Criteria of response and adaptation to high temperature for reproductive and growth traits in rabbits

Marai I.F.M., Abdel-Samee A.M., El Gafaary M.N.

in

Rouvier R. (ed.), Baselga M. (ed.).
Rabbit production and genetics in the Mediterranean area

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 17

1991
pages 127-134

Criteria of response and adaptation to high temperature for reproductive and growth traits in rabbits

I. F. M. MARAI*
A.M. ABDEL-SAMEE**
M.N. EL-GAFAARY***

* DEPARTMENT OF ANIMAL PRODUCTION, FACULTY OF AGRICULTURE, ZAGAZIG UNIVERSITY, ZAGAZIG, EGYPT

** DEPARTMENT OF ANIMAL PRODUCTION, FACULTY OF AGRICULTURAL AND ENVIRONMENTAL SCIENCE, SUEZ CANAL UNIVERSITY, AL-ARISH, EGYPT

*** ANIMAL WEALTH DEPARTMENT, INSTITUTE OF EFFICIENT PRODUCTIVITY, ZAGAZIG UNIVERSITY, ZAGAZIG, EGYPT

SUMMARY - Rabbits are very susceptible to heat stress, as they have few functional sweat glands and have difficulty in eliminating body heat when the environmental temperature is high. Exposing the female rabbits to high ambient temperatures (above 30°C) impairs the reproductive performance and embryonic development and increases the mortality rate among the offspring. In males, heat stress also affects deleteriously the testicular function and semen characteristics. Moreover, body weight and growth decrease due to hyperthermia. Different methods for amelioration of heat stress such as sheltering, drinking cool water, air conditioning, sprinkling tap water and shearing, have been shown.

Key words: Heat stress, reproduction, growth, mortality, thermotolerance, amelioration.

RESUME - "Critères relatifs à la tolérance et l'adaptation aux hautes températures chez le lapin, du point de vue des caractères reproductifs et de croissance". Les lapins sont très sensibles à la chaleur, car ils n'ont que peu de glandes sudoripares fonctionnelles, et éliminent donc difficilement la chaleur corporelle lorsque la température du milieu est haute. Le fait d'exposer des femelles à de hautes températures ambiantes (plus de 30°C) se répercute sur les résultats reproductifs et le développement embryonnaire, et fait augmenter le taux de mortalité chez la descendance. Chez les mâles, la chaleur affecte également de façon négative la fonctionnalité testiculaire et les caractéristiques du sperme. De plus, le poids corporel et la croissance diminuent à cause de l'hyperthermie. Plusieurs méthodes ont été étudiées afin de diminuer le stress provoqué par la chaleur, telles que construire des abris, faire boire de l'eau fraîche, climatiser, vaporiser de l'eau du robinet, ou tondre les animaux.

***Mots-clés:** Chaleur, reproduction, croissance, mortalité, thermotolérance, amélioration des conditions.*

Introduction

Human population is increasing rapidly, especially in all developing countries in Africa, Asia and Latin America. It is estimated that by the year 2000, there will be in the world an additional two billion people to feed (Allen, 1983). To maximize food production in all countries, all reasonable options must be considered and evaluated. Among these is the use of livestock species that, for one reason or another, have not played a major role in animal agriculture, such as rabbits. Such animals have a number of characteristics that make them suitable as meat-producing small livestock in developing countries. The small body size, short generation interval, high reproductive potential, rapid growth rate, genetic diversity and the ability to utilize forages and by-products as major diet components, favour them for the mentioned function (Cheeke, 1986). However, in the developing countries which are mostly localized in tropical and subtropical regions, animals are faced with many problems related to hot climate, particularly, heat stress, poor quality pastures, diseases and parasites.

This article will deal with the effects of heat stress on reproductive performance and growth in the rabbits and the methods of alleviation of heat stressed animals.

Physiological response of rabbits to high temperature

Among the climatic components that may impose stress on productive and reproductive performance of the animals are temperature, humidity, air movement and radiation, being perhaps the temperature the most important one. In developing countries, the most obvious limitation to rabbit production is the susceptibility to heat stress which is a systemic stress that evokes a series of changes in the biological function of homoeotherms.

A temperature of 21°C is known as the "Comfort Zone" for rabbits. At either higher or lower temperatures, the animal has to expend energy to maintain its body temperature. Exposure of rabbits to a high environmental temperature increases the heat load on animals. During the first few hot days of exposure, rabbits are more uncomfortable. Does that are well advanced in pregnancy and newborn litters are the most susceptible to injury.

