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Effects of Environmental Temperature on Egg Production, Food Intake and Water Consumption in Laying White Leghorns

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(Fig. 1; Tables 1-5)

It is known that chemical, physical and thermal factors control appetite of animals. The thermal factor may be connected with energy metabolism, food consumption and productivity of animals. Many researchers have reported in laying hens that summer climate or high environmental temperature reduces their egg production rate, egg weight, thickness of shell and food intake (WARREN and SCHNEPEL, 1940[1], HUTCHINSON, 1953[2], WILSON *et al.*, 1957[3], MUELLER, 1961[4]). These facts indicate that egg production is connected with environmental temperature being mediated by food intake.

According to HUTCHINSON (1954)[5], in India, adult fowl produces egg at 44°C, but there are many opinions as to the ideal temperature at which maximum egg production will be expected with minimum food consumption. The ideal temperature for laying hens has been changed gradually with the times; 2 to 10°C by BRUCKNER (1936)[6], 13 to 18°C by OTA (1960)[7] and considerably higher than 25°C by PAYNE (1967)[8]. These elevations of ideal level of environmental temperature may be mainly owing to the development of diet for laying hens. As the moderate low temperature increases food intake, only at that temperature range hens can make up for the uncertain deficient components in diet with a lot of food intake.

PAYNE (1967)[8] says that high temperature (30°C constant with 50% relative humidity) improved 20% more in food conversion efficiency than lower temperature (18–20°C) in laying White Leghorns. He emphasized that the advantage of high environmental temperature in White Leghorns is based on inherent superiority in terms of efficiency of food utilization.

The present experiment was performed in order to investigate the effects of constant environmental temperature during day and night on egg production, food intake and water consumption in laying White Leghorns.

MATERIALS AND METHODS

All the 15 White Leghorn hens researched in the present experiment were selected from the flocks which had been hatched at Fukuyama Poultry Center and reared in this Laboratory. They were laying at a rate above 70% under the natural environment using commercial standard food for the last 100 days.

In these hens, 10 hens were from 1 year old flock hatched on the 5th of August, 1968 (Group I), and 5 hens from 2 years old flock hatched on 7th of May, 1967 (Group II).

Each hen was kept in individual cage (40 × 25 × 40cm height) and was fed on commercial semimashed food for laying hens. The composition of the food was given in Table 1.

Table 1. Composition of the food.

Components	Percentage (%)
Crude Protein	17.7
Crude Fat	2.0
Crude Fiber	3.0
Nitrogen Free Extract	56.1
Crude Ash	7.8
Moisture	13.4

The cages were kept in the temperature room (2.6 × 3.8 × 2.6m height). And each cage was fixed on the frame 60cm height above floor.

Supplying of food and water, weighing of eggs and measurements of food intakes and water consumptions were done twice daily at 9 : 30 and 15 : 30.

Daily food intake was calculated from the difference between supplied food weight and remaining food weight.

Water supplying apparatus was shown in Figure 1. The chemical cylinder of

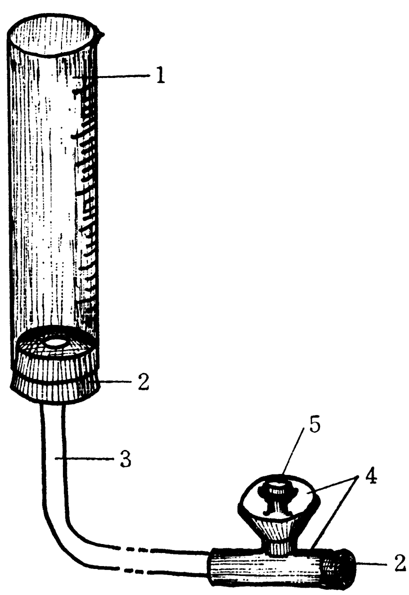

Fig. 1. Water supplying apparatus. 1; Chemical cylinder of 250ml, 2; Rubber plug, 3; Vinyl tube, 4; Water cup, 5; Red coloured valve.

250 ml was connected to water cup (Mode of Matsubara). Being pecked the red coloured valve of water cup, stocked water in each cylinder leaks out into the cup and hens can drink water freely. The difference of reading between supplied water and remaining water was calculated and expressed as consumed water per day per hen. The evaporation from the surface of the water cup and chemical cylinder was not measured.

Adding measurement of weight, produced eggs were observed whether the shell condition was normal or not, and both broken eggs and non-shelled eggs were recorded as abnormal eggs.

