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# MATHEMATICAL MODELING AND NUMERICAL SIMULATION FOR PREDICTING THE AMBIENT AIR TEMPERATURE AND RELATIVE HUMIDITY INSIDE RABBIT HOUSES

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## ABSTRACT

*The recent research work was carried out at the Rabbit Research Unit (RRU), Faculty of Agriculture, Cairo University, Giza, Egypt, during summer months, 2008 and 2009. It aimed to develop and validate a mathematical model for predicting the inside ambient air temperature ($T_a$) and relative humidity (RH) inside the rabbit housing systems. There are different factors are used in this analysis included the environmental parameters (air temperature, relative humidity and air velocity), structure thermal parameters [structure surfaces temperature for (walls – doors – windows – roofs – batteries)] physiological parameters and thermal-reactions (rectal, fur, skin and ear temperatures).*

*Visual studio express C # (C sharp) was used to develop the computer software to predict the ambient air temperature. The model has been validated through a comparison between measured air temperature and predicted air temperature, measured relative humidity and predicted relative humidity inside the rabbit houses. Model validation results conducted that the model is a useful tool to decide when and how much to adjust the internal environment conditions inside rabbit housing system. Also it becomes more critical when the weather conditions change rapidly or not as predicted especially in hot months.*

**Key words:** *Rabbit, Air temperature, Relative humidity, Rectal, Fur, Skin, Ear temperatures and Simulation model.*

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## INTRODUCTION

To design rabbit hosing system should be consider, together with the structural thermal properties, functional and dimensioning aspects, all the construction solutions aimed to obtain the best internal climate for rabbit production. The objective for rabbit housing systems design should then be the optimization of the internal climate conditions considering the global pattern of the whole day hours. To do this we need to an analytical tool that is able to simulate the internal climate for predicting the behavior of different types of rabbit housing systems under different climatic conditions and to evaluate any housing systems according to achieving the thermal comfort zone for rabbits. This development is mainly due to improve the rabbit genetic breeding, nutrition, sanitation and rabbit housing systems.

Mathematical and computational model development and application allow reducing time and costs of design or redesign. In this context, several models have been proposed to solve field problems and to facilitate the understanding of various physical processes such as models to predict heat transfer between an animal and its surroundings (***Gebremedhin & Wu, 2000; Aerts et al., 2003***); to predict heat or mass transfer in agricultural facilities (***Medeiros, 1997***), and to depict physiological responses of poultry (***Medeiros, 2001***), among others.

The thermal comfort zone is around 21 ºC for rabbits. Animals react to gradual exposition to higher ambient temperatures with internal physiological means to maintain homothermy: by varying position of the body, peripheral temperature of determined areas and respiratory frequency, animals are able to increase the dissipation of heat in order to restore thermal balance. Since most sudorific glands are not functional and skin transpiration is limited by fur, rabbits are able to dissipate heat mainly by means of the auricular pavilions and breathing (***Da Borso et al., 2006***).

Husbandry and management can dramatically affect rabbit welfare systems. Physiological and behavioral indicators may be useful in determining the animals' reactions towards both psychological and physical stressors. (***Verga et al., 2007***).

When the air temperature rises beyond the upper limit of thermo-neutrality range (32 ºC), physical regulation of body temperature is insured by the adjustment of blood flow to skin and by the perspiration mechanisms. Vasomotor and cardio-respiratory mechanisms are also involved, in addition to other physiological mechanisms. In general, chronic exposure to extremes of heat leads to decomposition of normal physiological and biological mechanisms with a consequent damage of many organs. (***Okab et al., 2008***).

The aim of the present work is to develop and validate a steady-state mathematical and computational model to predict the ambient air temperature and relative humidity inside the rabbit housing systems throughout different rabbit housing systems.

## MATERIALS AND METHODS

### Development of Mathematical Model

A mathematical model was developed assuming the following hypothesis:

(1) steady-state heat and mass transfer; (2) heat generation inside the house by rabbit of equal weight is constant; (3) heat flux is uniform and one-dimensional; (4) all factors affects total rabbit heat dissipation assumed constant except for the inside ambient air temperature and (5) uniform convection efficiency on house internal surfaces.

### Energy Balance

The difference between energy intake and energy losses is the net energy which is utilized by the animal for productive performance, reproduction and work. The feed intake and, therefore, the gross energy intake will increase during cold weather and decrease during hot weather. The metabolizable energy intake has been related graphically and mathematically to temperature and heat loss of the animal. (***Hellickson and Walker, 1983***).

