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

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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 (Ti) and mean radiant (MRT_1, MRT_2, MRT_3) temperatures in uninsulated poultry house (h_2) were found higher than adequately insulated poultry house (h_1) 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 (MRT_1, MRT_2) 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 cán ba 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.

House No	Long axis	k values ($kcal.m^{-2}.hr^{-1}.{}^{o}C^{-1}$) Wall	Roof
1	East - west	1,80	0,96
2	East - west	2,60	4,70

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 ≥ 30^{o}C) the following formula was used:

$$Tiy = Ti - Ri \frac{Ti - Ts}{R} \qquad (1)$$

Where;

Tiy = Inside surface temperature (^{o}C)

Ti = Inside air temperature (^{o}C)

Ts = Sol-air temperature (^{o}C)

Ri = Inside air film resistance ($\frac{1}{a_i}$, $m^2.hr.{}^{o}C.kcal^{-1}$)

R = Resistance ($\frac{1}{k}$ = Ri + ΣR + Ro,$m^2.hr.{}^{o}C.kcal^{-1}$)

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

$$Ts = T_o + \frac{I.a}{a_o} \qquad (2)$$

Where;

Ts = Sol-air temperature (^{o}C)

To = Outside air temperature (^{o}C)

I = Solar radiation ($kcal.m^{-2}.hr^{-1}$)

a = Solar absorptivity of the outside surface

a_o= Outside air film conductance ($kcal.m^{-2}.hr^{-1}.^{o}C^{-1}$)

The mean radiant temperature was calculated by the following formulas;

$$MRT_1 = \frac{Tiy_1\ \theta_1 + Tiy_2\ \theta_2 + \ldots + Tiy_n\ \theta_n}{360} \quad (3)$$

$$MRT_2 = \frac{(3 \times Ti) + Tiy_\theta}{4} \quad (4)$$

$$MRT_3 = \frac{Ti + 2\ Tiy_o}{3} \quad (5)$$

Where;

MRT_1, MRT_2, MRT_3 = Mean radiant temperature (^{o}C)

$Tiy_{1..n}$ = Inside surface temperatures (^{o}C)

$\theta_{1..n}$ = Surface exposure angle in degress

Ti = Inside temperature (^{o}C)

Tiy_o = Average inside surface temperature (^{o}C)

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

$$i = 0.24\ t_{db} + (595 + 0.47\ t_{db})\ X \quad (6)$$

Where;

i = Enthalpy ($kcal.kg^{-1}$. dry air)

0.24 = Specific heat of dry air ($kcal.kg^{-1}$. deg.)

t_{db} = Dry-bulb air temperature (^{o}C)

595 = Latent heat of evaporation at $o^{o}C$ ($kcal.kg^{-1}$.)

0.47 = Specific heat of water vapor ($kcal.kg^{-1}$.deg.)

X = Humidity ratio of air ($kg.kg^{-1}$. dry air).

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 (MRT_1, MRT_2, MRT_3) temperatures of uninsulated poultry house (h_2) were found higher than those of insulated poultry house (h_1) 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 + $0.65^{o}C$, 29.43 + $0.67^{o}C$ for insulated poultry house (h_1) and 34.74 + $0.74^{o}C$, 32.56 + $0.64^{o}C$) for uninsulated poultry house (h_2). The average mean radiant temperatures at 12-6 p.m. were calculated as 32.13 + $0.53^{o}C$ (MRT_1) 31.24 + $0.60^{o}C$ (MRT_2) 31.85 + $0.54^{o}C$ (MRT_3) in July, 30.41 + $0.54^{o}C$ (MRT_1), 29.72 + $0.62^{o}C$ (MRT_2), 30.23 + $0.55^{o}C$ (MRT_3) in August for insulated poultry house (h_1). 39.37 + $0.83^{o}C$ (MRT_1),35.85 + $0.60^{o}C$ (MRT_2), 37.70 + $0.63^{o}C$ (MRT_3) in July, 36.69 + $0.83^{o}C$ (MRT_1), 33.5 8 + $0.57^{o}C$ (MRT_2), 35.26 + $0.65^{o}C$ (MRT_3) in August for uninsulated poultry house (h_2).

