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in

Baselga M. (ed.), Marai I.F.M. (ed.).
Rabbit production in hot climates

Zaragoza : CIHEAM
Cahiers Options Méditerranéennes; n. 8

1994
pages 33-41

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Summary: *Temperature of 21 ^{o}C is the "comfort zone" in rabbits. When the animals are exposed to higher or lower temperature, the heat dissipation or heat production must be carried out to maintain its body temperature. Thermoregulation mechanism is conducted by different means. Respiration, the nasal mucose and the ear are the important heat dissipation pathways in rabbits.*

Key words: *Heat dissipation, respiration rate, nasal mucosa, ear, rabbits.*

Introduction:

The wild rabbits spend much of their lives in underground burrows where the variation in the environmental conditions is narrower than those that of the domestic rabbits. The diurnal and seasonal variations in body heat regulation, the response to climatic conditions and the means of heat dissipation in rabbits, will be discussed.

Diurnal and seasonal variations in body heat regulation:.

a. Diurnal variation:

Cyclic variation in the physiological reaction of rabbits is induced by diurnal variation of climatic temperature (Finzi et al, 1994). The average body temperature goes up from morning till night, while environmental air temperature goes up from morning till noon then decreases at night indicating that body temperature was not affected instantly by changes in air temperature during the day. Diurnal variation in body temperature varied within a very short range (0.2-0.3 ^{o}C) revealing a high efficiency of body heat regulation in rabbits (Shafie et al., 1970)

b. Seasonal variation:

With regard to seasonal variation, the average body temperature of rabbit is about 39.5^{o}C, respiration and pulse rates per minute are 168 and 235, respectively, in New Zealand White rabbits (Lee et al., 1976 and Davson, 1960), while in White Egyptian "Giza" rabbits, the respective values are 39.4°C, 85 and 137 cpm under summer conditions of Egypt (Shafie et al., 1982). Shafie et al. (1982) reported that when air temperature increased twofolds from winter to summer, respiration rate increased by 70% of its winter average, while Johnson et al. (1957) noticed that respiration rate of New Zealand White rabbits was tripled when air temperature was doubled and the ear lobe temperature increased at summer by 70% of its value at winter (15°C difference). Specially, Brody (1945) revealed that, in nonsweating animals like rabbits, respiration rate value goes up enormously by 5-6 for each 1°C increase in air temperature. Johnson et al. (1957) and Shafie et al., (1970) reported that respiration rate, pulse rate and ear lobe temperature were highly effected by monthly air temperature changes, due to the fact that the three physiological reactions are considered the major means which can keep body temperature within the normal range. The same authors added that the maximum values of these three items were observed during summer months but in different rates. Brody (1945) revealed that the slight change in pulse rate due to variation in air temperature is probably a counter mechanism to vasodilation in the ear lobe, indicating that, particularly, the two reactions: respiration rate and ear lobe temperature are the major physiological processes which regulate body temperature against any environmental changes. At summer, rabbits accelerate respiration rate to increase evaporative cooling. The respiratory centres are controlled by thermoregulating centres at the hypothalamus. Respiratory frequency and evaporative water loss are linearly related and increased with ambient temperature above the panting threshold (Richards, 1976) and these energy-consuming responses in a hot environment could reduce retention of metabolizable energy, thus reducing growth rate, fertility and hair growth (Eschborn, 1985).

Response of rabbits to the climatic conditions:

The main components of climate are temperature, humidity, air movement and radiation, but the temperature and humidity are perhaps the most important ones. The reaction of rabbits to each of these components is as follows:

a. Temperature:

Temperature of 21°C is known as the "comfort zone" for rabbits. At either higher or lower temperature, the animal has to expend energy to maintain its body temperature. Accordingly heat production and losses must vary to maintain body temperature by modifying their feed intake level and using three devices to modify heat loss: general body position, breathing rate and peripheral temperature, especially ears temperature. If ambient temperature is below 10^{o}C, animals curl up to minimize the total area loosing heat and lower their ear temperature. If the temperature is above 25 - 30^{o}C, the animals stretch out so they can loose as much heat as possible by radiation and convection and step up their ear temperature (Lebas et al., 1986). However, rabbits are much more tolerant to low temperatures than to high temperatures (Lebas and Matheron, 1982). Lebas (1989) confirmed that the major consideration under low temperatures is that feed consumption is increased so animals can maintain their body temperature.