The first law of thermodynamics is used to express the thermal energy balance of the animal as:

$$MHP \pm J \pm q_{rt} \pm q_{cv} \pm q_{cd} - EHL = W \cdot C_P \cdot \frac{dT_b}{dt} \tag{1}$$

The sign convention on the energy term is positive if the energy transfer tends to raise ambient air temperature.

$$MHP - EHL \pm J \pm q_{rt} \pm q_{cv} \pm q_{cd} = W \cdot C_P \cdot \frac{dT_b}{dt} \tag{2}$$

*MHP – EHL* can be calculated from this equation of (***Werner and Graener, 1986***).

$$h_b A_b = \frac{MHP - EHL - h_e A_e (T_{se} - T_a)}{T_s - T_a} \tag{3}$$

Then,

$$MHP - EHL = h_b A_b (T_s - T_a) + h_e A_e (T_{se} - T_a) \tag{4}$$

$$h_b A_b (T_s - T_a) + h_e A_e (T_{se} - T_a) \pm J \pm q_{rt} \pm q_{cv} \pm q_{cd} = W \cdot C_P \cdot \frac{dT_b}{dt} \tag{5}$$

The work term (*J*) is often neglected because it is usually small because the limited motions of rabbit inside batteries and it's very difficult to determine.

$$h_b A_b (T_s - T_a) + h_e A_e (T_{se} - T_a) \pm \frac{A_s \sigma (T_s^4 - T_e^4)}{1/\varepsilon_s + A_s / A_{en} (1/\varepsilon_{en} - 1)} \pm h_s A_s (T_s - T_a) \pm \frac{k_x A_c (T_s - T_x)}{x} = W \cdot C_P \cdot \frac{dT_b}{dt} \tag{6}$$

$$h_b A_b T_s - h_s A_s T_a + h_e A_e T_{se} - h_e A_e T_a \pm \frac{A_s \sigma (T_s^4 - T_e^4)}{1/\varepsilon_s + A_s / A_{en} (1/\varepsilon_{en} - 1)} \pm h_s A_s T_s - h_s A_s T_a \pm \frac{k_x A_c (T_s - T_x)}{x} = W \cdot C_P \cdot \frac{dT_b}{dt} \tag{7}$$

$$h_s A_s T_a + h_b A_b T_a + h_e A_e T_a = h_b A_b T_s + h_e A_e T_{se} \pm \frac{A_s \sigma (T_s^4 - T_e^4)}{1/\varepsilon_s + A_s / A_{en} (1/\varepsilon_{en} - 1)} \pm h_s A_s T_s \pm \frac{k_x A_c (T_s - T_x)}{x} - W \cdot C_P \cdot \frac{dT_b}{dt} \tag{8}$$

$$T_a\left(h_sA_s + h_bA_b + h_eA_e\right) = h_bA_bT_s + h_eA_eT_{se} \pm \frac{A_s\sigma\left(T_s^4 - T_e^4\right)}{1/\varepsilon_s + A_s/A_{en}\left(1/\varepsilon_{en} - 1\right)}$$
$$\pm h_sA_sT_s \pm \frac{k_xA_c\left(T_s - T_x\right)}{x} - W\cdot C_P\cdot\frac{dT_b}{dt} \qquad (9)$$

The mathematical model equation can be finally rewritten as:

$$T_a = \frac{h_bA_bT_s + h_eA_eT_{se} \pm \dfrac{A_s\sigma\left(T_s^4 - T_e^4\right)}{1/\varepsilon_s + A_s/A_{en}\left(1/\varepsilon_{en} - 1\right)} \pm h_sA_sT_s \pm \dfrac{k_xA_c\left(T_s - T_x\right)}{x} - W\cdot C_P\cdot\dfrac{dT_b}{dt}}{\left(h_sA_s + h_bA_b + h_eA_e\right)} \qquad (10)$$

**Table (1). Values of variables used in the calculations steady state heat and mass balance for house (A and B).**

| Variables | House A | House B |
|---|---|---|
| $h_s$ | 6.62 W m$^{-2}$ $^{o}$C$^{-1}$ | 6.62 W m$^{-2}$ $^{o}$C$^{-1}$ |
| $h_b$ | 4.25 W m$^{-2}$ $^{o}$C$^{-1}$ | 4.25 W m$^{-2}$ $^{o}$C$^{-1}$ |
| $h_e$ | 9 W m$^{-2}$ $^{o}$C$^{-1}$ | 9 W m$^{-2}$ $^{o}$C$^{-1}$ |
| $A_s$ | 0.196 m$^2$ | 0.196 m$^2$ |
| $A_b$ | 0.172 m$^2$ | 0.172 m$^2$ |
| $A_e$ | 0.023 m$^2$ | 0.023 m$^2$ |
| $A_{en}$ | 1089.4 m$^2$ | 1265.4 m$^2$ |
| $\sigma$ | 5.67 x 10$^{-8}$ Wm$^{-2}$ K$^{-4}$ | 5.67 x 10$^{-8}$ Wm$^{-2}$ K$^{-4}$ |
| $\varepsilon_s$ | 0.2 | 0.2 |
| $\varepsilon_{en}$ | 0.9 | 0.9 |
| $K_x$ | 45.3 W m$^{-1}$ $^{o}$C$^{-1}$ | 45.3 W m$^{-1}$ $^{o}$C$^{-1}$ |
| $X$ | 0.004 m | 0.004 m |
| $W$ | 2.75 kg | 2.75 kg |
| $C_p$ | 3400 J kg$^{-1}$ $^{o}$C$^{-1}$ | 3400 J kg$^{-1}$ $^{o}$C$^{-1}$ |