The differences between inside (Ti) and mean radiant temperatures (MRT_1, MRT_2, MRT_3) for insulated poultry house (h_1) were found insignificant but these differences for uninsulated poultry house (h_2) were found significant at 12-6 p.m. In uninsulated poultry house (h_2) the differences between Ti - MRT_2 and MRT_1 - MRT_3 were insignificant but the mean radiant temperatures (MRT_1, MRT_3) 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-$15.0^{o}C$ provide the desirable temperature range for adult egg-laying hens housing. The relative humidity appears to have no effect on performance at housing temperatures below $26.7^{o}C$, although it

Table 2: Inside and mean radiant temperatures

Months	Hours	House 1				House 2			
		Ti	MRT_1	MRT_2	MRT_3	Ti	MRT_1	MRT_2	MRT_3
JULY	2^{00}	22.80	22.36	22.68	22.48	23.11	21.84	22.78	22.22
	4^{00}	21.88	21.90	21.89	21.91	22.22	22.52	22.30	22.43
	6^{00}	22.32	22.99	22.53	22.87	23.15	25.60	23.76	24.78
	8^{00}	23.99	25.03	24.31	24.85	25.70	30.36	26.86	28.79
	10^{00}	26.44	28.29	27.00	27.94	29.17	35.59	30.75	33.38
	12^{00}	29.01	30.69	29.52	30.38	32.63	39.36	34.29	37.04
	14^{00}	31.03	32.59	31.48	32.22	35.15	41.14	36.60	39.02
	16^{00}	31.94	33.19	32.31	32.92	36.06	39.83	36.95	38.44
	18^{00}	31.50	32.04	31.65	31.90	35.11	37.14	35.55	36.29
	20^{00}	29.84	30.02	29.88	29.95	32.56	32.04	32.37	32.05
	22^{00}	27.39	26.86	23.22	24.61	29.09	27.10	28.53	27.59
	24^{00}	24.81	24.13	24.61	24.27	25.64	22.71	24.44	23.46
AUGUST	2^{00}	23.30	22.33	23.03	22.57	22.35	20.97	21.96	21.30
	4^{00}	22.27	22.23	22.27	22.26	21.56	21.92	21.67	21.86
	6^{00}	22.33	22.90	22.49	22.76	22.41	24.75	23.01	24.00
	8^{00}	23.47	23.96	23.70	24.07	24.66	2880	25.68	27.37
	10^{00}	25.37	26.64	25.50	25.72	27.71	33.31	29.13	31.50
	12^{00}	27.54	28.85	27.94	28.61	30.74	36.26	32.13	34.45
	14^{00}	29.39	30.65	29.79	30.45	32.95	38.29	34.28	36.48
	16^{00}	30.42	31.28	30.67	31.09	33.73	37.65	34.67	36.22
	18^{00}	30.36	30.86	30.49	30.71	32.88	34.56	33.22	33.87
	20^{00}	29.22	29.26	29.20	29.17	30.63	30.51	30.56	30.44
	22^{00}	27.31	26.38	27.03	26.56	27.58	26.15	27.17	26.47
	24^{00}	25.14	24.28	24.84	24.35	24.55	22.52	24.01	23.11

