THE ESTIMATION METHODS OF BIOCLIMATIC COMFORT IN
POULTRY HOUSES AND MAXIMUM VENTILATION RATE FOR
SUMMER
Salim MUTAF*

SUMMARY

The aim of this study was to analyse comparatively the estimation
methods of bioclimatic comfort in poultry houses and to describe the mean
radiant temperature.

The inside (T₁) and mean radiant (MTH₁, MTH₂, MRT₁) temperatures in
uninsulated poultry house (h₁) were found higher than adequately insulated
poultry house (h₂) between 12-6 p.m. (P< 0.05; P< 0.01).

For the determination of bioclimatic comfort in adequately insulated
poultry houses only inside dry-bulb and wet-bulb air temperatures and enthalpy
should be used. In uninsulated poultry house, in addition to inside dry-bulb
and wet-bulb air temperatures and enthalpy, inside surface temperatures should
be taken into account and mean radiant temperatures (MRT₁, MRT₂) estimation
methods should be employed.

INTRODUCTION

Today, with genetically superior laying hens and scientifically
balanced feed rations, it is only with an optimum climatic
environment that maximum use of their genetic potential and feed
conversion can be realized. The climatic environment components
are air temperature, relative humidity and radiation. The
environmental temperature should be defined as mean radiant
temperature of the environment, which would include all of the
variable climatic factors of not only dry-bulb temperature, but also
wet-bulb temperature, radiation and temperature of surroundings.
The humidity level of environmental air has a significant effect
on the rate of heat loss from laying hens particularly at high
ambient temperatures.

The aim of this study was to analyse comparatively the

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estimation methods of bioclimatic comfort in poultry houses and to describe the mean radiant temperature.

MATERIAL AND METHODS

This research had been conducted in two poultry houses that had different construction and insulation materials (Table 1).

Table 1. Properties of the houses.

<table>
<thead>
<tr>
<th>House No</th>
<th>Long axis</th>
<th>$k$ values (kcal. m$^{-2}$.hr$^{-1}$.°C$^{-1}$)</th>
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Inside-outside dry-bulb and wet-bulb temperatures were recorded all time in July and August.

In order to calculate the inside surface temperature of building elements on the tropic days (high temperature $\geq 30^\circ$C) the following formula was used:

$$T_{iy} = Ti - Ri - \frac{T_i - Ts}{R}$$  \hspace{1cm} (1)

Where:

- $T_{iy}$: Inside surface temperature \(^\circ\)C
- $Ti$: Inside air temperature \(^\circ\)C
- $Ts$: Sol-air temperature \(^\circ\)C
- $R$: Resistance \((-\frac{1}{\text{m}^2\cdot\text{hr}\cdot\text{oC}\cdot\text{kcal}^{-1}}\))
- $R_i$: Inside air film resistance \((-\frac{1}{\text{m}^2\cdot\text{hr}\cdot\text{oC}\cdot\text{kcal}^{-1}}\))

The sol-air temperature was calculated by the following formula:

$$Ts = T_o + \frac{a_o}{a_o}$$  \hspace{1cm} (2)

Where;
\[ T_s = \text{S}ol\text{-air temperature (}^\circ\text{C}) \]
\[ T_o = \text{Outside air temperature (}^\circ\text{C}) \]
\[ I = \text{Solar radiation (kcal.m}^{-2}\text{.hr}^{-1}) \]
\[ a = \text{Solar absorptivity of the outside surface} \]
\[ a_o = \text{Outside air film conductance (kcal.m}^{-2}\text{.hr}^{-1} \cdot ^\circ\text{C}^{-1}) \]

The mean radiant temperature was calculated by the following formulas:

\[
\text{MRT}_1 = \frac{T_{iy_1} \cdot \Theta_i + T_{iy_2} \cdot \Theta_i + \cdots + T_{iy_n} \cdot \Theta_i}{360} \quad (3)
\]

\[
\text{MRT}_2 = \frac{(3 \times T_i) + T_{iy_o}}{4} \quad (4)
\]

\[
\text{MRT}_3 = \frac{T_{iy_o}}{3} \quad (5)
\]