**Moisture (Latent Heat) Balance**

Moisture balance can be used to develop an equation to predict humidity ratio of inside air and then calculate inside relative humidity.

$$V_l = \frac{\nu \cdot M_w}{W_i - W_o} \tag{11}$$

$$M_w = \frac{EHL}{\lambda} \tag{12}$$

$$W_i = W_o + \frac{\nu \cdot EHL}{2430 \cdot V_{total}} \tag{13}$$

Natural ventilation due to wind and thermal buoyancy separately and then combine them using the equation (***ASHRAE, 2009***).

$$V_{total} = \left(V_{wind}^2 + V_{thermal}^2\right)^{0.5} \tag{14}$$

$$V_{wind} = C_v \cdot A \cdot u \tag{15}$$

$$V_{thermal} = C_d A \sqrt{2g\,\Delta H_{NPL}\left(T_o - T_a\right)/T_o} \tag{16}$$

Equation (16) applies when $T_a < T_o$, if $T_a > T_o$ replace $T_a$ in the denominator with Ta, and replace ($T_o - T_a$) in the numerator with ($T_a - T_o$) (***ASHRAE, 2009***). Available data on the neutral pressure level (NPL) in various kinds of buildings are limited. The NPL in tall buildings varies from 0.3 to 0.7 of total building height (***ASHRAE, 2009***). A discharge coefficient of $C_d$ = 0.65 should then be used (***ASHRAE, 2009***).

Multiple regression approach was used to derive a regression equation (17), a regression equation was developed by software Data Fit version 9.0.59 to calculate the rate of latent heat production inside rabbit houses by using reviewed data cited by ***Lebas et al., (1997)*** between ambient air temperature (°C) and release of latent heat (W/kg). Coefficient of Multiple Determination of the regression equation is $R^2$ = 0.99990177 and its Probability ($P$) = 0.01

$$EHL = \mathrm{a} \cdot \mathrm{T}_a{}^5 + \mathrm{b} \cdot \mathrm{T}_a{}^4 + \mathrm{c} \cdot \mathrm{T}_a{}^3 + \mathrm{d} \cdot \mathrm{T}_a{}^2 + \mathrm{e} \cdot \mathrm{T}_a + \mathrm{f} \tag{17}$$

**Table (2). Values of variables of the regression equation.**

| Variable | Value | 95 % (+/-) |
|---|---|---|
| a | 1.13E-06 | 1.99E-06 |
| b | -1.06E-04 | 2.00E-04 |
| c | 3.73E-03 | 7.45E-03 |
| d | -0.05817 | 0.12741 |
| e | 0.403515 | 0.972146 |
| f | -0.42571 | 2.547219 |

$$W_i = W_o + \frac{\nu \cdot \mathrm{W} \cdot \mathrm{n}\left(\mathrm{a} \cdot \mathrm{T}_a^{\ 5} + \mathrm{b} \cdot \mathrm{T}_a^{\ 4} + \mathrm{c} \cdot \mathrm{T}_a^{\ 3} + \mathrm{d} \cdot \mathrm{T}_a^{\ 2} + \mathrm{e} \cdot \mathrm{T}_a + \mathrm{f}\right)}{24.30 \times 10^5 \cdot \sqrt{\left[C_v \cdot A \cdot u\right]^2 + \left[C_d A \sqrt{2g\,\Delta H_{NPL}\left(T_o - T_a\right)/T_o}\right]^2}} \qquad (18)$$

$$W_i = W_o + \frac{\nu \cdot \mathrm{W} \cdot \mathrm{n}\left(1.13 \times 10^{-6}\,\mathrm{T}_a^{\ 5} - 1.06 \times 10^{-4}\,T_a^{\ 4} + 3.73 \times 10^{-3}\,\mathrm{T}_a^{\ 3} - 0.0581\ \ \mathrm{T}_a^{\ 2} + 0.4035\ \ \mathrm{T}_a - 0.4257\right)}{24.30 \times 10^5 \cdot \sqrt{\left[C_v \cdot A \cdot u\right]^2 + \left[C_d A \sqrt{2g\,\Delta H_{NPL}\left(T_o - T_a\right)/T_o}\right]^2}} \qquad (19)$$

This study was carried out at the Rabbit Research Unit (RRU), Faculty of Agriculture, Cairo University, Giza, Egypt, during hot months of July and August, 2008 and 2009, from 08:00 AM to 06:00 PM.