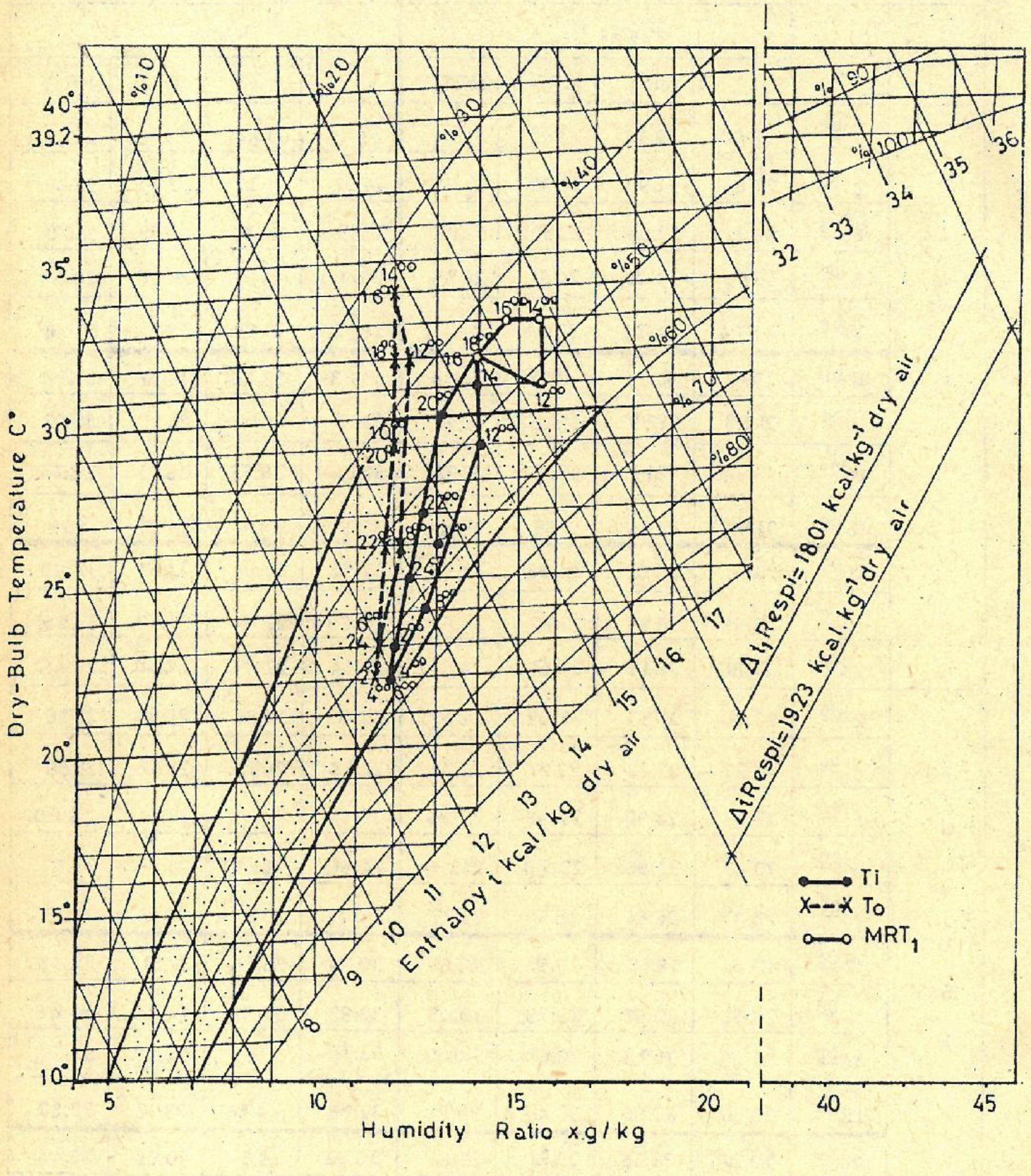

Fig. 1. Psychrometric results during July in poultry house number 1.