With continuous decrease in environmental temperature a greater quantity of feed energy is used to maintain body temperature and poorer feed conversion occurs. Accordingly, in cold weather extra feed must be provided. It is also expected that water consumption increased as temperature drops, because of the increase in feed intake. Restricted availability of water under cold conditions (e.g. from frozen water lines) will reduce performance more than its restriction at comfort zone. In some breeds such as the Californian, Siames Satin and Sable, if the fur on an adult is shaved and then exposed to cold, the fur will temporarily grow in black in areas where it is normally white. Fluctuations in temperature may trigger out-breaks of enteritis, especially, following the start of a cold snap. One possibility to account for this is that a sudden drop in temperature triggers an increase in feed intake. However, this could cause carbohydrate overload, i.e. proliferation of pathogens in the gut with the production of lethal toxins.

Exposure of rabbits to a high environmental temperature increases the heat load on animals (Mclein, 1963). Particularly, increasing environmental temperature from 10 to 30oC elevates body temperature from 39.67 to 40.5^{o}C and pulse rate from 122 to 156 pulses/ minute in New Zealand White rabbits (Johnson et al., 1957). The respiration rate increased rapidly from 69 to 190 breaths/ minute by raising air temperature from 18.3 to 33.3^{o}C. Particularly, respiration rate of Angora rabbits increased enormously by exposure to air temperature above 24^{o}C for short periods (Lee et al., 1976).

Above 35^{o}C, rabbits can no longer regulate their internal temperature and heat prostration sets in (Lebas et al., 1986). At 40°C considerable panting and salivation occurred. The concentration of the metabolic hormones and enzymes decrease significantly as a function of heat stress in an attempt by animals to diminish heat production to counteract the increased heat load (Johnson, 1980). However, animals routinely kept under high temperature develop metabolic mechanisms to adapt to heat stress since it is observed that in the trotopics, new Zealand White rabbits are successfully raised under conditions in which the temperature is consistently 32 - 35°C, while rabbits of the same breed adapted to cool conditions of the Pacific North West of the United States may die of heat stress when the temperature on rare occasions exceeds 35°C (Cheeke et al., 1982).

b. Humidity:

Rabbits are sensitive to very high humidity and may be affected by abrupt changes in humidity, but not with constant humidity which depends on housing design. This may be due to the fact that wild rabbits spend much of their lives in underground burrows with humidity level near saturation point (100%). Lebas et al. (1986) reported that French breeders found that adequate humidity level is 60 - 65%, in winter.

Latent heat can no longer be dissipated when temperature is too high and humidity is also high. In the latter case the result is discomfort which can be followed by prostration. In tropical climates, very hot spells with near 100% humidity which often occurs during the rain season can cause serious problems, while air which is too dry (below 60% RH) and hot is even more dangerous, since it do not only upset the secretion of mucus, but the ensuing evaporation shrinks the size of droplets carrying infection agents, ending then to penetrate more easily the respiratory apparatus. However, humidity level does not seem to trouble rabbits in moderate temperatures.

c. Ventilation:

Rabbits are much more sensitive to air quality (relative humidity, concentration of noxious gases and air movement) than to temperature. High relative humidity linked with a high concentration of noxious gases (especially NH_3) and high air speed in the vicinity of animals, greatly favour diseases of the respiratory system, particularly contagious snuffles (Eschborn 1985). Accordingly, a minimum ventilation is needed in the rabbitry to evacuate the harmful gases given off by rabbits (CO_2, NH_3, H_2S, CH_4 and so on) and get rid of excess humidity (from evaporation of animals' breath) and access heat given off by rabbits. However, ventilation needs can vary enormously depending especially on climate, cage type and population density.

The most important measures for attaining tolerable concentrations of noxious gases in closed sheds are the immediate separation of dung and urine after excretion by a urine drainage system and repeated sprinkling of the dung with superphosphate if it remains in the shed for a long time. Sparing use of water in the shed (no dripping drinker - nipples, no flushing and removal of manure, ... etc.), no adjoining dropping pits, gullies or air vents between the various sections of the shed, help in preventing transfer of pathologenic germs. Eschborn (1985) indicated that efficient ventilation systems for closed sheds are those with a rate of circulation of about 2- 3 square meters air / kg live weight/ hour and the air movement in the vicinity of the animals must not exceed 0.5 meter / second.