Two house systems were used to perform field experiment. House “A” was roofed by 0.6 cm thickness steel ceiling and its dimension (ridge height, length and width) were 5.80 m, 38.90 m and 14.90 m respectively. House “B” was roofed by a double metal ceiling of 5 cm thickness and its dimension of 6.00 m, 36.60 m and 14.90 m as ridge height, length and width respectively.

Two houses were naturally ventilated by windows and there are ceiling fans for mixing air. ***Tri Sense*** was used to measure air temperature, relative humidity and air velocity. Temperature of structures surface for (walls – doors – windows – roofs – batteries) measured by ***Infra Red Thermometer*** Fig. (1). Physiological parameters and thermal-reactions (Rectal, Skin, Ear and Fur temperatures) were measured by using ***Digital Thermometer***.


a b

**Fig. (1). a - Infra Red Thermometer, b - Tri Sense, Model No. 3700-0.**

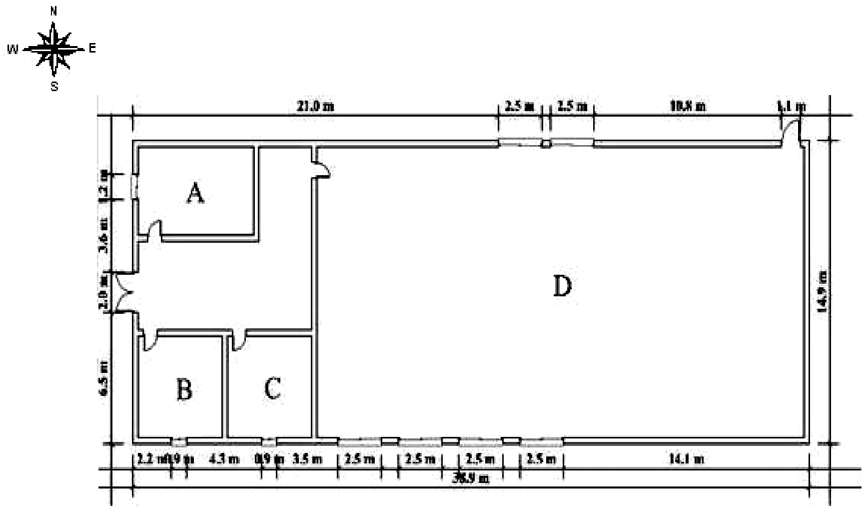


**Fig. (2). Plane of rabbits house "A" under investigation.**

A: Administration room, B: Labors room, C: Diets room, D: Rabbits breeding place.