For control of room temperature, two pairs of 600W electric heaters with fans were used. Each heater was connected to a thermoregulator and was switched on and off between 0.5°C of sensibility.

The room temperature was continuously recorded using a self-registering thermometer during experimental period, and using mercury thermometers (1/10°C), each measurement of dry and wet bulb temperature was done at daily measurement times.

It was artificially lighted by 2 electric bulbs of 60W being switched on or off with a time-switch, from 6 o'clock in the morning until 8 o'clock in the evening.

Each of 10 or 15 days trial was conducted between May 9 and July 10, 1969, under room temperatures at 25°C, 27.5°C, 30°C, 32.5°C and 35°C. As for 25°C regime, during the first 1 week, it was a preliminary experiment and was not contained in this data. Set temperature, mean measured temperature and the relative humidity are given in Table 2. Body weight was measured at initial and final day of the period of each temperature regime.

Table 2. Set temperature, mean measured temperature and relative humidity.

Set temperature °C	Date from to	Mean measured temp.		Relative humidity
		Dry bulb °C	Wet bulb °C	%
25	15 May 24 May	25.3	20.2	58
27.5	27 May 5 June	28.1	23.1	60
30	6 June 17 June	29.8	21.9	43
32.5	18 June 28 June	32.4	24.6	44
35	29 June 8 July	34.6	26.4	42

RESULTS

As shown in Table 3, mean figure of daily food intake per kg of body weight, was decreased with the elevation of environmental temperature. Based on mean

Table 3. Body weight, daily food intake, daily water consumption, water/food ratio and productivity of eggs.

Temperature (°C)	25	27.5	30	32.5	35
Body weight (Kg)	1.80 2.42 2.00	1.78 2.45 2.00	1.75 2.45 1.99	1.71 2.40 1.95	1.64 2.30 1.87
(A) Food intake* (g/day/Kg of BW)	63.7 53.3 59.7	58.7 51.9 56.0	55.2 50.2 53.0	51.0 44.5 48.3	39.0 29.9 35.1
(B) Dry matter intake (g/day/Kg)	55.2 46.2 51.7	50.8 44.9 48.5	47.8 43.5 45.9	44.2 38.5 41.8	33.8 25.9 30.4
(C) Water consumption (g/day/Kg)	116 106 112	134 114 126	147 121 136	191 165 176	205 163 188
Egg weight (g/Kg)	32.1 26.1 29.8	32.2 25.5 29.6	32.5 25.4 29.5	32.4 25.7 29.6	32.5 25.4 29.5
(D) Egg production (g/day/Kg)	29.9 24.4 27.8	29.0 23.0 26.6	29.8 22.4 26.7	28.8 22.4 26.1	24.1 18.2 21.6
(E) Net egg production (g/day/Kg)	29.9 23.9 27.6	28.3 22.4 26.0	29.3 22.0 26.2	28.5 21.7 25.1	18.0 10.6 14.9
Egg production rate (%)	93.3 93.3 93.3	90.0 90.0 90.0	91.7 88.3 90.6	88.9 87.3 88.3	74.1 71.7 73.2
Net egg production rate (%)	93.3 91.7 92.7	88.0 88.0 88.0	90.0 86.7 88.9	87.9 83.6 86.4	55.6 41.7 50.6
Appearing rate of abnormal eggs (%)	0 1.8 0.7	2.2 2.2 2.2	1.8 1.9 1.8	1.1 4.2 2.3	25.0 41.9 30.9
(D/A) Efficiency of egg production (%)	47 46 47	49 44 48	54 45 50	57 50 54	62 61 61
(E/A) Efficiency of normal egg production (%)	47 45 46	48 43 46	53 44 49	56 48 53	46 35 42
(C/A) Water/Food intake ratio	1.82 1.99 1.88	2.28 2.20 2.25	2.67 2.40 2.56	3.75 3.70 3.64	5.26 5.45 5.35
(C/B) Water/Dry matter intake ratio	2.10 2.29 2.17	2.64 2.54 2.60	3.08 2.78 2.96	4.32 4.29 4.21	6.07 6.29 6.18

Note: In each column, each figure shows from upper to lower Group I, Group II and mean figure of both groups.

* Containing of moisture.

figure at 25°C, mean figure of food intake at 27.5°C, 30°C, 32.5°C, 35°C was 94%, 89%, 81%, 59% respectively. Remarkable decrease of food intake was observed at 35°C, and in this temperature regime, Group I was 61% of the figure at 25°C, likewise Group II was 56%.