Where:

\[ \text{MRT}_1, \text{MRT}_2, \text{MRT}_3 = \text{Mean radiant temperature (}^\circ\text{C)} \]
\[ T_{iy_1..n} = \text{Inside surface temperatures (}^\circ\text{C)} \]
\[ \Theta_i = \text{Surface exposure angle in degrees} \]
\[ T_i = \text{Inside temperature (}^\circ\text{C)} \]
\[ T_{iy_o} = \text{Average inside surface temperature (}^\circ\text{C)} \]

The enthalpy of an air-vapor mixture was calculated by the following formula:

\[ i = 0.24 \times \frac{t_{db}}{595 + 0.47 \times t_{db}} \times X \quad (6) \]

Where:

\[ i = \text{Enthalpy (kcal.kg}^{-1} \cdot \text{dry air)} \]
\[ 0.24 = \text{Specific heat of dry air (kcal.kg}^{-1} \cdot \text{deg.)} \]
\[ t_{db} = \text{Dry-bulb air temperature (}^\circ\text{C)} \]
\[ 595 = \text{Latent heat of evaporation at } 0^\circ\text{C (kcal.kg}^{-1} \cdot \text{.)} \]
\[ 0.47 = \text{Specific heat of water vapor (kcal.kg}^{-1} \cdot \text{deg.)} \]
\[ X = \text{Humidity ratio of air (kg.kg}^{-1} \cdot \text{dry air)} \]

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RESULTS AND DISCUSSION

Inside And Mean Radiant Temperatures

The inside and estimated mean radiant temperatures were summarized in Table 2.

The inside (Ti) and mean radiant (MRT1, MRT2, MRT3) temperatures of uninsulated poultry house (h2) were found higher than those of insulated poultry house (h1) at 12-6 p.m. (P < 0.05; P < 0.01).

In July and August the average inside temperatures at 12-6 p.m. were calculated as 30.87 + 0.65°C, 29.43 + 0.67°C for insulated poultry house (h1) and 34.74 + 0.74°C, 32.56 + 0.64°C for uninsulated poultry house (h2). The average mean radiant temperatures at 12-6 p.m. were calculated as 32.13 + 0.53°C (MRT1), 31.24 + 0.60°C (MRT2), 31.85 + 0.54°C (MRT3) in July, 30.41 + 0.54°C (MRT1), 29.72 + 0.62°C (MRT2), 30.23 + 0.55°C (MRT3) in August for insulated poultry house (h1). 39.37 + 0.83°C (MRT1), 35.85 + 0.60°C (MRT2), 37.70 + 0.63°C (MRT3) in July, 36.69 + 0.83°C (MRT1), 33.58 + 0.57°C (MRT2), 33.26 + 0.65°C (MRT3) in August for uninsulated poultry house (h2).

The differences between inside (Ti) and mean radiant temperatures (MRT1, MRT2, MRT3) for insulated poultry house (h1) were found insignificant but these differences for uninsulated poultry house (h2) were found significant at 12-6 p.m. In uninsulated poultry house (h2) the differences between Ti - MRT2 and MRT1 - MRT3 were insignificant but the mean radiant temperatures (MRT1, MRT3) were found significantly higher than inside temperature (Ti)(P < 0.05; P < 0.01).

Bioclimatic Comfort

The results of bioclimatic comfort were summarized in Figure 1, 2, 3, 4.

The upper and lower optimum housing temperatures of 29.5°C and 15.0°C provide the desirable temperature range for adult egg-laying hen housing. The relative humidity appears to have no effect on performance at housing temperatures below 26.7°C, although it
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Fig. 1. Psychrometric results during July in poultry house number 1.
Fig. 2. Psychrometric results during August in poultry house number 1.
Fig. 3. Psychrometric results during July in poultry house number 2.
Fig. 4. Psychrometric results during August in poultry house number 2.
may affect performance at higher housing temperatures (1).

Enthalpy losses in the respiration air are based upon research findings that exhaled air may be assumed to be about 1.9°C below body temperature and 90 % R.H. (2). At body temperature of 34.1°C the exhaled air temperature would be 39.2°C and 90 % R.H. From the psychrometric chart or from calculation of equation 6 the enthalpy of the exhaled air is 34.78 kcal.kg⁻¹ dry air.