Since most of the sweat glands in rabbits are not functional and perspiration (the evacuation of water through the skin) is never great because of the fur, the only controlled means of latent heat evacuation is by altering the breathing rate. The significance of the increase in respiration is that it enables the animal to dissipate heat by vaporizing the moisture through the respiratory air, which accounts for about 30% of the total heat dissipation (Abdel Samee, 1987). These systems work between 0° and 30°C, but when ambient temperature exceeds 30°C, the animal stretches out so it can loose heat as much as possible by radiation and convection and a significant increase in both rectal temperature and ear temperature occurs (Kamar *et al.,* 1975; Shafie *et al.,* 1982; Abo-Elezz et al., 1984 and Wolfenson and Blum, 1988). Thus the appetite is depressed, the productive and reproductive performances are impaired and the resistance to disease is decreased. Above 35°C, rabbits can no longer regulate their internal temperature and heat prostration sets in (Lebas *et al.,* 1986).

The mortality among the offspring was found to increase significantly at temperatures above 30°C (Rafai and Papp, 1984). Particularly, exposure of rabbits to prolonged periods for more than three hours daily for a period of 8 weeks during June and July, in Egypt, increased mortality and the losses were confined to dark coloured animals (Abo-Elezz *et al.,* 1984). Such colour absorbs great amounts of the visible spectrum (Shafie *et al.,* 1970 and Findlay, 1972) resulting in an excessive heat load and a possible failure in the animal's heat balance. However, such deaths might be due to the interference with the animal's function by the failure in acid-base balance (Shafie *et al.,* 1970). From another point of view, the study of the mortality rate in the different seasons of the year in Egypt proved that the losses were the lowest in Giza White rabbits (Ragab and Wanis, 1960) and Baladi Red rabbits (Nossier, 1970) born during January and February (Figure 1). Emara (1982) attributed the lower percentages of litter losses during January to April with respect to the remaining months of the year, to the higher availability and better nutritive value of green fodder, in addition to milder weather, especially the atmospheric temperature which prevails in January, February, March and April. However, Gualterio *et al.* (1988) found that the mortality rate at birth was higher in winter and summer than in spring, due to presence of some cold and hot days. El-Maghawry *et al.* (1988) confirmed that the month of kindling affected significantly the preweaning mortality.

The estimated heat tolerance coefficient was considerably higher for the native Giza White (76.6%) than for Bouscat (67.5%) bucks, under the environmental conditions of Egypt (Abdelrazik *et al.,* 1985). When testing thermotolerance in New Zealand rabbits to different ambient temperatures, Finzi *et al.* (1988) obtained the best experimental results when the animals were exposed for a long period (90 minutes) to an ambient temperature of 25-35°C and a relative humidity of 90%.

Reproductive traits response

IN FEMALES

Under high environmental temperature, mating and conception rates or fertility of the doe appear to be lowered (Matassino *et al.,* 1970) due to a complex set of events, which are expressed in a significant reduction in total young born and an increase in the percentage of young born dead.

Such phenomena are due to a marked decline in each of postcoital ovulation (Farrell *et al.,* 1968), ovulation rate (Hahn and Gabler, 1971), percentage of corpora lutea associated with the formation of detectable implantation sites or viable embryos, i.e., number of implantation sites/doe and number of viable embryos/doe (El-Fouly *et al.,* 1977). Accordingly, seasonal differences were observed in ovulation rate (Hahn and Gabler, 1971), implantation rate, gestation period (El-Fouly *et al.,* 1977) and litter size (Figure 1). El-Sheikh and Casida (1955) confirmed the significant effect of heat on the ratio of fertilized to unfertilized ova in test females with some recovery by 21 to 30 days after treatment. Rathore (1970) postulated that heat stress resulted in reduction of fertilization rate, smaller blastocysts and embryos and an increased embryonic mortality rate. However, Wolfenson and Blum (1988) reported that ovarian weight, embryo implantation rate and embryo survival rate did not vary significantly in rabbits as a function of exposure to hot climate. Similarly, El-Fouly *et al.* (1977) did not find significant effects for hot summer season on fertilization rate and the diameter of the blastocyst including the mucus coat. From another point of view, Edwards (1978) postulated that early stages of pregnancy are more sensitive than later ones to heat stress. Embryonic losses frequently occurred when the animals were exposed to severe heat stress during the first 6 days of pregnancy. In addition, it was found that embryonic mortality increased in does inseminated with heated sperm cells (Burfening and Ulberg, 1968), or when zygotes were heated during the division of the first cells (Alliston *et al.*, 1965). However, Abo-Elezz *et al.* (1984) reported that heat stress may affect late embryonic or very early postnatal death rates.