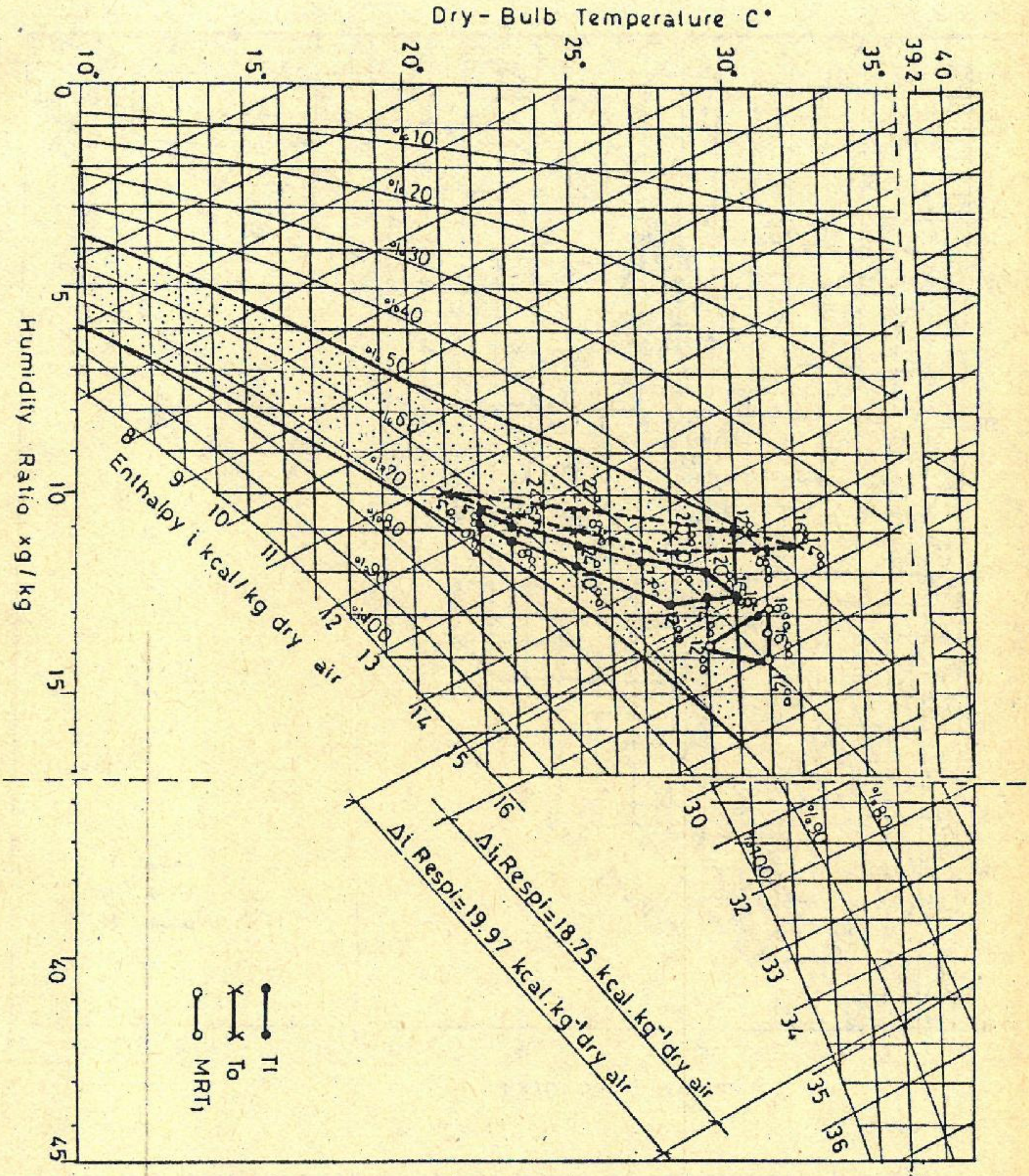

Fig. 2. Psychrometric results during August in poultry house number 1.

