World Rabbit Sci. 2019, 27: 49-55
doi:10.4995/wrs.2019.10588

TECHNICAL NOTE: IMPROVING THE MICROCLIMATE OF A RABBIT HOUSE: THERMAL INSULATION AND AIR HANDLING

BODNÁR K.*, BODNÁR G.†, MAKRA L.‡, FÜLÖP A.§, FARKAS Z.#, CSÉPE Z.‡, PRIVÓCZKI Z.I.¶

*Szent István University Faculty of Agricultural and Economic Studies, Szabadság 1-3, H-5540 Szarvas, Hungary.
†University of Debrecen Faculty of Engineering, Ótemető 2-4, H-4028 Debrecen, Hungary.
‡University of Szeged, Faculty of Agriculture, Andrássy 15, H-6800 Hódmezővásárhely, Hungary.
§Hungarian Meteorological Service, P.O.B. 39, H-1675 Budapest, Hungary.
#Lepusfarm Ltd., Vécsey 15, H-4100 Berettyóújfalu, Hungary.
¶Kaposvár University, Doctoral (PhD) School of Management and Organizational Science, Guba S. 40, H-7400 Kaposvár, Hungary.

Abstract: The aim of the paper is to modernise a farm building for rabbits and provide a possible solution for other farms. The model calculations are focused on the welfare viewpoint of rabbit breeding, i.e. first of all on ventilation, cooling and heating of the shed in order to approach the microclimate for meat rabbit production. The planned air handling unit can ensure the optimal temperature range (15-25°C) for rabbits all year round. In addition, thermal insulation and mechanical components of a rabbit house were planned and the possibility of reducing the energy demand of the building by more than 40% was analysed. The renewed rabbit farm is better suited to animal welfare requirements, as it can meet the environmental needs in production and reduces the building's impact on the surrounding area.

Key Words: rabbit production, rabbit farm, microclimate, thermal insulation, air handling, energy demand.

INTRODUCTION

There is growing pressure emerging from public opinion and consumers to improve housing conditions and for farms to comply with animal welfare standards. Hungarian rabbit producers in SME (small to medium-sized enterprise) sector are suffering from several unfavourable factors: the abattoirs stopped buying rabbits from small farms; outdated housing conditions; continental climate of the country, etc. One common problem is high indoor temperature of the rabbit farm in summer and imperfect ventilation throughout the year.

Exposure of growing and adult rabbits to severe heat stress during summer adversely affects their growth and reproductive traits and reduces resistance to diseases (Marai *et al.,* 2001). In female rabbits, conception rate, embryonic development, litter size, litter weight and milk production decrease and age at puberty and pre- and post-weaning mortality increase due to exposure to heat stress. In males, temporary sterility may occur, with testosterone concentration, libido, ejaculate volume, sperm concentration and motility in semen decreased by exposure to extreme excess heat. The drastic changes that occur in rabbits' biological functions are depression in feed intake, feed efficiency and utilisation, disturbances in metabolism of protein, energy, and water and mineral balances (Marai *et al.,* 2002).

Atmospheric pollution from livestock production has also become an issue of increasing interest. Noxious gases such as carbon dioxide (CO_2), ammonia (NH_3), methane (CH_4) and, during improper manure management, hydrogen

Correspondence: K. Bodnar, bodnarkaroly.dr@gmail.com. Received *August 2018* - Accepted *February 2019.*
https://doi.org/10.4995/wrs.2019.10588

sulphide (H_2S) can accumulate inside farms without proper ventilation. However, information on these emissions from rabbit farming and the limits of gas levels are scarce (Calvet *et al.,* 2012; Borso *et al.,* 2016).

The aim of the present study was to prepare an example for the rabbit producers, especially for young farmers, to improve the microclimate of old buildings in 2 ways: *i)* by thermal insulation of the old building, reducing the heat transmission of the structure; and *ii)* by modernising the technical background, which means the replacement of traditional ventilators with multifunctional (ventilation, thermal control, relative air humidity (RH) control and air filtering) air handling units.

MATERIALS AND METHODS

The model calculations were based on the climatic patterns of the study area, the environmental requirements of the rabbit, the structure of the building, the characteristics of thermal insulation and the possible technical equipment.