Particularly, severe sustained heat stress of 35°C reduced the conception rate from 66% in the first parity to 33% in the second parity against 100% in winter (Shafie *et al.*, 1984).

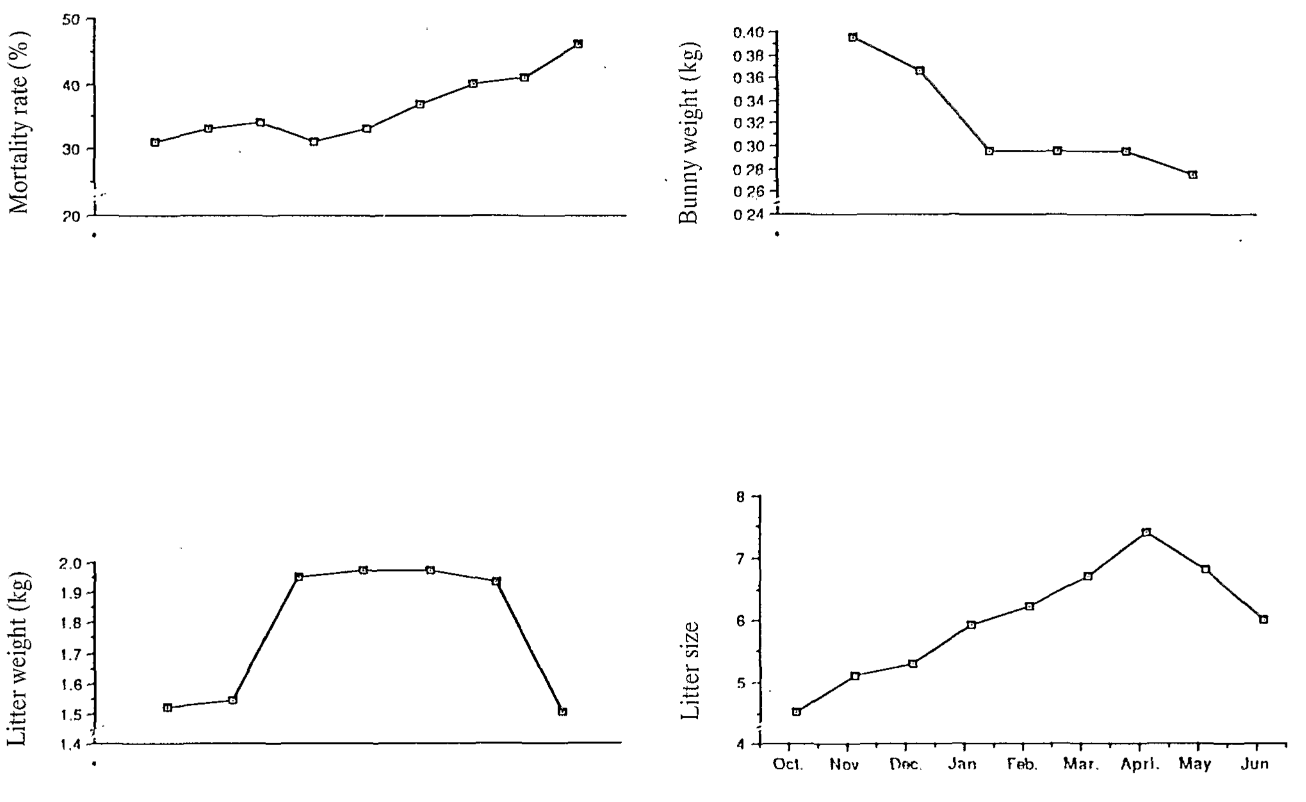

Fig. 1: Seasonal effects on litter size (1), litter weight (2), bunny weight (3) and mortality rate (4) in rabbits, under Egyptian conditions as cited from the literature.

IN MALES

Exposing the bucks to heat stress resulted in a reduction in testicular measurements (testis weight and length). This reduction suggests a degeneration in the germinal epithelium and a partial atrophy in the seminiferous tubules (Chou *et al.,* 1974), since the average number of testicular cells, especially the secondary spermatocytes and spermatids of types B, C and D, the ratio of sertoli cells to other cells and the diameter of the seminiferous tubules were adversely affected by heat stress (El-Sherry *et al.,* 1980a). Similar criteria were observed in domestic animals, i.e., degeneration of the germinal epithelium and seminiferous tubules were observed in bulls (Alba and Riera, 1966), rams (Voglmayer *et al.,* 1971), boars (Mazzaria *et al.,* 1968) and rats (Sod-Moriah *et al.,* 1974) when exposed to heat. However, Hafez (1965) reported that the testes of farm animals do not undergo marked seasonal changes in size.

