial II are summarized in Table VIII. Although the mean number of corpora lutea favored the cool chamber gilts, this difference was not significant. Teague et al. (1966) also reported a lowered number of corpora lutea with an increase in heat stress. The average weight of the corpora lutea for gilts maintained in the cool and heat chambers was 9.6 gm. and 8.9 gm., respectively. However, these differences were not significant.

In comparing the number of normal embryos at 30 days post-breeding, the cool chamber gilts had significantly

TABLE VIII

REPRODUCTIVE PERFORMANCE FOR GILTS CONFINED TO THE CHAMBERS PRIOR TO BREEDING AND SLAUGHTERED 30 DAYS POST-BREEDING

Comparison	Heat Chamber	Cool Chamber
Number of gilts	6	8
Number of corpora lutea	16.33±1.06	17.12±0.91
Normal embryos per gilt[a,b]	10.41±1.10	12.70±0.96
Embryo survival, percent	62.3±6.1	75.3±5.2
Embryo length, mm.[c]	28.56±0.76	28.23±0.66
Dead embryos per gilt	0.83±0.37	0.75±0.29

[a]Differences between heat and cool chambers significant (P<.05).
[b]Adjusted number of embryos holding corpora lutea constant.
[c]Adjusted embryo length holding days pregnant constant.

(P<.05) more normal embryos when number of corpora lutea were held constant by use of covariance analysis. Likewise, the differences in percent survival approached significance (P<.10). Since the differences observed in number of corpora lutea were not significant, this increased number of normal embryos must be the result of differences in fertilization rate and embryo survival. These data suggests the need for additional studies to include observations on fertilization rate before the effect of pre-estrus heat stress can be accurately assessed.

No significant differences were found in the length of embryos when number of days pregnant were held constant. This indicates that the development of the surviving embryos was not affected by heat stress prior to breeding. Although slightly more dead embryos were noted among heat chamber gilts, the differences were not significant.

Based on these limited preliminary data, it would appear that heat stress prior to breeding may be an important factor in embryonic death loss.

SUMMARY

Two temperature control chambers were utilized to study the effect of heat stress on the reproductive performance of sows and gilts. In the first trial, conducted during the summer of 1966, 46 crossbred sows were utilized. One group of sows was exposed to a heat chamber (approximately 95°F. at floor level and 50 percent humidity) from 9 a.m. to 4 p.m. each day for the first 10 days post-breeding, a second group from the 11th through 20th day post-breeding and a third group was maintained under conventional management facilities. There were no significant differences in ovulation rate, number of normal embryos at 30 days post-breeding or survival rate when these three treatments were compared. A fourth group of sows was maintained in a cool chamber (72°F. and 50 percent humidity) throughout gestation and compared to a group carried full term in outside lots under the conventional management facilities. There were no significant differences in number of pigs born, pig birth weight, litter birth weight or 21-day pig weight between these two groups.

Trial II was conducted during the first three months of 1967. In this trial, eight gilts were maintained in the cool chamber (74°F. and 35 percent humidity) for one

estrous cycle prior to breeding and 10 gilts were exposed to heat stress (102^{o}F. and 35 percent humidity) from 4 p.m. to 9 a.m. (17 hours) each day for one estrous cycle prior to breeding. Three of 10 gilts exposed to the heat chamber died, presumably as a result of the exposure to high temperatures, and one gilt failed to conceive at time of breeding.

There was a significant (P<.05) increase in length of estrous cycle during confinement for the heat chamber gilts when compared to their average cycle length prior to confinement. However, no significant differences were found in estrous cycle length between the cool chamber and heat chamber gilts during confinement.

Differences in ovulation rate, embryo size or number of dead embryos per gilt were not significant, but there was a trend toward more dead embryos among the heat chamber gilts. Gilts confined to the cool chamber had significantly (P<.05) more normal embryos at 30 days post-breeding than those maintained in the heat chamber. There was a tendency for higher survival rates among the cool chamber gilts with the differences approaching significance (P<.10).

In both trials the experimental animals showed definite response to heat stress on the first day of exposure as indicated by elevated rectal temperatures. Rectal temperatures declined for the first five or six days of exposure, and then tended to level off indicating adjustment to the stress conditions.

In this study, heat stress applied prior to breeding appeared to be more of a factor in reducing reproductive efficiency than when applied post-breeding. However, the degree of heat stress applied prior to breeding (Trial II) was more severe than that applied post-breeding (Trial I). In Trial II gilts were exposed to 17 hours of heat stress while those in Trial I were exposed for only 7 hours. The death of the three gilts in Trial II is further evidence of more severe stress in Trial II. Results obtained in this study were obtained from a small number of experimental units and should be considered as a preliminary investigation since more extensive studies are being planned based on these results.

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