Means of heat dissipation:

a. Respiration:

The only controlled means of latent heat evacuation is by altering the breathing rate, since most of sweat glands in rabbits are not functional and perspiration (the evacuation of water through the skin) is never great because of the fur (Mclein, 1963). The significance of the increase in respiration is that it enables the animal to dissipate heat by vaporizing high moisture through the respiratory air which accounts for about 30% of the total heat dissipation. These systems work between 0°C and 30°C, but when ambient temperature exceeds, the animal stretches out so it can loose heat as much as possible by radiation and convection and a significant increase in each of rectal temperature and ear temperature may occur (Wolfenson and Blum,1988). Thus the appetite is depressed, the productive and reproductive performances are impaired and resistance to disease is decreased.

b. Nasal mucosa

In medium sized (such as rabbits) and large homeotherms, heat from body core is transported through circulating blood and when animals are exposed to heat, panting occurs and nasal mucosa serves as an important area of heat dissipation. The ventral nasal conicha serves as a good heat exchanger due to its extensive and highly vascularized surface of lamellar system which is in contact with the respiratory air (Caputa et al., 1976 a and b).

Cooling of exhaled air over the large and complex surfaces of the nasal cavity is an important factor of heat and water conservation (Caputa, et al., 1976a). During inhalation, the mucosal surfaces are cooled because their heat and evaporated water are added to the incoming air which leaves the lungs saturated with water vapour at body temperature, passes over these cool surfaces, giving up heat, but a part of its water content is recondensed on the mucosal surface (Caputa et al., 1976b).

The temperature gradients along the ventral nasal conicha of the rabbit are influenced strongly by ambient temperature. The exchange of both heat water between the air and nasal mucus is facilitated by the nature of the ventral nasal conicha through which all the respiratory air passes. The nasal conicha is about 25 millimeters long and consists of a system of temperatures providing a pathway for air movement which has a large surface area with a short distance for the counter of air stream to the mucosal wall (Caputa et al., 1976a). The nasal cooling is determined not only by the nature of nasal cavity but also by the rate of blood flow through it. The ventral nasal conicha is drained by many parallel small arteries, running from the proximal to distal part of the conicha (Bugge, 1968 and Godynicki, 1975). Many arteriovenous anastomoses are found in the conicha (Bugge. 1968). The blood supply is advantageous for respiratory heat loss, during panting due to counter current heat exchange between the blood and the inhaled dry air. Caputa et al., (1976b) confirmed that the decrease of nasal mucosal temperatures in rabbits under mild heat stress (35^{o}C) is indicative of enhanced respiratory evaporative heat loss due to accelerated breathing (panting). Under these conditions, the ventral nasal conicha had the function of a thermolytic organ. On the other hand, vasoconstriction of the nasal vessels in cold environment prevents mucosal warming with arterial blood and prevents respiratory heat loss. Hayward and Baker (1969) and Caputa et al. (1976 a) confirmed that spontaneous motor activity is accompanied by cooling of nasal mucosa due to constriction of its vessels. Heat exchange between respiratory passages and inhaled air is nearly complete when air leaves the ventral nasal conicha, because the temperature of the proximal part of the conicha is not much lower than deep body temperature, even in cold exposed rabbits. Accordingly, the conicha is considered as an important effector of temperature regulation for both heat conservations and heat dissipation.

c. The ear:

The ear function in rabbit is like a car radiator (Lebas et al., 1986). The physiological pathway of the ear lobe temperature is through the control of blood circulation from the body core to special blood vessels bed in the ear lobes. The lobes of ears are supplied with a very big meshwork of blood capillaries and arteriovenous which could be dilated or contracted by vasomotor mechanism (Johnson et al., 1957). The tip region of the ear lobe was always of lower temperature than the middle region because the blood vessels of the tip are less abundant and of smaller calliper than those of the middle, so the blood circulation in vasodilation is more effective on the surface temperature of the middle ear lobe region. The temperature of internal surface of ear lobe is higher than that of the external surface of the same region. During summer, the animal stretches ear pimae and releases it far from the body, exposing surfaces to the ambient or surroundings to increase heat dissipation by convection, radiation and evaporation to maximum, while during winter the ear pimae are folded to cut-away its internal surface from contact with air, at the same time, it drags the ear to bring it closer to the body (Shafie et al., 1970).

Skin temperature was nearly stable allover the year due to the efficient insulation by hair coat. Johnson et al. (1957) and Harrison et al., (1959) observed that the coat was denser and taller at winter season than at summer to enable rabbits to conserve heat during winter.

Conclusion

In rabbits, the sweat glands are not functional and perspiration (the evacuation of water through the skin) is not great due to the fur. Heat dissipation is carried out by altering the breathing rate to increase vaporizing of the high moisture through the respiratory air. In addition the nasal mucosa and the ear play a big role in that respect.

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