In addition, the studies in Egypt showed that exposure of male rabbits to hot summer season resulted in a significant increase in each of reaction time, total sperm abnormalities, sperm mortality rate, methylene blue reduction time and seminal plasma total calcium and fructose concentrations. At the same time, there was a significant decrease in ejaculate volume, sperm concentration, mass motility, semen density, spermatozoal total nitrogen and phosphorus concentration (El-Sherbiny, 1987). Oloufa *et al.* (1951) confirmed the above results in volume and concentration of the ejaculate, sperm motility and bucks sexual desire in a high environmental temperature at 35°C. The deleterious effects of solar radiation on semen quality and fertility may be attributed to sustained damage during the late stages of spermatogenesis.

Injection of the heat stressed male rabbits with LH significantly increased the total number of spermatocytes and promoted their rapid division. The number of type A spermatids increased, while that of type B decreased. The seminiferous tubules diameter, the total number of spermatogonia and sertoli cell numbers were restored to normal and the number and ratio of type B spermatogonia were restored to above normal level by the treatment. However, type D spermatids did not return to their normal level (El-Sherry *et al.,* 1980e). Similarly, the combined FSH-LH treatment of heat stressed testes increased seminiferous tubules diameter to nearly normal, but decreased the sertoli cell number, total spermatogonia and total spermatocytes. The FSH-LH glucocorticoids treatment restored seminiferous tubules diameter, total spermatocytes and total spermatids to normal, but did not correct retarded spermatid differentiation (El-Sherry *et al.,* 1980d). In another trial, El-Sherry *et al.* (1980c) found that the treatment with glucocorticoids under thermoneutral conditions increased seminiferous tubules diameter, the number of spermatocytes and number and ratio of type A spermatids, while the total number of spermatogonia and the other types of spermatids decreased. The seminiferous tubules diameter and sertoli cell number, sertoli cell ratio and the total number of spermatocytes were restored almost to normal levels, but the number and ratio of spermatogonia decreased by the treatment. The FSH treatment prevented the decrease in seminiferous tubules diameter and increased the number and ratio of type B spermatogonia and prevented the decrease in the total number of spermatocytes caused by exposing rabbits to heat stress (El-Sherry *et al.*, 1980b).

Growth response

It is known that growth is a complex set of metabolic events which are genetically and environmentaly controlled. The role of environment in the performance and health of domestic animals is well known for every specialist. However, the literature dealing with the effect of high temperature on growth of rabbits is rather conflicting.

Some studies showed that exposure of rabbits to a high environmental temperature decreased the embryo's weight and length (Radwan, 1975; Edwards, 1978 and Wolfenson and Blum, 1988), live body mass (Rafai and Papp, 1984) and body weight (Abo-Elezz *et al.,* 1984 and Fekry, 1989) due to hyperthermia. Abo-Elezz *et al.* (1984) attributed that to the decrease in feed consumption and possibly to dehydration of the animals and/or to tissue catabolism. However, Abdel-Samee (1982), Kamal (1982) and Kamal *et al.* (1989) reported that the changes in body due to heat stress in animals are controversial and the live body weight is not a reliable estimate for detecting changes in actual tissue mass, since it depends on the changes in both total body water and body solids and the counteraction between tissue destruction and water retention. Other studies showed that exposing rabbits to heat stress (35°C and 65% RH) caused a significant increase in body weight, total body water and water turnover rate, while total body solids and biological half-life time of tritiated water (T 1/2) decreased significantly (Abdelrazik *et al.,* 1985). Wolfenson and Blum (1988) confirmed that exposing rabbits to controlled hot climate produced a slight increase in body weight at birth and a significant decrease in daily body gain. From another point of view, Ragab and Wanis (1960), Shawer (1963), Nossier (1970), Khalil (1980) and Emara (1982) reported that rabbits body weight changed according to month of birth. It increased from September to February and decreased thereafter during April and May, while litter weight and bunny weight at weaning increased from October to March and April, in Egypt (Figure 1).

However, Fekry (1989) showed that exposure of rabbits to solar radiation had no significant effects on body composition (percentages of water, protein, fat and ash), carcass composition (carcass weight and percentages of water, protein, fat and ash) and haemoglobin content.