Study area

The examined rabbit farm is located cca. 5 km from the village of Bakonszeg (47°11'N, 21°27'E) in the eastern part of Hungary, about 50 km south from Debrecen. The area is characterised by an extensive flat landscape, with an elevation of about 90 m above sea level). The climate is warm-temperate, with hot summers and a fairly uniform distribution of precipitation. It is classified as *Cafx* in climate classification (Köppen, 1931). The number of sun hours per year is approximately 2000. The mean annual temperature is 10-10.2°C, while the mean air temperature of the vegetation period is 17-17.2°C. Furthermore, the mean maximum temperature in summer is 34.2-34.6°C, while the mean minimum temperature in winter is around –16.5 - –17°C. The annual rainfall is 530-550 mm, while its amount in the vegetation period is 310-320 mm.

Requirements for a rabbit house

For effective meat production in an industrial scheme, rabbits have to be housed exclusively indoors and under a controlled environment. Air temperature should be kept between 15-25°C (Cervera and Carmona, 2010). Minimum temperature of not lower than 15°C is advisable for does at time of kindling and lactation, as well as for growing rabbits. Air flow rate, dust level, relative air humidity and concentrations of CO_2, NH_3 and other air pollutants in the rabbit house should be kept to a level which is not harmful for rabbits (Hoy, 2008).

Facilities and the rabbit house structure

The shed is constructed as follows:

a) The building dimensions are: width 15 m, length 100 m, height 3.5 m. The orientation of the building is north-south. This type of sheds was built in the 70s and early 80s in a type of design originally recommended for poultry production (Horn, 1981) or for the farming of other species.

b) The walls are made of 30 cm ceramic masonry blocks (B30 type) with a 1.5 cm lime mortar layer both on the inner and outside. The thermal insulation of the wall is planned from 10 cm NC100 EPS (Nikecell 100 mm, expanded polystyrene foam) insulating material.

c) The 15 cm thick ferro-concrete floor lies on 10 cm thick gravel filling.

d) The roof is made of corrugated slate (1 cm) and the ceiling is 2 cm chipboard. Under the roof a thermal insulation layer is also planned from 15 cm thick surface coated (aluminium foil) mineral wool.

e) The wooden door (4×3.5 m) is on the south wall. There are no windows on the walls. They have air intake vents for the ventilation system in the original building, but after the proposed changes a fresh air inlet and exhausted air outlet will be planned only for the air handling unit.

Meteorological and animal data used in technical calculations

When insulating the rabbit shed, planning and calculations were made by using the WinWatt software package (BAUSOFT Pécsvárad Kft.). The main input data were as follows:

a) As the nearest climatological station to Bakonszeg is Debrecen city, daily mean temperature data of Debrecen for the period 1981-2010 (Hungarian Meteorological Service, www.met.hu) were taken into account;

b) the structural parameters of the building;

c) the required temperature range of the shed (minimum temperature: 15°C, maximum temperature: 25°C (Cervera and Carmona, 2010);

d) the required RH in the shed (between 55-80%) (Morisse, 1981; Lebas *et al.,* 1997);

e) the rate of ventilation (minimum: 3 m^3 of air/h kg body weight) (Morisse, 1981);

f) maximum air speed in the building at animal level (0.3 m/s) (Morisse, 1981);

g) a lighting schedule was applied (16 h light and 8 h dark, Matics *et al.,* 2014), the light performance was 50 W/m^2 (EFSA, 2005);

h) the estimated maximum number of animals;

i) the maximum density of animal stock [800 breeding animals (does and bucks) and their progeny of different age]. Rabbit does and fattening rabbits are kept in the same temperature range. Authors have written about a single thermal comfort zone for rabbit production (Patton, 1994; Lebas *et al.,* 1997). Only new-born kits have insufficient thermal regulation and they need higher ambient temperature (Anonymous, 2011). Nest boxes with hair and bedding ensure them a constant temperature.

Probabilities and differences of daily mean temperatures beyond the threshold values

As the nearest climatological station to Bakonszeg is Debrecen (around 50 km distance from the rabbit farm), daily mean temperature data for Debrecen (Hungarian Meteorological Service) were taken into account to determine temperature-related statistical consequences on the rabbit breeding in the farm examined. For each day, we determined the probability of daily mean temperatures lower than 15°C (blue/light) and higher than 25°C (red/dark) (Figure 1).

Mean differences of the actual daily mean temperatures from the threshold temperatures are also calculated, as follows. For every day of the year we took the difference (t_{lt}–t_{cmean}) in the case of t_{cmean}<t_{lt} and the difference (t_{cmean}–t_{ut}) in the case of t_{cmean}>t_{ut}, where t_{lt} = lower threshold (15°C), t_{ut} = upper threshold (25°C), and t_{cmean} = actual mean daily temperature) (Figure 2).