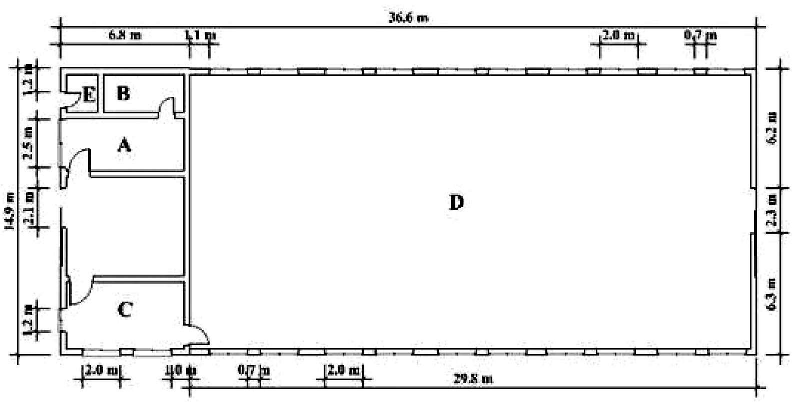


**Fig. (3). Plane of rabbits house "B" under investigation.**

**A: Administration room, B: Rest room, C: Labors room, D: Rabbits breeding place, E: Bath room.**

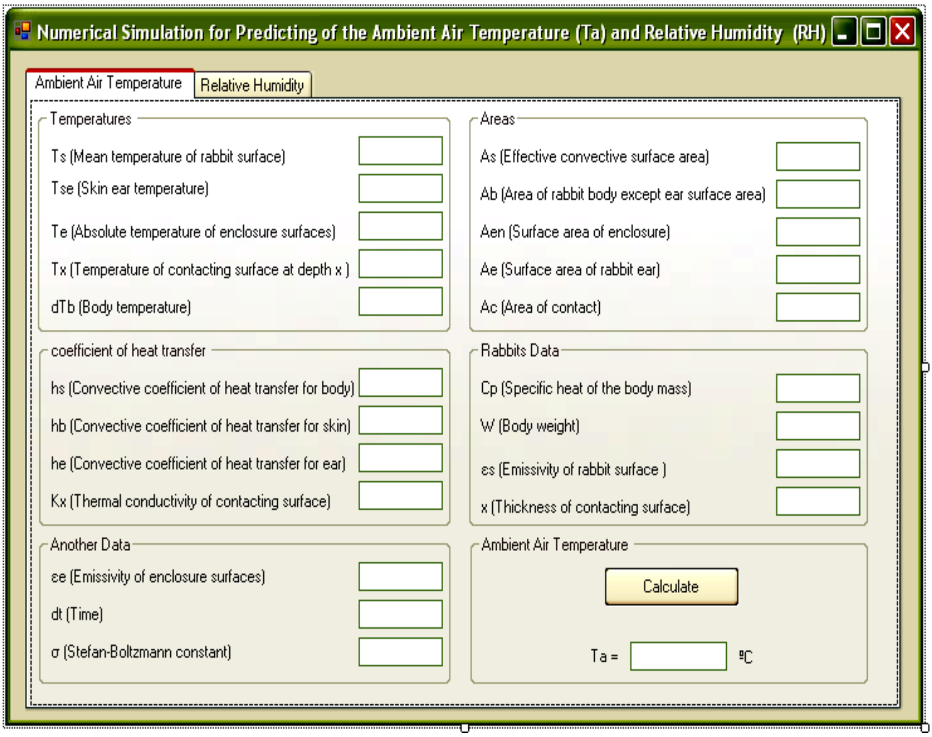


**Fig. (4). Numerical simulation for predicting the ambient Air temperature ($T_a$) and relative humidity (*RH*).**

## RESULTS AND DISCUSSION

### Model Validation

The model has been validated with the collected data from the rabbit houses, located in the Rabbit Research Unit (RRU), Faculty of Agriculture, Cairo University, Giza, Egypt.

Figures (5 and 6) and tables (3 and 4) present the comparison between the measured and predicted values of the internal ambient air temperature inside two rabbit housing systems (house A and house B). Fig. (5) shows that predicted ambient air temperature was slightly higher than measured inside ambient air temperature, predicted ambient air temperature and measured ambient air temperature is lower than outside ambient air temperature at 10:00 to 14:00 in house "A". The difference between predicted ambient air temperature and measured ambient air temperature varied from 0.2729 °C at 08:00 to 0.4615 °C at 12:00 with an average of 0.3578 ºC.

**Table (3). Outside air temperature, measured ambient air temperature and predicted ambient air temperature inside house "A" during 2008 and 2009.**

| *Time, h* | $T_{outside}$ | $T_{a\ predicted}$ | $T_{a\ measured}$ |
|---|---|---|---|
| 8:00 | 28.11 | 28.55 | 28.28 |
| 10:00 | 32.88 | 32.53 | 32.17 |
| 12:00 | 35.87 | 34.74 | 34.28 |
| 14:00 | 37.64 | 36.96 | 36.63 |
| 16:00 | 36.33 | 36.21 | 35.83 |
| 18:00 | 34.94 | 35.67 | 35.33 |

**Table (4). Outside air temperature, measured ambient air temperature and predicted ambient air temperature inside house "B" during 2008 and 2009.**

| *Time, h* | $T_{outside}$ | $T_{a\ predicted}$ | $T_{a\ measured}$ |
|---|---|---|---|
| 8:00 | 28.11 | 27.89 | 27.56 |
| 10:00 | 32.88 | 30.46 | 29.96 |
| 12:00 | 35.87 | 31.82 | 31.52 |
| 14:00 | 37.64 | 32.87 | 32.44 |
| 16:00 | 36.33 | 32.46 | 32.11 |
| 18:00 | 34.94 | 32.15 | 31.66 |

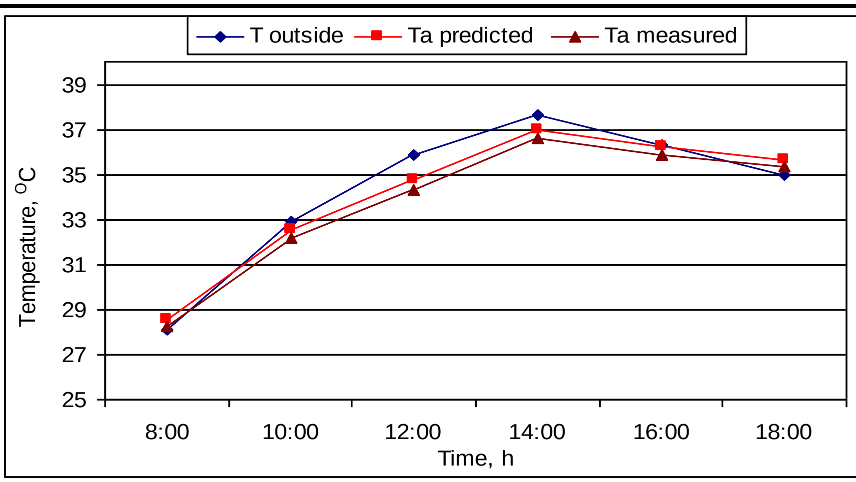


**Fig. (5). Outside air temperature, measured ambient air temperature and predicted ambient air temperature inside house "A" during 2008 and 2009.**