Generally, the decrease in productivity under high environmental temperature is a result of disturbing the normal physiological balance of the animal's body, particularly energy, hormonal, thermal and water balances (Kamal, 1975; Johnson, 1980; Abdel-Samee *et al.*, 1989; Daader *et al.*, 1989 and Habeeb *et al.*, 1989). Such disturbance is expressed as negative nitrogen balance (Kamal *et al.*, 1962; Kamal and Johnson, 1970 and 1971 and Ames *et al.*, 1980) and negative mineral balance (Kamal and Abdelaal, 1972; Kamal and Johnson, 1977; Kamal, 1982 and Kamal *et al.*, 1984) which are a result of the dramatic reduction in feed consumption (Rafai and Papp, 1984; Wolfenson and Blum, 1988 and Fekry, 1989). Another explanation of that phenomenon may be through the activity of the metabolic hormones and enzymes, since their concentrations decrease significantly as a function of heat stress in an attempt by the animals to diminish heat production to counteract the increased heat load (Johnson, 1980 and Abdel-Samee, 1987). Postulately, animals routinely kept under high temperature develop metabolic mechanisms to adapt to heat stress, since it is observed that in the tropics, New Zealand White rabbits are successfully raised under conditions in which the temperature is consistently 32.2 - 35.0°C, while rabbits of the same breed adapted to cool conditions of the Pacific Northwest of the United States may die of heat stress when the temperature on rare occasions exceeds 32.2°C.

Amelioration of heat stress

Temperature, humidity and air current all have a direct bearing and each rabbitry is an individual problem.

Different physical and physiological methods have been used to alleviate the heat load in heat stressed animals. The physical methods used are such as sheltering, air conditioning, zone air cooling, drinking cool water, using wet or iced sacks in the cages, spray or sprinkling the roofs and floor with tap water and shearing. However, in all cases rabbits must be kept dry, since wet coats are predisposing causes for pneumonia and respiratory troubles.

Rabbits must be protected from high temperature, rain and sun by providing adequate sheltering. Good circulation of air throughout the rabbitry is a must, but strong drafts and winds should be avoided. Rabbits that show symptoms of suffering should be removed to a quiet, well ventilated place.

In areas of high temperature such as the tropics, it is essential that the rabbits have a supply of cool water available at all times, since they consume large quantities of water and less feed than in temperate climates. Provision of adequate cool water is critical under these conditions (Cheeke, 1986).

Considerable relief can be given by placement of wet jute sacks in the cage to lie on. In the case of the doe that has advanced to the stage where hemorrhage is occurring, a quick action is necessary. Placing cracked ice between the folds of a wet jute sack and placing it in the cage to lie on, is quite effective and may save many does which are about to kindle. Immersing the entire rabbit in cold water for three seconds is another emergency measure to save heat stressed rabbits (Cheeke *et al.,* 1982).

Sprinkling the roof and floor of the rabbitry will give considerable relief. If a roof sprinkler is thermostatically controlled, it will change the environment conditions quickly and will be especially useful if the caretaker is not available for regulating the sprinkler (Cheeke et al., 1982).

Shearing the fur coat induced a significant decrease in body skin and ear lobe temperatures. Respiration and pulse rates also decreased (Kamar *et al.,* 1975). Removing of the fur in the mice caused a drop in body temperature and an increase in the rate of oxygen consumption by 35%.

The physiological methods used for alleviation of the heat load in the heat stressed animals are such as treatments with hormones (as injections of the males with LH, FSH... etc, which are mentioned before), antihormones, diopheretics and diuretics.

References

ABDELRAZIK, M.A., KATTAB, Y.A. and GEBRIEL, G.M. (1985). Effect of heat stress on body fluids and heat tolerance coefficient of White Giza and Bouscat buck rabbits. Egyptian Journal of Animal Production, 25(2), 165-172.

ABDEL-SAMEE, A.M. (1982). The role of water metabolism in the heat stress syndrome with the use of radioisotopes in cattle. M.Sc. Thesis, Faculty of Agriculture, Mansoura University, Mansoura, Egypt.

ABDEL-SAMEE, A.M. (1987). The role of cortisol in improving productivity of heat stressed farm animals with different techniques. Ph.D. Thesis, Faculty of Agriculture, Zagazig University, Zagazig, Egypt.

ABDEL-SAMEE, A.M., HABEEB, A.A., KAMAL, T.H. and ABDELRAZIK, M.A. (1989). The role of urea and mineral mixture supplementation in improving productivity of heat stressed Friesian calves in the subtropics. Proceedings of the 3rd Egyptian-British Conference on Animal, Fish and

Poultry Production, Alexandria University, Alexandria, Egypt. 2, 637-641.