The maximum enthalpy of the inhaled air of insulated poultry house (h₁) in July and August respectively at 32°C (Ti) and 43 % RH₁ would be 15.55 kcal.kg⁻¹ dry air while that for air at 33°C (MRT₁) and 46 % RH₁ would be 16.77 kcal.kg⁻¹ dry air, at 30°C (Ti) and 47 % RH₁ would be 14.81 kcal.kg⁻¹ dry air, while that for air at 31°C (MRT₁) and 50 % RH₁ would be 16.03 kcal.kg⁻¹ dry air in Fig. 1, 2.

\[
\begin{align*}
\text{max. } & \Delta_j^1 \quad (\text{Ti}) = 34.78 - 15.55 = 19.23 \text{ kcal.kg}^{-1}\text{ dry air, at 18.00} \\
\text{max. } & \Delta_j^1 \quad (\text{MRT}_1) = 34.78 - 16.77 = 18.01 \text{ kcal.kg}^{-1}\text{ dry air, at 14.00} \\
\text{max. } & \Delta_j^1 \quad (\text{Ti}) = 34.78 - 14.81 = 19.97 \text{ kcal.kg}^{-1}\text{ dry air, at 18.00} \\
\text{max. } & \Delta_j^1 \quad (\text{MRT}_1) = 34.78 - 16.03 = 18.75 \text{ kcal.kg}^{-1}\text{ dry air, at 14.00}
\end{align*}
\]

The maximum enthalpy of the inhaled air of uninsulated poultry house (h₂) in July and August respectively at 36°C (Ti) and 32 % RH₁ would be 15.86 kcal.kg⁻¹ dry air while that for air at 41°C (MRT₁) and 33 % RH₁ would be 19.66 kcal.kg⁻¹ dry air, at 34°C (Ti) and 35 % RH₁ would be 15.30 kcal.kg⁻¹ dry air while that for air at 38°C (MRT₁) and 37 % RH₁ would be 18.49 kcal.kg⁻¹ dry air in Fig. 3, 4.

\[
\begin{align*}
\text{max. } & \Delta_j^1 \quad (\text{Ti}) = 34.78 - 15.86 = 18.92 \text{ kcal.kg}^{-1}\text{ dry, at 16.00} \\
\text{max. } & \Delta_j^1 \quad (\text{MRT}_1) = 34.78 - 19.66 = 15.12 \text{ kcal.kg}^{-1}\text{ dry air, at 14.00} \\
\text{max. } & \Delta_j^1 \quad (\text{Ti}) = 34.78 - 15.30 = 19.48 \text{ kcal.kg}^{-1}\text{ dry air, at 16.00} \\
\text{max. } & \Delta_j^1 \quad (\text{MRT}_1) = 34.78 - 18.49 = 16.29 \text{ kcal.kg}^{-1}\text{ dry air, at 14.00}
\end{align*}
\]
Heat removed by the lungs is equal to the enthalpy difference between inhaled and exhaled air. The heat removing by the respiration of adult egg-laying hens was calculated as 19.23 - 19.97 kcal.kg\(^{-1}\) dry air \(\Delta_i\), 18.01 - 18.75 kcal.kg\(^{-1}\) dry air \(\Delta_i\) for insulated poultry house \(h_1\); 18.92 - 19.48 kcal.kg\(^{-1}\) dry air \(\Delta_i\), 15.12 - 16.29 kcal.kg\(^{-1}\), dry air \(\Delta_i\) for uninsulated poultry house \(h_2\).

The differences between \(\Delta_i\) for insulated poultry house \(h_1\) were insignificant but these differences for uninsulated poultry house \(h_2\) were significant.

When the enthalpy of inhaled air is low, then more heat will be removed by respiration. Therefore the enthalpy of inhaled air is more important than temperature. In order to raise the heat of inhaled air to the exhaled air state, the necessary quantity of heat is:

\[
Q = V (i_e - i_i) \text{ kcal.min}^{-1}.
\]

Where:

\(Q\) = Quantity of heat (kcal.min\(^{-1}\).)

\(V\) = Respiratory rate (kg.min\(^{-1}\).)

\(i_e\) = Enthalpy of exhaled air (kcal.kg\(^{-1}\).)