Fig. (6) shows that predicted ambient air temperature was slightly higher than measured inside ambient air temperature, predicted ambient air temperature and measured ambient air temperature is lower than outside ambient air temperature at 08:00 to 18:00 in house “B”. The difference between predicted ambient air temperature and measured ambient air temperature varied from 0.3028 °C at 12:00 to 0.4933 °C at 10:00 with an average of 0.3983 °C.

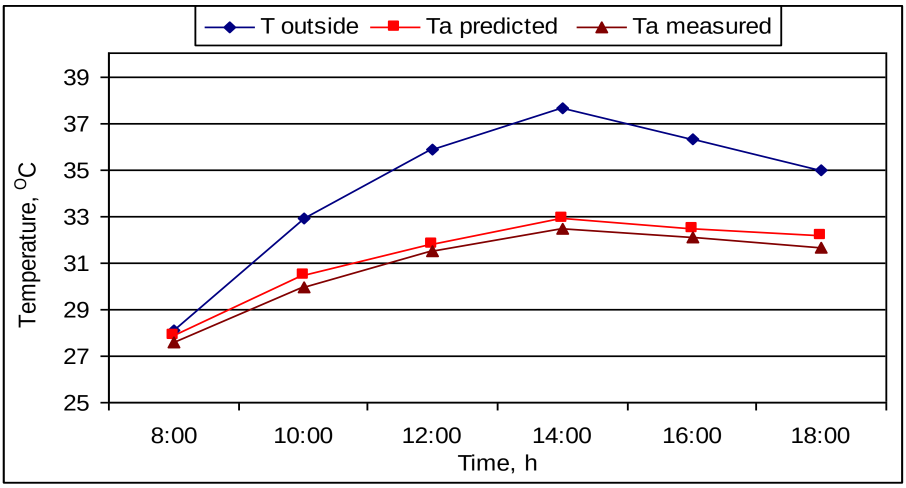


**Fig. (6). Outside air temperature, measured ambient air temperature and predicted ambient air temperature inside house “B” during 2008 and 2009.**

Figures (7 and 8) and tables (5 and 6) present the comparison between the measured and predicted values of the relative humidity inside two rabbit housing systems (house A and house B). There is no big difference between the measured and predicted relative humidity in two rabbit housing systems. Fig. (7) shows that predicted *RH* was slightly lower than measured *RH*; measured *RH* is higher than outside RH at 08:00 to 18:00. The difference between predicted RH and measured RH varied from 0.7532 % at 08:00 to 1.4225 % at 18:00 with an average of 1.0297 %.

**Table (4). Outside relative humidity, measured relative humidity and predicted relative humidity inside house "A" during 2008 and 2009.**

| *Time, h* | *$RH_{outside}$* | *$RH_{predicted}$* | *$RH_{measured}$* |
|---|---|---|---|
| 8:00 | 70.48 | 70.00 | 70.76 |
| 10:00 | 54.50 | 56.28 | 57.33 |
| 12:00 | 44.68 | 48.33 | 49.10 |
| 14:00 | 38.59 | 41.46 | 42.61 |
| 16:00 | 40.08 | 42.41 | 43.43 |
| 18:00 | 45.25 | 45.24 | 46.66 |

**Table (5). Outside relative humidity, measured relative humidity and predicted relative humidity inside house "B" during 2008 and 2009.**

| *Time, h* | *$RH_{outside}$* | *$RH_{predicted}$* | *$RH_{measured}$* |
|---|---|---|---|
| 8:00 | 70.48 | 72.43 | 73.33 |
| 10:00 | 54.50 | 62.50 | 63.62 |
| 12:00 | 44.68 | 55.98 | 57.06 |
| 14:00 | 38.59 | 49.88 | 50.95 |
| 16:00 | 40.08 | 49.74 | 50.85 |
| 18:00 | 45.25 | 53.71 | 54.43 |