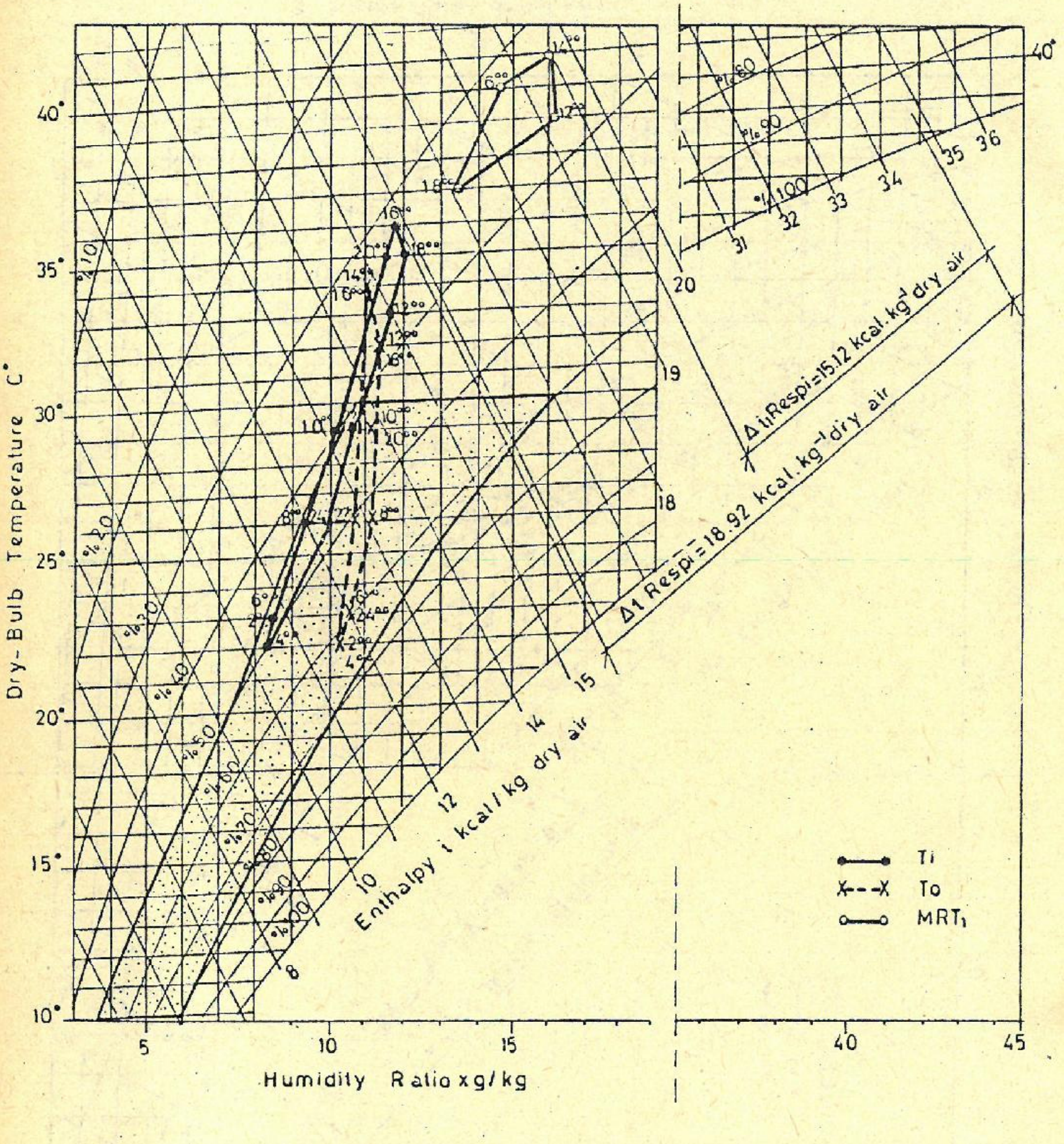

Fig. 3. Psychrometric results during July in poultry house number 2.

