

Heat may be dissipated by various combinations of convective, evaporative, radiant and conductive heat losses. Farm livestock are not as efficient in the use of sweat glands as man. However, evaporative heat dissipation is significant. Evaporation from the respiratory tract, lungs (air sacs in poultry), and body surface account for latent heat dissipation in cattle up to about two-thirds of which is from the outer body surface.⁴ Recent studies indicate that chickens may dissipate as much as 50 percent of their heat production by radiation.⁵ Heat losses by conduction are generally considered insignificant when animals are standing as the contact area is very small. Conduction losses when lying down are retarded by straw or other bedding. However, the use of warm floors for small calves and pigs has been effective.

The ability of cattle to adjust their rate of evaporative heat dissipation is shown in Fig. 1. Note that the rates of heat dissipation gradually increase as temperature increases to about 65 F, rapidly increase up to about 85 F, and thereafter increase more gradually again. Here the difference in evaporative heat dissipation between cattle and humans is readily apparent. Generally the sweat glands of cattle do not bring visible droplets of water to the skin surface. Thus, the evaporative cooling ability of humans continues to rise at an increasing rate after 85 F.

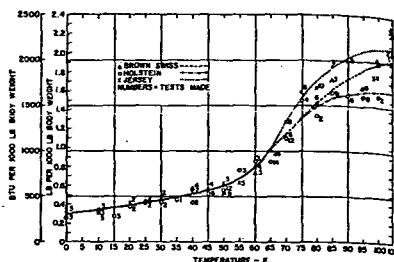
Further evidence of an animal's ability to exercise some control upon its rate of heat dissipation and the avenues by which it is dissipated is shown in shivering and erection of hair or feathers in cold weather and increased respiration (and generally increased respiratory ventilation rates) in hot weather. These are visible responses that can be brought into use very quickly. A change in feed consumption, as an effort to increase or decrease heat production as the need may be, is a slower response. Even slower responses are those that are associated with acclimatization such as changes in hair color, thicker depositions of fat beneath the skin, and changes in the density of hair or feather coats. Long term changes are considered adaptive changes. These express themselves as genetic changes. The humps, extra folds of skin, and the long ears of the Brahman cattle may be adaptive changes to increase convective heat dissipation in the warm climate where they originated. Some recent studies,⁷ however, indicate that the hump and folds of skin of the Brahman cattle are not highly efficient heat dissipators.

Reproduction

Generally low temperatures, even well below freezing, do not appear to affect the reproductive performance of farm livestock, but the breeding efficiency of both males and females decreases under summer conditions. Temperatures above 85 F may cause a decrease in the fertility,⁸ sperm production and semen quality of males and increase anoestrus and the incidence of embryonic death in females. The extent of the reaction depends upon the degree of temperature rise and the duration of the exposure.

In bulls and rams the scrotum behaves very much like a thermostat; holding the testes close to the body when the air temperature is around 40 F or below; allowing them to drop to a maximum distance from the body when temperatures rise above 75 F.⁹ Temperatures above 75 F will cause a decrease in spermatogenesis¹⁰ and long exposures to 85 F or above will cause a temporary sterility.¹¹ In the warmer climates fans and sprinklers are being used effectively to prevent summer sterility in bulls.¹² Under range conditions, spring or early summer breeding is practiced to maintain high breeding efficiency.

Sheep are most susceptible to sterility at high temperatures.¹³ Most ewes anoestrus from May until September and



* Tests conducted in constant temperature environments with relative humidities from 55 to 70 percent. From Reference 6.

Fig. 1 . . . Effect of Temperature on Total Vaporization from Lactating Dairy Cattle*

semen quality of rams is lowered, therefore, sheep are usually considered seasonal breeders.¹⁴ Studies have shown that the conception rate of ewes can be increased during the summer months when kept at 65 F for as little as 8 days post-mating.¹⁵ Cooling either the ewe or ram results in a conception rate of 45 percent, but when both ram and ewe are kept cool the rate increases to about 60 percent. In many areas the breeding season for sheep can be extended for one month in summer by keeping the ram in a cooled barn. This practice is coming into general use.

In the southern United States the conception rate of dairy cows decreases 30 to 60 percent during the summer even when frozen semen is used.¹⁶ Present evidence indicates this is due to an upset of certain physiological processes that prevent fertilization or an elevated uterine temperature that is fatal to the embryo. The frequency and duration of oestrus both tend to be lower during the summer. Reports from the southern United States show that, during the summer, the fertile period during oestrus is about 1/2 that expected in the north.

If swine are provided with wallows, cooled floor or fogging, satisfactory reproductive efficiency can usually be maintained.¹⁷ Under controlled laboratory conditions, temperatures up to 99 F had no apparent effect on sows pregnant for 85 days or more. Boars do not appear susceptible to summer sterility except under extreme conditions. In most cases, summer farrowing is avoided because of the loss of sows by heat exhaustion during labor. Small portable air conditioners appear effective in preventing sow losses.

Summer temperature conditions have indirect effects on reproduction in poultry. Under high temperatures, both egg size and shell thickness decrease. Which in turn reduce hatchability and survival.