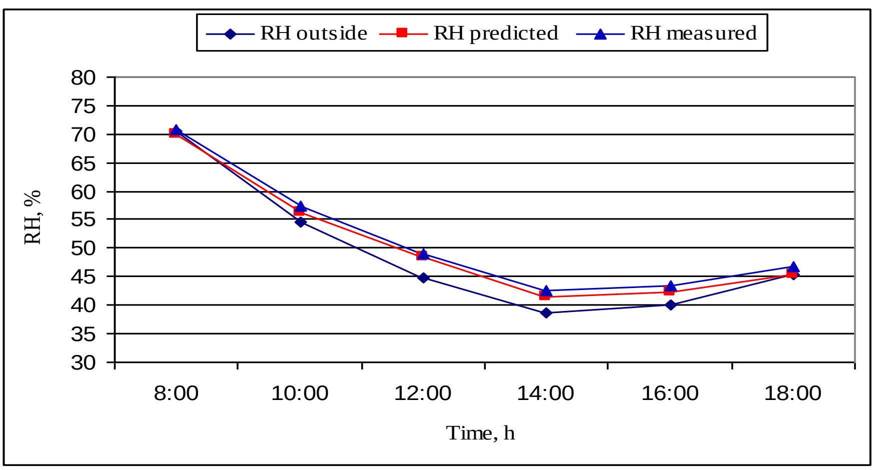


**Fig. (7). Outside relative humidity, measured relative humidity and predicted relative humidity inside house "A" during 2008 and 2009.**

Fig. (8) shows that predicted *RH* was slightly lower than measured *RH*; measured *RH* is higher than outside *RH* at 08:00 to 18:00. The difference between predicted *RH* and measured *RH* varied from 0.7253 % at 18:00 to 1.1193 % at 10:00 with an average of 1.001 %.

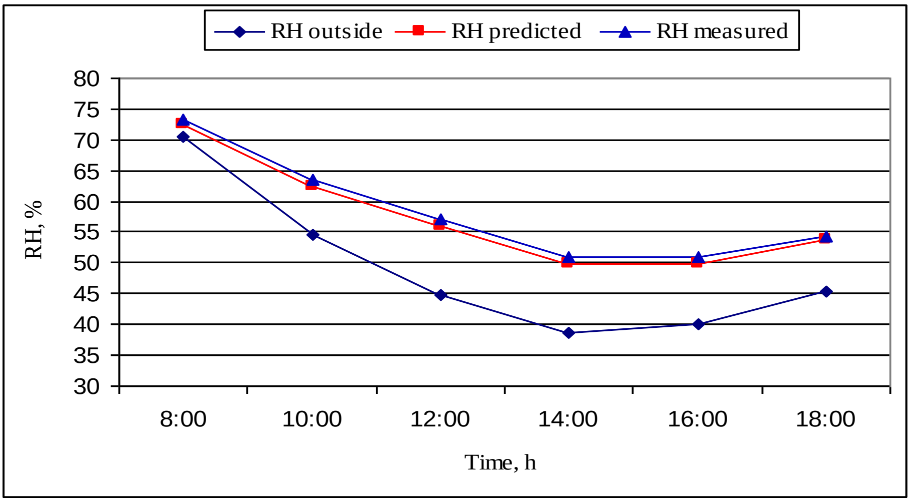


**Fig. (8). Outside relative humidity, measured relative humidity and predicted relative humidity inside house "B" during 2008 and 2009.**

## CONCLUSION

The computer program is a useful tool to decide when and how much to adjust the internal environment conditions inside rabbit housing system. Also it becomes more critical when the weather conditions change rapidly or not as predicted especially in hot months. The computer model could be used to study thermal environment in any rabbit housing systems at any location. The model would help in efficient designing of rabbit housing systems structures under varied environmental conditions.

## NOMENCLATURE

| | | |
|---|---|---|
| ***MHP*** | : | Rate at which thermal energy is produced by metabolism, W. |
| ***J*** | : | Rate of mechanical work, W. |
| $q_{rt}$ | : | Rate of radiant heat transfer, W. |
| $q_{cv}$ | : | Rate of convective heat transfer, W. |
| $q_{cd}$ | : | Rate of conductive heat transfer, W. |
| ***EHL*** | : | Rate of loss of heat by evaporation of water, W. |