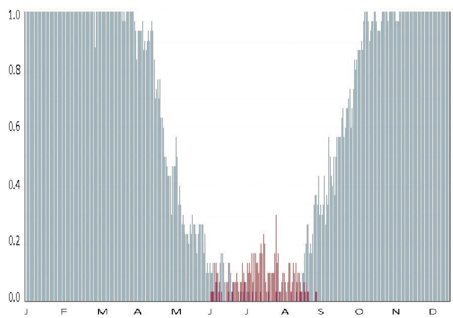

Figure 1: Probability of daily mean temperatures, Debrecen, 1981-2010. Blue/light: <15°C and red/dark: >25°C.

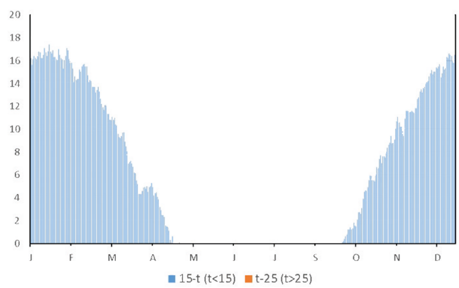

Figure 2: Mean differences of the actual daily mean temperatures from the threshold temperatures, Debrecen, 1981-2010. [If daily mean temperature is (t)<15°C (>25°C), then heating or cooling, respectively, is required].

The software database contains the technical parameters of the structural elements and building materials according to the manufacturers.

During the calculations and planning we focused on: (1) the thermal insulation of the building, and its effect on the transmission heat flow, (2) the optimal temperature and RH for rabbit production and (3) better ventilation to remove exhaust air and harmful gases.

Heat transmission calculations

One objective of the plan is to reduce the energy requirement of the farm with thermal insulation. When planning a rabbit house, heat transmission calculations are of crucial importance in order to reduce overheads. When calculating heat transmission, the so-called heat exchange formula (Homonnay, 2001) was used:

$$Q = U \times A \times \Delta T$$

where Q: heat quantity (W), U: heat transmission coefficient (W/(m^{2}K)), A: area of the wall (m^2), ΔT: temperature difference between the 2 sides of the wall (K).

RESULTS AND DISCUSSION

Probabilities and differences of daily mean temperatures beyond the threshold values

Based on 30-year (1981-2010) daily mean temperatures and standard deviations for Debrecen, we determined for every day of the year the probability of daily mean temperatures lower than 15°C (blue/light) and/or higher than 25°C (red/dark), in order to ensure an acceptable temperature interval for rabbit breeding in the farm (Figure 1).

Regarding the fairly high upper threshold of the optimum temperature range (25°C), cooling is only necessary from the middle of May until the beginning of September, which covers a less than 3-mo period. At the same time, heating energy in order to reach the lower threshold of the optimum temperature range (15°C), is necessary during cca. 170 days, i.e. almost a half-year period. In addition, on the remaining days of the year, i.e. in the transitional seasons, heating is also at least partly necessary (Figure 1). Mean differences in the actual daily mean temperatures from the threshold temperatures were also calculated. From the last third of November until the middle of February, the mean daily temperatures were at least 14°C lower than the lower threshold of the optimum temperature range (15°C). Moreover, in the high winter period the above differences exceeded 16°C. At the same time, the optimal period for rabbit breeding without the use of energy is the period from the middle of April until the last third of September (Figure 2). Note that the air temperature inside the shed is higher than the ambient air temperature. Thus, the period without energy demand may extend from around the beginning of April until the end of September. However, due to the high sensitivity of new-born kits to temperature, and concerning the strong daily course of temperature, early dawn heating may be necessary even within the period free from energy use (days without blue columns in Figure 2). Obviously, areas with less extreme climates need to use less energy for heating or cooling. It is not surprising that areas in south-western Hungary require the lowest total heating and cooling energy. At the same time, the largest heating and cooling energy demand is experienced in North-East Hungary (Makra *et al.,* 2017). We stress again that the ventilation system (heating/cooling) should be planned in order to maintain the optimum temperature range [15-25°C] in the shed. Selecting the coldest and warmest days is necessary to determine the maximum performance of the ventilation equipment (in Hungary, –20°C and +40°C extreme outside temperatures are generally expected when planning sheds).

Heat transmission

The basic point regarding the building to be constructed was energy saving. The ceiling was rebuilt using a 15 cm thermal insulation that dramatically reduced the building's heat loss.