ABO-ELEZZ, Z., SALEM, M.H., ABDEL-FATTAH, G.A. and YASSEN, A.M. (1984). Effect of exposure to direct solar radiation on body weight, thermoregulation and reproductive efficiency in the male rabbits. Proceedings of the 1st Egyptian-British Conference on Animal and Poultry Production. Zagazig University, Zagazig, Egypt. 1, 119-135.

ALBA, J.DE. and RIERA, S. (1966). Sexual maturity and spermatogenesis under heat stress in the bovine. Animal Production, 81, 137-144.

ALLEN, C.E. (1983). New horizons in animal agriculture: Future challenges for animal scientists. Journal of Science, 57 (Supplement 2), 16.

ALLISTON, G.W., HOWARTH, B. and ULBERG, L.C. (1965). Embryonic mortality following culture in vitro of one and two-cell rabbit eggs at elevated temperatures. Journal of Reproduction and Fertility, 9, 337.

AMES, D.R., BRINK, D.R. and WILLMS, C.L. (1980). Adjusting proteins in feedlot rations during thermal stress. Journal of Animal Science, 50, 1-11.

BURFENING, P.J. and ULBERG, L.C. (1968). Embryonic survival subsequent to culture of rabbit spermatozoa at 38° and 40°C. Journal of Reproduction and Fertility, 15, 87.

CHEEKE, P.R. (1986). Potentials of rabbit production in tropical and subtropical agricultural systems. Journal of Animal Science, 63, 1581-1586.

CHEEKE, P.R., PATTON, N.M. and TEMPLETON, G.S. (1982). Care of the herd during period of high temperatures. In: Rabbit production, edited by P.R. Cheeke, N.M. Patton and G.S. Templeton, 5th Edition. pp. 85-86. Copyright by the Interstate Printers and Publishers Inc.

CHOU, J.P., YI-CHUAN, L. and CHEN-CHAO, C. (1974). Effects of heating on rabbit spermatogenesis. Chinese Medical Journal, 6, 365-367.

DAADER, A.H., MARAI, I.F.M., HABEEB, A.A.M. and YOUSEF, H.M. (1989). Improvement of growth performance of Friesian calves under Egyptian sub-tropical conditions. 1. Internal cooling technique using diuretics and drinking cool water, Proceedings of the 3rd Egyptian-British Conference on Animal, Fish and Poultry Production, Alexandria University, Alexandria, Egypt, 2, 595-607.

EDWARDS, M.J. (1978). Congenital defects due to hyperthermia. Advances in Veterinary Sciences, Comp. Medecine, 22-52.

EL-FOULY, M.A., BORADY, A.M.A., RADWAN, A.A. and KAMAR, G.A.R. (1977). Seasonal variation in some reproductive traits of Bouscat and Giza White rabbits. Egyptian Journal of Animal Production, 17(1), 9-19.

EL-MAGHAWRY, A.M., YAMANI, K.A. and MARAI, I.F.M. (1988). A preliminary study on performance of some productive traits in New Zealand White and Californian rabbits, under Egyptian environments. Proceedings of the 4th Congress of the World Rabbit Science Association, Budapest, Hungary, 1, 264-268.

EL-SHEIKH, A.S. and CASIDA, L.E. (1955). Mortality and fertility of spermatozoa as affected by increased ambient temperature. Journal of Animal Science, 14, 1146-1150.

EL-SHERBINY, A.M. (1987). Seasonal variation in seminal characteristics of rabbits. M.Sc. Thesis, Department of Animal Production, Faculty of Agriculture, Ain Shams University, Egypt.

EL-SHERRY, M.I., EL-NAGGAR, M.A. and NASSAR, S.M. (1980a). Experimental study of summer stress in rabbits. 2. The quantitative and qualitative pathogenesis of spermatogenic cell cycle in rabbits. Assiut Veterinary Medical Journal, 7(13/14), 17-31.

EL-SHERRY, M.I., EL-NAGGAR, M.A. and NASSAR, S.M. (1980b). Experimental study of summer stress in rabbits. 3. The quantitative and qualitative effect of FSH and FSH in combination with thyroxine on the spermatogenic cell cycle in stressed rabbits. Assiut Veterinary Medical Journal, 7 (13/14), 33-47.

EL-SHERRY, M.I., EL-NAGGAR, M.A. and NASSAR, S.M. (1980c). Experimental study of summer stress in rabbits. 5. The quantitative and qualitative effects of glucocorticoids injection on spermatogenic cell cycle of normal and stressed rabbits. Assiut Veterinary Medical Journal, 7(13/14), 65-81.