Mean figure of daily water consumption per kg of body weight increased with the rise of environmental temperature. Based on mean figure at 25°C, water consumption was calculated as 113, 122, 157, 168% at each increase of temperature. Radical increases were observed at the temperatures over 32.5°C.

Although egg weights were conversely decreased with the increase of temperature, egg weight per kg of body weight on each temperature regime, was almost constant. Each figure of mean $\pm$ standard deviation was 32.3 $\pm$ 0.14g in Group I, and 25.6 $\pm$ 0.3g in Group II.

Daily egg production per kg of body weight was almost constant till 32.5°C, but at 35°C severe decrease was observed in both groups. Each figure based on the temperature above mentioned, Group I and Group II was 81% and 75%, respectively. At 35°C appearing rate of abnormal eggs attained to 25% in Group I, 42% in Group II. Excluding abnormal eggs, the normal net egg production was therefore calculated as 60% and 45% of the figure at 25°C, respectively, in each group at 35°C.

With regard to egg production rate, it was almost constant, being about 90% till 32.5°C, but at 35°C it decreased to 73%, and the rate of normal egg production was calculated as the same rate above mentioned till 32.5°C, but at 35°C it became less, being 51%.

In each temperature regime, the percentage of mean body weights based on 25°C was 100, 100, 98, and 94% respectively. At 32.5°C each figure based on the 25°C was 95% in Group I and 99% in Group II, and at 35°C it was 91% and 95%, respectively. Decrease of body weights was larger at higher range in Group I than in Group II.

The mean figure of efficiency of egg production, was calculated as follows on each temperature based on 25°C; 102, 106, 115, 130% respectively. The higher the temperature became, the higher became the efficiency. But excluding abnormal eggs, the efficiency of normal egg production based on 25°C became 100, 107, 115, 91% respectively. In both groups at 32.5°C it was indicated the highest efficiency of egg production per kg per one g of food consumption.

The ratio of water consumption per one g of food intake increased with temperature rising gradually till 30°C, and radically from over 32.5°C. Based on 25°C and calculating the change of this ratio, it became 120, 136, 194, 285% respectively, in order of each rising temperature.

DISCUSSION

The higher the environmental temperature becomes, the less food intake was observed. This tendency agreed with other reports (WILSON *et al.*, 1957[3]), ROMJIN and LOKHORST, 1964[9]). The mean reduction of 1.2% was observed in food intake per Centigrade degree rise in environmental temperature from 25°C to 32.5°C, and 1.6% per Centigrade degree rise from 25°C to 35°C. It is interesting that this value agreed with that of PAYNE (1967)[8] being 1.6%.

Water consumption increased gradually till 32.5°C, and did not differ between 32.5 and 35°C. In high temperature over 30°C, water loss will increase remarkably mainly from the mouth cavity and the trachea being due to panting, therefore water supply is important especially for hens in temperature regime of 32.5 and 35°C. Some water being consumed is attributable to the water accompanied with food intake. But as mentioned above, the higher temperature over 30°C reduces food intake, so water requirement also decreases together with reduction of food intake. And this may be a reason for the small difference between 32.5 and 35°C. Decrease of egg production rate to 73% from about 90% may be also an another reason that water requirement at 35°C has not been increased. Anyhow, high environmental temperature increased water intake, and brought high watery excreta as reported by WILSON *et al.* (1957)[3].

Absolute weights of produced eggs were slightly decreased approximately 0.14% per Centigrade degree with rise of temperature. But egg weight per kg of body weight did not change. PAYNE (1967)[8] pointed out that the insufficient calorie intake partially relates the decrease of egg weight. He showed the absolute value to Metabolizable Energy (ME) required for maximum egg production. PAYNE's figure and ME intake in this experiment on each temperature regime were given in Table 4. An importnat question in PAYNE's figure must be pointed out, because body

Table 4. Daily ME intake and absolute necessity of ME for maximum egg production.

Temperature (°C)		25	27.5	30	32.5	35
Absolute necessity of ME (Cal)		340*	335*	330	325*	320*
ME** intake (Cal)	Group I	330 (97)***	301 (90)	278 (84)	251 (77)	184 (67)
	Group II	371 (109)***	366 (109)	355 (108)	308 (95)	198 (67)
	Mean	344 (101)***	323 (96)	304 (92)	271 (83)	198 (59)

Note: * Calculated from PAYNE's data (1957)[8].
** ME content in food postulating 2.88 Cal/g.
*** % based on the PAYNE's figure at each temperature.

weight difference was not considered. The lower satisfication of PAYNE' figure in Group I, may be explained from this point. As food intake will be related to body weight, Group I with lighter body weight, will have lower ME intake than in Group II. Especially at 35°C Group I was low being 58%. It is interesting that these figures were proportional to those of the change of body weight.