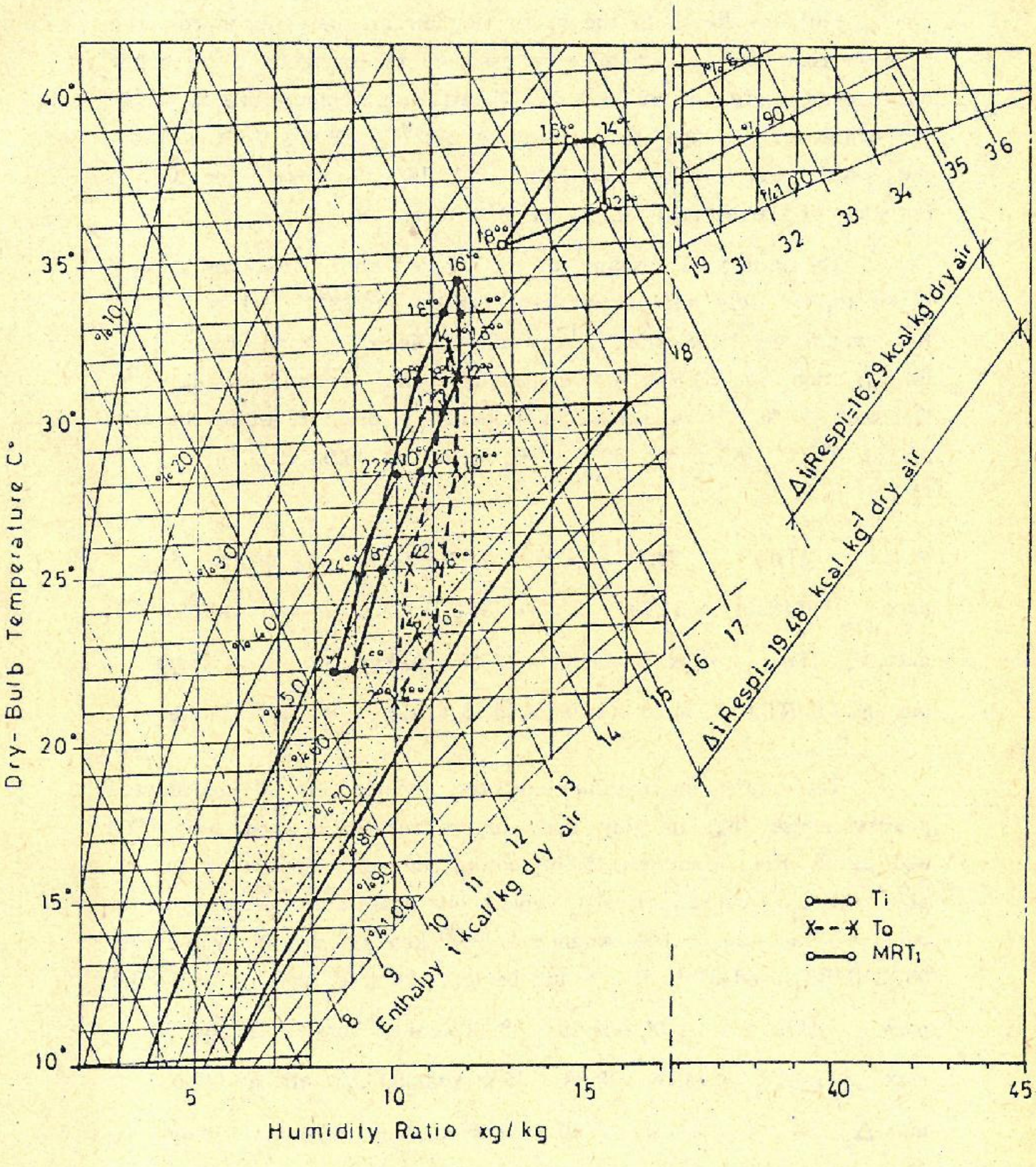

Fig. 4. Psychrometric results during August in poultry house number 2.

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 41.1°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 (h_1) in July and August respectively at 32°C (Ti) and 43 % RH_i would be 15.55 $kcal.kg^{-1}$.dry air while that for air at 33°C (MRT_1) and 46 % RH_i would be 16.77 $kcal.kg^{-1}$.dry air, at 30°C (Ti) and 47 % RH_i would be 14.81 $kcal.kg^{-1}$ .dry air, while that for air at 31°C (MRT_1) and 50 % RH_i would be 16.03 $kcal.kg^{-1}$.dry air in Fig. 1, 2.