| | | |
|---|---|---|
| $W$ | : | Body weight, kg. |
| $Cp$ | : | Specific heat of the body mass, J $kg^{-1}$ $^{o}C^{-1}$. |
| $dT_b$ | : | Body temperature, $^{o}C$. |
| $dt$ | : | Time, s. |
| $h_e$ | : | Convective coefficient of heat transfer for ear, W $m^{-2}$ $^{o}C^{-1}$. |
| $h_s$ | : | Convective coefficient of heat transfer for whole body, W $m^{-2}$ $^{o}C^{-1}$. |
| $h_b$ | : | Convective coefficient of heat transfer for skin, W $m^{-2}$ $^{o}C^{-1}$. |
| $T_a$ | : | Ambient air temperature inside the rabbit housing, K or $^{o}C$. |
| $T_o$ | : | Outdoor temperature, K or $^{o}C$. |
| $T_s$ | : | Mean temperature of rabbit surface, $^{o}C$. |
| $T_{se}$ | : | Skin ear temperature, $^{o}C$ |
| $T_e$ | : | Absolute temperature of enclosure surfaces, $^{o}C$. |
| $T_x$ | : | Temperature of contacting surface at depth x from the rabbit and surface interface, $^{o}C$. |
| $A_s$ | : | Effective convective surface area, $m^2$. |
| $A_b$ | : | Surface area of rabbit body except ear surface area, $m^2$. |
| $A_{en}$ | : | Surface area of enclosure, $m^2$. |
| $A_e$ | : | Surface area of rabbit ear, $m^2$. |
| $A_c$ | : | Area of contact, $m^2$. |
| $K_x$ | : | Thermal conductivity of contacting surface, W $m^{-1}$ $^{o}C^{-1}$. |
| $\sigma$ | : | Stefan-Boltzmann constant (5.67 x $10^{-8}$ $Wm^{-2}$ $K^{-4}$). |
| $\varepsilon_s$ | : | Emissivity of rabbit surface (dimensions less). |
| $\varepsilon_e$ | : | Emissivity of enclosure surfaces (dimensions less). |
| $x$ | : | Thickness of contacting surface, m. |
| $V_l$ | : | Ventilation rate for moisture (latent heat) balance, $m^3$ $s^{-1}$. |
| $q_l$ | : | Rate of latent heat production within the shelter, W $kg^{-1}$. |
| $v$ | : | Specific volume of air, $m^3$ $kg^{-1}$ dry air. |
| $M_w$ | : | Rate of water vapour production within the shelter, kg $H_2O$ $s^{-1}$. |
| $W_i$ | : | Humidity ratio of inside air, kg $H_2O$. $kg^{-1}$ dry air. |
| $W_o$ | : | Humidity ratio of outside air, kg $H_2O$. $kg^{-1}$ dry air. |
| $\lambda$ | : | Latent heat of vaporization of water at 30 ºC 2430. kJ $kg^{-1}$ $H_2O$. |
| $V_{wind}$ | : | Airflow rate (by wind only), $m^3$ $s^{-1}$. |
| $C_v$ | : | Effectiveness of openings ($C_v$ is assumed to be 0.5 to 0.6 for perpendicular winds and 0.25 to 0.35 for diagonal winds, (unit less)). |

| | | |
|---|---|---|
| $A$ | : | Free area of inlet openings, $m^2$. |
| $u$ | : | Air velocity, $m\ s^{-1}$. |
| $V_{thermal}$ | : | Airflow rate (by thermal forces only), $m^3\ s^{-1}$. |
| $C_d$ | : | Discharge coefficient for opening. |
| $\Delta H_{NPL}$ | : | Height from midpoint of lower opening to NPL, m. |
| $n$ | : | Number of rabbits. |

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## الملخص العربي

# النمذجة الرياضية والمحاكاة العددية للتنبؤ بدرجة الحرارة والرطوبة النسبية داخل مساكن الأرانب

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أجري هذا البحث في الآونة الأخيرة في وحدة بحوث الأرانب (RRU)، كلية الزراعة، جامعة القاهرة، الجيزة، مصر. خلال أشهر الصيف لعامى ٢٠٠٨ و ٢٠٠٩. و تهدف الدراسة الحالية إلى تطوير واعتماد نموذج رياضي للتنبؤ بدرجة حرارة الهواء المحيط والرطوبة النسبية داخل نظم إسكان الأرانب. هناك عوامل مختلفة استخدمت في التحليل وشملت هذه العوامل المعايير البيئية مثل (درجة حرارة الهواء - الرطوبة النسبية - سرعة الهواء) ، المعايير الحرارية للمبنى مثل [درجة حرارة أسطح المبنى (الجدران - الابواب - الشبابيك - الأسقف - البطاريات)] و أخيرا المعايير الفسيولوجية والتفاعلات الحرارية مثل (درجة حرارة المستقيم - درجة حرارة الفراء - درجة حرارة الجلد - درجة حرارة الأذن).

أستخدم برنامج فيجوال استوديو اكسبريس سى # (شارب) لكتابة برنامج الكمبيوتر للتنبؤ بدرجة حرارة الهواء المحيط. وقد تم التحقق من صحة هذا النموذج من خلال مقارنة تمت بين درجة حرارة الهواء المقاسة ودرجة حرارة الهواء المتنبئ بها ومقارنة الرطوبة النسبية المقاسة بالرطوبة النسبية المتنبئ بها داخل مساكن الأرانب. حيث دلت نتائج التي أجريت للتحقق من صحة النموذج أن النموذج يعمل كأداة مفيده لتقرر متى وإلى أي مدى يتم ضبط الظروف البيئة الداخلية داخل نظم اسكان الأرانب. كما أن النموذج الرياضى يصبح أيضا أكثر أهمية عندما تتغير الأحوال الجوية بسرعة أو لا يمكن توقعها وخاصة في الأشهر الحارة.

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