The heat transmission coefficient of the profiled slate roof was U = 2.87 W/(m^{2}K) and the walls (B30 blocks) had U = 1.37 W/(m^{2}K). At the same time, that of the insulated roof structure became U = 0.25 W/(m^{2}K) and the insulated walls could have U = 0.3 W/(m^{2}K), which meant that the heat requirement of the building was reduced

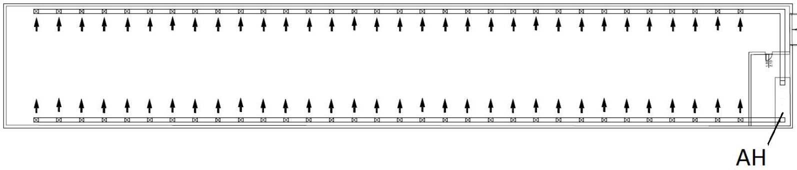

Figure 3: Top view of the improved rabbit house (AH: air handling unit, arrows: direction of the air flow in the building).

from Q_W = 343.3 kW to 176.9 kW in winter and the thermal load in summer was changed from Q_S = 236.8 kW to 134.8 kW, according to the plains.

The newly planned and technically modified rabbit house has a room for rabbits and another one (engine room) in which an air handling unit (AH), gas boiler and cooler ensures fresh air and heating in winter and cooling in summer (Figure 3).

The air flows from the air handling unit (AH) to the rabbit rooms via air ducts (E) (cross section size: 600×600 mm) (Figure 4). One of the ventilators (Figure 5: G) is blowing the air into the building, which causes a slight overpressure inside. The AH unit is a commercial type device (Figure 5) that allows 12000 m^3/h of air input with cooling, heating, heat exchange, RH regulation and air filtration facilities.

The heat demand of the building is 176.9 kW. Three condensing gas boilers (65 kW/each) provide the heat to the calorifier of the AH unit.

Cooling in summer is provided by a cooler with a cooling capacity: 150 kW which is able to supply the 134.8 kW cooling demand of the building.

The capacity of the gas boilers and the cooler was chosen by the outside design temperatures, so considering the temperature data of the area the devices will not work continuously and will not render their maximum output.

The AH unit (Figure 5) sucks in fresh air through the air inlet vent (A), where the air could be preheated (B) if necessary. The fresh air goes to the heat exchanger (C), where the system takes energy from the exhausted air. The fresh air goes through a heating calorifier (K) and cooler calorifier (J), humidifier/dehumidifier (I), followed by a heater calorifier (H). The sucking ventilator (G) loads the fresh air into the air duct (F). Suction of the exhausted air is done by a sucking ventilator (D) through the exhaust air inlet vent (E) and the air is discharged after the heat exchanger unit (C) to outside the building (M).

The planned reconstruction of the rabbit farm may result in several positive consequences. The thermal insulation reduces the energy loss by 48.5% (Q_W = 343.3 kW to 176.9 kW) in winter, and the thermal load with 43% in summer (Q_S = 236.8 kW to 134.8 kW). The data refer to the design state.

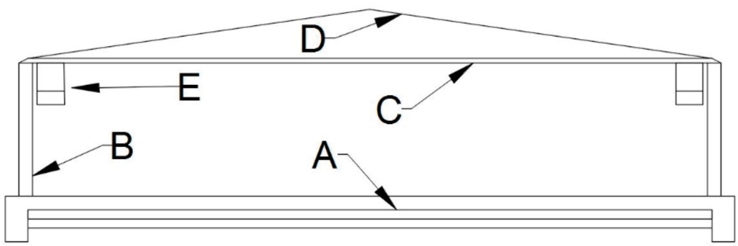

Figure 4: Cross section of the improved rabbit house (A: floor, B: wall, C: ceiling, D: roof, E: air duct).