max.Δ_i (Ti) = 34.78 - 15.55 = 19.23 $kcal.kg^{-1}$.dry air, at 18.oo

max.Δ_{i_1} (MRT_1) = 34.78 - 16.77 = 18.01 $kcal.kg^{-1}$.dry air, at 14.oo

max.Δ_i (Ti) = 34.78 - 14.81 = 19.97 $kcal.kg^{-1}$.dry air, at 18.oo

max.Δ_{i_1} (MRT_1) = 34.78 - 16.03 = 18.75 $kcal.kg^{-1}$.dry air, at 14.oo

The maximum enthalpy of the inhaled air of uninsulated poultry house (h_2) in July and August respectively at 36°C (Ti) and 32 % RH_i would be 15.86 $kcal.kg^{-1}$.dry air while that for air 41°C (MRT_1) and 33 % RH_i would be 19.66 $kcal.kg^{-1}$.dry air, at 34°C (Ti) and 35 % RH_i would be 15.30 $kcal.kg^{-1}$.dry air while that 38°C (MRT_1) and 37 % RH_i would be 18.49 $kcal.kg^{-1}$.dry air in Fig.3,4.

max.Δ_i (Ti) = 34.78 - 15.86 = 18.92 $kcal.kg^{-1}$.dry, at 16.oo

max.Δ_{i_1} (MRT_1) = 34.78 - 19.66 = 15.12 $kcal.kg^{-1}$.dry air, at 14.oo

max.Δ_i (Ti) = 34.78 - 15.30 = 19.48 $kcal.kg^{-1}$.dry air, at 16.oo

max.Δ_{i_1} (MRT_1) = 34.78 - 18.49 = 16.29 $kcal.kg^{-1}$.dry air, at 14.oo

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 (Δ_i), 18.01 - 18.75 $kcal.kg^{-1}$.dry air (Δ_{i_1}) for insulated poultry house (h_1); 18.92 - 19.48 $kcal.kg^{-1}$.dry air (Δ_i), 15.12 - 16.29 $kcal.kg^{-1}$. dry air (Δ_{i_1}) for uninsulated poultry house (h_2).

The differences between $\Delta_i - \Delta_{i_1}$ 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;

$$Q = V\,(i_e - i_i)\ kcal.min^{-1}. \qquad (7)$$

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;

$$Q_L = V(i_i - i_o)\ (kcal.hr^{-1}\ .live\ wt.) \qquad (8)$$

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 $\geq 30^oC$);

$$Q_L = Q_{Ti} + Q_{BR} \qquad (9)$$

Maximum Ventilation Rate For Summer Conditions

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

$$V = \frac{Q_{Ti} + Q_{BR}}{0.29\ (\Delta_t)} \qquad (10)$$

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.)

Δ_t = Difference between inside and outside air temperature(^oC)

Between 28-32^oC 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 intu account and the mean radiant temperatures (MRT_1, MRT_3) estimation methods should be employed.

ÖZET

KÜMESLERDE BİYOKLİMATİK RAHATLIĞI BELİRLEME YÖNTEMLERİ VE YAZ DÖNEMİ MAKSİMUM HAVA DEBİSİ

Araştırma, kümeslerde biyoklimatik rahatlığı belirleme yöntemlerinin karşılaştırmalı analizi ve ortalama radyant sıcaklığın tanımlanması amacı ile yapılmıştır.

Kümes içi (Ti) ve ortalama radyant (MRT_1, MRT_2, MRT_3),sıcaklıklar yapı elemanları yalıtımı yetersiz olan kümeste (h_2), yapı elenları yalıtımı

yeterli sayılan kümes'e (h_1) oranla saat 12^{00} - 18^{00} arasında daha yüksek bulunmuştur ($P < 0.05$; $P < 0.01$).

Kümeslerde biyoklimatik rahatlığın belirlenmesinde, yapı elemanları yalıtımı yeterli olduğunda yalnızca iç havanın kuru-ıslak termometre sıcaklıkları ve antalpi ölçüt olarak alınmalı, yapı elemanları yalıtımı yetersiz olduğunda ise, iç havanın kuru-ıslak termometre sıcaklıklarına ve antalpisine ek olarak yapı elemanları iç yüzey sıcaklıkları da ölçüt olarak alınmalı ve ortalama radyant sıcaklık (MRT_1, MRT_2) belirleme yöntemleri kullanılmalıdır.

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