EL-SHERRY, M.I., EL-NAGGAR, M.A. and NASSAR, S.M. (1980d). Experimental study of summer stress in rabbits. 6. The quantitative and qualitative effects of hormonal injection on spermatogenic cell cycle of stressed rabbits. Assiut Veterinary Medical Journal, 7(13/14), 83-101.

EL-SHERRY, M.I., NASSAR, S.M. and EL-NAGGAR, M.A. (1980e). Experimental study of summer stress in rabbits. 4. The quantitative and qualitative effect of LH injection on spermatogenic cell cycle of normal and stressed rabbits. Assiut Veterinary Medical Journal, 7(13/14), 49-63.

EMARA, M.E.M. (1982). Effect of crossbreeding on some productive traits in rabbits. Ph.D. Thesis, Faculty of Agriculture Sciences. Moushtohor, Zagazig University, Egypt.

FARREL, G., POWERS, D. and OTANI, T. (1968). Inhibition of ovulation in the rabbit, seasonal variation and the effects of indoles. Endocrinology, 83, 599.

FEKRY, A.E. (1989). Body composition responses to exposure to direct solar radiation. Proceedings of the 3rd Egyptian-British Conference on Animal, Fish and Poultry Production, Alexandria University, Alexandria, Egypt, 2, 649-656.

FINDLAY, J.D. (1972). Climatological data needed to specify climatic stress. World Review of Animal Production, 8, 28-44.

FINZI, A., MORERA, P. and KUZMINSKY, G. (1988). Acclimatization and repeatability of thermotolerance parameters in rabbit. Proceedings of the 4th Congress of the World Rabbit Science Association. Budapest, Hungary, 419-424.

GUALTERIO, L.A., VALENTINI, A. and BAGHACCA, M. (1988). Effect of season and parturition order on mortality rate at birth and in the nest. Proceedings of the 4th Congress of the World Rabbit Science Association, Budapest, Hungary, 182-188.

HABEEB, A.A., ABDEL-SAMEE, A.M. and KAMAL, T.H. (1989). Effect of heat stress, feed supplementation and cooling technique on milk yield, milk composition and some blood constituents in Friesian cows, under Egyptian conditions. Proceedings of the 3rd Egyptian-British Conference on Animal, Fish and Poultry production, Alexandria University, Alexandria, Egypt, 2, 629-635.

HAFEZ, E.S.E. (1965). Environment and reproduction in farm animals. World Review of Animal Production, 1, 118-128.

HAHN, J. and GABLER, G. (1971). Fertility in rabbit does with reference to individual arid seasonal variations. Zuchtungskunde, 4, 456 (Cited by Animal Breeding Abstract, 40, 3588).

JOHNSON, H.D. (1980). Environmental management of cattle to minimize the stress of climatic change. Inter. J. Biomet., 24, 5-14.

KAMAL, T.H. (1975). Heat stress concept and new tracer methods for heat tolerance in domestic animals. Iraqi Atomic Energy Commission, 230-235.

KAMAL, T.H. (1982). Heat-induced mineral imbalances in animals. In: The use of isotopes to detect moderate mineral imbalances in farm animals. IAEA-TECDOC-267, Vienna, 49-61.

KAMAL, T.H. and ABDELAAL, A.E. (1972). Seasonal changes in P32 and Ca45 metabolism in Friesians and water buffaloes. (FAO/IAEA Symposium on “Isotope studies on the physiology of domestic animals, Athens, Greece). Proceedings Series, IAEA, Vienna, 95-102.

KAMAL, T.H., HABEEB, A.A., ABDEL SAMEE, A.M. and ABDEL- RAZIK, M.A. (1989). Supplementation of the heat stressed Friesian cows with urea and mineral mixture and its effect on the milk production in the subtropics. Proceedings of the International Symposium on the Constraints and Possibilities of Ruminant Production in the Dry Subtropics, Cairo, Egypt, 183.

KAMAL, T.H. and JOHNSON, H.D. (1970). Whole body 40k loss as a predictor of heat tolerance in cattle. Journal of Dairy Sciences, 53, 1734-1738.

KAMAL, T.H. and JOHNSON, H.D. (1971). Total body solids loss as a measure of a short term heat stress in cattle. Journal of Animal Science, 32, 306-311.

KAMAL, T.H. and JOHNSON, H.D. (1977). Effect of high environmental temperature and age on trace elements metabolism in cattle. Symposium on “Trace elements in drinking water, agriculture and human life” Cairo, Egypt. 54-68.