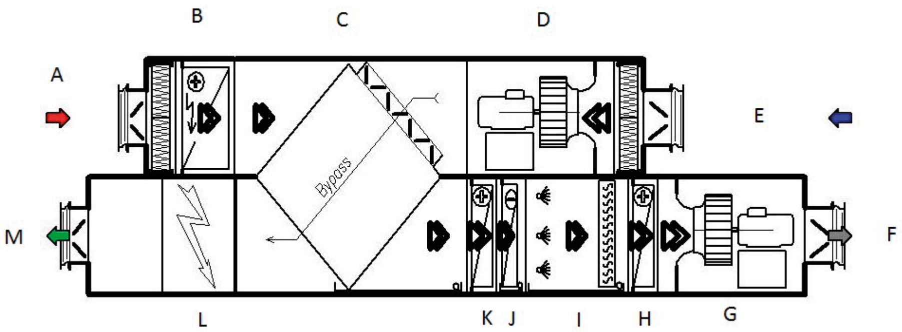

Figure 5: Air handling unit (AH). A: fresh air inlet, B: electric heating unit, C: heat exchanger, D: exhaust fan, E: exhaust air inlet, F: treated fresh air outlet, G: inlet air fan, H: heater calorifier, I: humidifier/dehumidifier, J: cooler calorifier, K: heater calorifier, L: control unit, M: air outlet, arrows: direction of the air flow. (Figure 5 is the modification of Bodnar *et al.,* 2017).

Application of the AH unit gives us the possibility of regulating the microclimate of the rabbit farm. The temperature can be controlled accurately and when it fits the optimal thermal range for rabbit in winter, the rabbits will consume less feed, or they will not use the concentrate to compensate the low environmental temperature. In summertime, the rabbits will consume the necessary amount of feed for production. The proper ventilation helps to remove the dangerous gases (NH_3, H_2S, CO_2) from the building, and provides fresh air to the animals. The gas exchange with the control of RH will reduce the risk of different diseases, e.g. respiratory diseases. The AH unit's inlet and/or outlet vent can be mounted with different filters. The air at the inlet can be filtered from dust and can keep the mosquitoes away. The filtration of exhausted air from smell (gases), dust and hair can reduce the environmental load of the rabbitry, which is sometimes not negligible. Bonci *et al.* (2011) studied environmental and hygienic parameters in an intensive rabbit farm in Italy. The highest levels of RH were measured during summer, due to activation of the evaporative cooling system. The highest NH_3 and CO_2 concentrations occurred parallel to minimum airflow rates (i.e. cold season, night-time, early hours). The peak values of H_2S concentrations occurred when manure scrapers were in operation. Total dust levels were higher during autumn and winter, when minimum ventilation levels occurred.

Summing up, we can state that due to the modernisation of the building the energy consumption of the farm could be reduced, the animal welfare is more appropriate, the feed conversion of the rabbits is improved, the production becomes better and safer and the environmental impact of the farm is decreased.

Young farmers can finance such a reconstruction partly with the support of the European Union's European Agricultural Fund for Rural Development (EAFRD, 2013). The title and code of the Hungarian call was: Modernisation of livestock farms (VP2-4.1.1.1.-16).

CONCLUSIONS

The reduced heat transmission due to thermal insulation provides a reduction in the energy demand of the building, but its degree in practice depends on several factors, such as actual weather, the location of the building and the shading of the elements in the environment.

The planned air handling unit provides the possibility of proper regulation of the microclimate in a rabbit farm.

REFERENCES

Anonymous 2011. Guide for the care and use of laboratory animals. *National Research Council, The National Academies Press, Washington D.C. Available at: https://grants.nih.gov/grants/olaw/guide-for-the-care-and-use-of-laboratory-animals.pdf. Accessed January 2018.*

BAUSOFT Pécsvárad Kft.: WinWatt software. *Available at: http://www.bausoft.hu. Accessed January 2018.*

Bodnar K., Bodnar G., Csaky I., Makra L., Privoczki Z.I. 2017. Model calculation for the improvement of the microclimate of a rabbit house. *Lucrari Stiintifice, Seria I, 19: 35-40. http://lsma.ro/index.php/lsma/article/view/1080/pdf. Accessed January 2018.*

Bonci M., Borso F. da, Mezzadri M., Teri F., Bano L., Drigo I., Agnoletti F. 2011. Annual monitoring of environmental and hygienic parameters in an intensive fattening rabbit farm. *In proc.: XVth International Congress of the International Society for Animal Hygiene, 3-7. July 2011, Vienna, Austria, 1: 91-94. https://isah-soc.org/userfiles/downloads/proceedings/2011_Proceeding1.pdf. Accessed January 2018.*

Borso da F., Chiumenti A., Mezzadri M., Teri F. 2016. Noxious gases in rabbit housing systems: effects of cross and longitudinal ventilation. *J. Agr. Eng., 47: 222-229. https://doi:10.4081/jae.2016.572*

Calvet S., Cambra-López M., Adell E., Torres A.G., Estellés F. 2012. Rabbit rearing and air quality: state-of-the-art and key unknowns. *In proc.: 10th World Rabbit Congress, September 3-6. 2012, Sharm El-Sheikh, Egypt, 787-791. Available at: https://world-rabbit-science.com/WRSA-Proceedings/Congress-2012-Egypt/Papers/04-Management/M-Calvet.pdf. Accessed January 2018.*