Growth and Production

The improvement of growth and production are goals when modifying environments for livestock shelters. The effects of thermal environments on production have received attention during the past ten years. Recommendations based on this research are confounded by the interacting effects of health, stage of adaptive adjustment, plane of nutrition, stage of gestation, and level of production. A clear concept of climate in relation to livestock production is further confounded by variations within and between breed groups.

Generally the smaller the size of a specie (a Jersey is smaller than a Holstein) the narrower is the range over which either

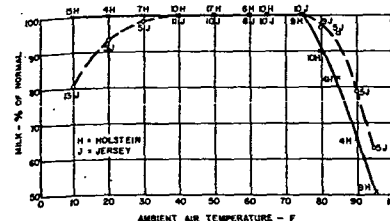


Fig. 2 . . . Milk Production at Various Environmental Temperatures with Relative Humidities from 55 to 70 Percent

maximum or efficient production may be maintained. Adaptive physiological adjustments take place that improve the ability to withstand an otherwise harmful environment. High producing animals are more adversely affected by high temperatures than low producing animals, and those with adequate feed can withstand cold better than those which are underfed.

The evaluation of thermal environments themselves present a problem as air dry-bulb temperature, humidity, wind velocity, and temperature of the surroundings are factors to be considered. In general, increasing the air velocity at temperatures below internal body temperatures ameliorates and increasing humidity and radiant heat loads accentuate the harmful effects of high temperature. In cold environments, the effects of wind and radiation are the reverse of those at high temperatures. The effect of humidity at low temperatures is not clear except that relative humidities above 75 percent should be avoided from the standpoint of structural damage, feed deterioration and the prevention of respiratory diseases. Humidities below 50 percent increase the dust problem.

Fig. 2 shows the effect of various air temperatures on milk production. Maximum production is indicated for both breeds from freezing temperatures to 75 F. Within this range no measurable effects from winds, radiation, or humidity were noted. However, at temperatures above 75 F (wind, radiation, and humidity) began confounding the effect of air temperature (see Fig. 3). Generally the higher the ambient dry-bulb temperature the greater the effect of a given increment of humidity, wind, or radiation change. The more efficient production is at the upper end of the full production curve as feed consumption gradually decreases with increasing temperature.¹⁸ Although the results shown in Figs. 2 and 3 were obtained under constant temperature conditions, other tests indicate that within normal outside diurnal temperature cycles, the average daily temperature and a constant temperature condition of the same magnitude would have about the same effect on milk production.¹⁹

The range of tolerance of beef cattle to thermal environments is as great as that of any farm livestock. Mature beef cattle can withstand temperatures within a range from well below freezing to 75 F with protection from wind and precipitation required only under extremely cold conditions. Young calves are somewhat less tolerant to cold than a mature animal, and they may need additional protective care.

It has been shown that live weight is significantly related to the temperature at which maximum gains are obtained in swine. Table 2 indicates the nature of the rate of gain for various weights. The most efficient gain (the least amount of

Table 2 . . . Effect of Ambient Air Temperature and Mean Liveweight on Rate of Gain of Swine

Mean liveweight, lb	Average daily gain in pounds per pig at various air temperatures, F							
	40	50	60	70	80	90	100	110
100		1.37	1.58	2.00	1.97	1.40	0.39	-1.32
150	1.27	1.47	1.75	2.16	1.82	1.14	-0.19	-2.60
200	1.19	1.57	1.91	2.22	1.67	0.88	-0.77	
250	1.10	1.67	2.08	2.14	1.51	0.62	-1.36	
300	1.02	1.77	2.24	2.06	1.36	0.36	-1.95	
350	0.94	1.87	2.41	1.98	1.21	0.10	-2.53	

feed per pound of gain) was at 70 F for a 100 lb hog and at 60 for a 200 lb hog.¹⁸

The effects of humidity and wind on swine growth have not been studied extensively. However, it appears that humidity affects the growth of swine less than it does any other specie of farm livestock. Spray, fogs, shades, and wallows have proven to be effective hot weather countermeasures.

Only limited information is available on the effect of climate on growth and wool production of sheep. Since body temperatures begin rising between 80 and 90 F some depression in the rate of gain might be expected.²⁰ Although temperate breeds tend to have more fleecy coats than tropical breeds, the effects of thermal environments on wool quality have not been identified.

The effect of thermal environments on the rate of gain of broilers is complicated by rapid changes in that industry. Within 10 years, the time required to raise a broiler from its

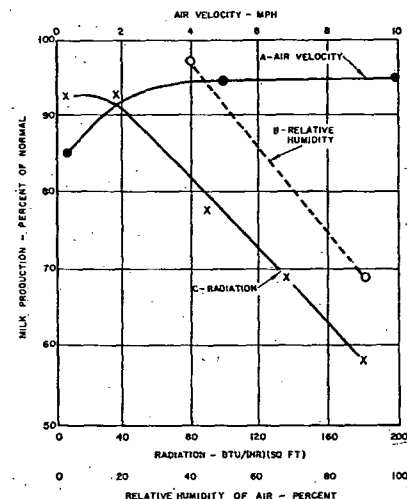


Fig. 3 . . . Examples of the Effect of Radiation, Air Velocity, and Relative Humidity on Milk Production of Holstein Cows¹⁸