KAMAL, T.H., JOHNSON, H.D. and RAGSDALE, A.C. (1962). Metabolic reactions during thermal stress (35 to 95°F) in dairy animal acclimated at 50° and 80°F. Missouri Agriculture Experimental Station Research Bulletin, 785.

KAMAL, T.H., MEHREZ, A.Z., EL-SHINNAWY, M.M. and ABDEL-SAMEE, A.M. (1984). Estimation of evaporative water loss in mild hot climates with the use of tritiated water dilution technique in cattle. Proceedings of Egyptian-British Conference on Animal and Poultry Production, Zagazig, 2, 8-14.

KAMAR, G.A.R., SHAFIE, M.M. and ABDEL-MALEK, E.G. (1975). Temperature gradient in rabbits in relation to heat tolerance. Egyptian Journal of Animal Production, 15(1), 47-56.

KHALIL, M.H.E. (1980). Genetic and environmental studies on some productive traits, M.Sc. Thesis, Faculty of Agricultural Science, Moshtohor, Zagazig University, Egypt.

LEBAS, F., COUDERT, P., ROUVIER, R. and ROCHAMBEAU, H. DE (1986). Reproduction and environment. In: The rabbit husbandry health and production. Food and Agriculture Organization of the United Nations (FAO), Rome. Animal Production and Health Series, 21, 60-62.

MATASSINO, D., BORDI, A. and NARDONE, A. (1970). Some vital statistics of the native improved breed of rabbit. Produzione Animale, 9, 21.

MAZZARIA, G.F., DU MESNIL, DU BUISSON and ORTAVANT, R. (1968). Action of temperature on spermatogenesis, sperm production and fertility of the boar. Proceedings of the 6th International Congress of Animal Reproduction and A.I., Paris, 1, 305-308.

NOSSIER, F.M. (1970). A study on some economical characteristics in some local and foreign breeds. Acta Zoological Nitra, 25, 179-191.

OLOUFA, M.M., BOGART, R. and MCKENZIE, F. (1951). Effect of environmental temperature and the thyroid gland on fertility in the male rabbit. Fertility and Sterility, 2, 223-228.

RADWAN, A.A. (1975). Comparative studies between production and reproduction in rabbits (Bouscat and Giza White). M.Sc. Thesis, Faculty of Agriculture, Cairo University.

RAFAI, P. and PAPP, Z. (1984). Temperature requirement of rabbit does for optimal performance. Archiv für Experimentale Veterinär Medizin, 38(3), 450-457.

RAGAB, M.T. and WANIS, A.A. (1960). Litter size in the Baladi rabbit as affected by heredity and environment. Bulletin of the Faculty of Agriculture, Cairo University, 221, pp. 13.

RATHORE, A.K. (1970). High temperature exposure of male rabbits. Indian Veterinary Journal, 47, 837-840.

SHAFIE, M.M., ABDEL MALEK, E.G., EL-ISSAWI, H.F. and KAMAR, G.A.R. (1970). Effect of environmental temperature on physiological body reactions of rabbits under sub-tropical conditions. U.A.R. Journal of Animal Production, 10, 133-149.

SHAFIE, M.M. KAMAR, G.A.R., BORADY, A.H.A. and HASSANIEN, A.M. (1982). Thermoregulation in rabbits under different environmental conditions. Proceedings of the 6th International Conference on Animal and Poultry Production, Zagazig University, Zagazig, Egypt. 21-23.

SHAFIE, M.M., KAMAR, G.A.R., BORADY, A.H.A. and HASSANIEN, A.M. (1984). Reproductive performance of Giza rabbit does under different natural and artificial environmental conditions. Egyptian Journal of Animal Production, 24(1-2), 167-174.

SHAWER, M.F.K. (1963). A comparative study of production traits between Egyptian and standard breeds of rabbits. M.Sc. Thesis, Alexandria University, Alexandria, Egypt.

SOD-MORIAH, U.A., GOLDBERG, G.M., and BEDRAK, E. (1974). Intrascrotal temperature, testicular histology and fertility of heat-acclimated rat. Journal of Reproduction and Fertility, 37, 263-268.

VOGLMAYER, J.K., SETCHELL, B.P. and WHITE, I.G. (1971). The effects of heat on the metabolism and ultrastructure of ram testicular spermatozoa. Journal of Reproduction and Fertility, 24, 71-80.

WOLFENSON, D. and BLUM, O. (1988). Embryonic development, conception rate, ovarian function and structure in pregnant rabbits heat-stressed before or during implantation. Animal Reproduction Science, 17, 259 - 270.