Cervera C., Carmona F.J. 2010. Nutrition and the Climatic Environment. *In: The nutrition of the rabbit. 2nd ed. (Eds C. de Blas & J. Wiseman), 273-295. CABI Publishing, Wallingford, UK. https://doi.org/10.1079/9781845936693.0267*

EAFRD. 2013. Regulation (Eu) No 1305/2013 Of The European Parliament And Of The Council Of 17 December 2013. *Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32013R1305. Accessed January 2019.*

EFSA. 2005. The impact of the current housing and husbandry systems on the health and welfare of farmed domestic rabbits. *Scientific Report, EFSA Journal, 267.*

Estellés F., Bustamante E., Torres A.G., Calvet S. 2012. Evaluation of climate control strategies in rabbit houses. *In proc.: 10th World Rabbit Congress. September 3-6, 2012, Sharm El-Sheikh, Egypt, 793-797. Available at: https://world-rabbit-science.com/WRSA-Proceedings/Congress-2012-Egypt/Papers/04-Management/M-Estelles.pdf. Accessed January 2018.*

Homonnay Gy. (ed.) 2001: Épületgépészet 2000. II. Fűtéstechnika. *Épületgépészet Kiadó Kft. Budapest (in Hungarian) 595-598.*

Horn P. (ed.) 1981. A baromfitenyésztők kézikönyve. *Mezőgazdasági Kiadó, Budapest, (in Hungarian) 236-259.*

Hoy St. 2008. Guidelines for minimum standards on rabbit housing in Germany. *In proc.: 9th World Rabbit Congress, 10-13, June 2008, Verona, Italy, 1183-1188. Available at: https://world-rabbit-science.com/WRSA-Proceedings/Congress-2008-Verona/Papers/W-Hoy.pdf. Accessed January 2018.*

Hungarian Meteorological Service: *Available at: http://www.met.hu. Accessed January 2018.*

Köppen W. 1931. Grundriss Der Klimakunde. (The basics of Climate.) *Berlin: Walter De Gruyter & Co. (in German).*

Lebas F., Coudert P., de Rochambeau H., Thébault R.G. (1997): The rabbit husbandry, health and production. *FAO UN, Rome, Available at: http://www.fao.org/docrep/014/t1690e/t1690e.pdf. Accessed January 2018.*

Makra L., Ionel I., Bodnár K., Sümeghy Z., Tusnády G. 2017. Environmental objective analysis, ranking and clustering of Hungarian cities. *Journal of Environmental Protection and Ecology, 18: 202-224. Available at: http://www2.sci.u-szeged.hu/eghajlattan/pdf/MAKRA_et_al_JEPE_2017.pdf. Accessed January 2018.*

Marai I.F.M., Habeeb A.A.M., Gad A.E. 2002. Rabbits' productive, reproductive and physiological performance traits as affected by heat stress: a review. *Livest. Prod. Sci., 78: 71-90. https://doi.org/10.1016/S0301-6226(02)00091-X*

Marai I.F.M., Ayyat M.S., Abd El-Monem U.M. 2001. Growth performance and reproductive traits at first parity of New Zealand White female rabbits as affected by heat stress and its alleviation under Egyptian conditions. *Trop. Anim. Health Prod., 33: 451-462. https://doi.org/10.1023/A:1012772311177*

Matics Zs., Gerencsér Zs., Radnai I., Mikó A., Kasza R., Szendrő Zs. 2014. Eltérő fényintenzitás hatása az anyanyulak termelésére. *In proc.: 26th Hungarian Conference on Rabbit Production, 33-36. 21 May, 2014. Kaposvár, Hungary. (in Hungarian).*

Morisse J.P. 1981. L'influence de l'environnement sur la pathologie respiratoire: les résultats d'une enquéte sur le terrain. *Courr. Avicole, 812: 13-16.*

Patton N.M. 1994. Colony husbandry. *In: Manning P.J., Ringler D.H., Newcomer C.E. (ed.): The biology of the laboratory rabbit. Academic Press Inc., San Diego, California, USA. https://doi.org/10.1016/B978-0-12-469235-0.50008-7*

VP2-4.1.1.1-16 Állattartó telepek korszerűsítése. *Available at: https://www.palyazat.gov.hu/vp2-4111-16-llattart-telepek-korszerstse. Accessed March 2019.*