\(i_i\) = Enthalpy of inhaled air (kcal.kg\(^{-1}\).)

Necessary quantity of ventilation heat in poultry houses is calculated by the following equation:

\[
Q_L = V (i_i - i_o) \text{ kcal.hr}^{-1}.\text{live wt.}
\]

Where:

\(Q_L\) = Quantity of ventilation heat (kcal.hr\(^{-1}\).kg\(^{-1}\).live wt.)

\(V\) = Ventilation rate (kg.hr\(^{-1}\).kg\(^{-1}\).live wt.)

\(i_i\) = Inside air enthalpy (kcal.kg\(^{-1}\).)

\(i_o\) = Outside air enthalpy (kcal.kg\(^{-1}\).)

For tropic days (high temperature \(\geq 30^\circ\text{C}\));

\[
Q_L = Q_{Ti} + Q_{BR}
\]
Maximum Ventilation Rate For Summer Conditions

Maximum ventilation rate in the poultry houses at tropic days should be calculated by the following equation:

\[ V = \frac{Q_{Ti} + Q_{BR}}{0.29 (\Delta_t)} \]  (10)

Where:

- \( V \) = Ventilation rate (m\(^3\) . hr\(^{-1}\) . live wt.)
- \( Q_{Ti} \) = Sensible heat production of laying hens (kcal.hr\(^{-1}\) . kg . live wt.)
- \( Q_{BR} \) = Conduction and radiation heat gain through structure elements (kcal.hr\(^{-1}\) . kg\(^{-1}\) . live wt.)
- \( \Delta_t \) = Difference between inside and outside air temperature(\(^\circ\)C)

Between 28-32\(^\circ\)C ambient temperatures, 40 % of the total heat diffused by the laying hens is sensible, while 60 % is latent heat (3-4). The heat load from structure elements by conduction and radiation in adequately insulated poultry buildings is about 65-68 % of the sensible heat produced by the laying hens (5). In this case \( Q_{TD} / Q_{BR} \) is 2.4 kcal.hr\(^{-1}\) . kg\(^{-1}\) . live wt. and summer ventilation rate is 4 m\(^3\) . hr\(^{-1}\) . kg\(^{-1}\) . live wt. (6).

**CONCLUSION**

For the determination of bioclimatic comfort in adequately insulated poultry houses only inside dry-bulb and wet-bulb air temperatures and enthalpy should be used. In uninsulated poultry houses, in addition to inside dry-bulb and wet-bulb air temperatures and enthalpy, inside surface temperature should be taken into account and the mean radiant temperatures (MRT\(_1\), MRT\(_2\)) estimation methods should be employed.

**ÖZET**

**KÜMESLERDE BIYOKLIMATİK HAYATLIĞI BELİRLÊME YÖNTEMLERİ VE YAzł DÖNEMİ MÜKÜMEN HAVA DEBİSİ**

Araştırma, kümeslerde biyoklimalık rehatlığı belirleme yöntemlerinin karşılaştırmalı analizi ve ortalama radyant sıcaklığının tanımlanması amacıyla ile yapılmıştır.

Kümes içi (TL) ve ortalama radyant (MRT\(_1\), MRT\(_2\), MRT\(_3\)) sıcaklıklar yapı elemanları yeralımı yetersiz olan kümem (h\(_2\)), yapı elemanları yeralımı
yeterli sayılan kümes'e (h.) oranla saat 12^{00} - 10^{00} arasında daha yüksek bulunmuştur (P < 0.05; P < 0.01).

Kümeslerde biyoklimatik rahatlığın belirlenmesinde, yapı elemanları yahut yeterli olduğunda yalnızca iç havanın kuru-ıslak termometre sıcaklıklarını ve antalpi ölçütlere alınmalı, yapı elemanları yahut yetersiz olduğunda ise, iç havanın kuru-ıslak termometre sıcaklıklarına ve antalpisine ek olarak yapı elemanları iç yüzey sıcaklıklarını da ölçütlere alınmalı ve ortalamaları radyatif sıcaklık (MAT₁, MAT₂) belirlemeye yardımcı kullanılarak kullanmalıdır.

REFERENCES