Decrease of egg production rate at higher temperature was the same tendency observed by other researchers in White Leghorns (Wilson *et al.*, 1957[3]), Mueller, 1961[4]).

Appearing rate of abnormal eggs at 35°C being 25% and 42%, and 2 years old hens had a higher rate. This may be due to significant decrease of food intake per body weight, because at this high temperature, significant decrease of appetite was induced. And insufficiency of food intake brought calcium insufficiency, and this brought a thinner egg shell. Thinner shelled eggs are feasible to break at a slight touch of feet or a beak or at the stage of oviposition on the cage. From the point of view of the weakness of bones being observed, it is likely that this is an explanation for increase of broken eggs. Conrad (1939)[10] reported that the decrease of blood calcium at the higher temperature (34°C). And Warren and Schnepel (1940)[1] related second quality eggs induced at high temperature, to blood calcium level. But in other ways it may be explained by other factors that the oviduct will be stressed under high temperature, as Hurwitz and Griminger (1962)[11] suggested more complicated mechanism.

In the present experiment added calcium was not supplied, but in the next experiment it will be designed to see if the supplement of calcium might have a effect for prevention of abnormal eggs at higher environmental temperature.

Efficiency of egg production, being calculated from the egg production divided by food intake, was highest at 35°C, but excluding abnormal eggs, net efficiency of egg production was highest at 32.5°C.

Caloric efficiency and ME intake per Metabolic Body Size ($kg^{3/4}$) in each temperature were shown in Table 5. Caloric efficiency of egg production was also highest at 35°C but excluding abnormal eggs, net caloric efficiency was highest at 32.5°C.

Table 5. ME intake per Metabolic Body Size and caloric efficiency for egg production.

Temperature (°C)		25	27.5	30	32.5	35
ME/M. B. S. ($Cal/Kg^{3/4}$)	I	213	196	183	167	127
	II	191	187	181	159	106
	M	205	192	180	164	118
Calorie into produced egg* (Cal)	I	57	55	57	54	45
	II	50	47	46	46	37
	M	55	52	52	51	42
Caloric efficiency** for egg production (%)	I	27	28	31	32	35
	II	26	25	26	29	35
	M	27	27	29	31	35
Calorie into net produced egg (Cal)	I	57	54	56	54	34
	II	49	46	46	44	22
	M	54	51	51	50	29
Net caloric efficiency (%)	I	27	28	30	32	27
	II	26	25	25	28	20
	M	27	27	28	30	24

Note: * 1.65 Cal Gross Energy/g of egg.

** Efficiency = Gross Energy in Egg/Metabolizable Energy of Food.

I; Group I, II; Group II, M; mean figure of both groups.

PAYNE (1967)[8] pointed out that 20% higher food converting efficiency will be expected in 30°C housing than in 18–20°C. Breed difference was reported by HASTON *et al.* (1957)[12], that White Leghorn hens had more tolerance for high environmental temperature and better food converting efficiency for egg production in high temperature than New Hampshires and White Plymouth Rocks. The superiority of food converting rate and energy utilizable rate for net egg production at 32.5°C could be explained from the energetic point. At 32.5°C ME intake does not decrease so much, and both Resting Metabolic Rate (RMR) and Fastig Metabolic Rate (FMR) decrease being 3.7% in RMR, 3.2% in FMR with one Centigrade degree rising to almost 30°C (BERMAN *et al.*, 1969[13]), and the difference of these two figures which is called heat increment for food intake, is almost constant irrespective of temperature (BERMAN and SNAPIR, 1964[14]). Quoting from YOUSEF *et al.* (1968)[15], the reason of the decrease of metabolic rate is caused by

a) decrease in food intake,
b) decrease in endocrine functions; particularly thyroid,
c) a direct effect of ambient temperature on the heat production center in the hypothalamus.

Using Table 5 and from the data of BERMAN and SNAPIR (1964)[14] in laying White Leghorns, postulating proportional reduction till 35°C, RMR at 32.5°C being 88 Cal /kg $^{3/4}$/day, at 35°C being 76Cal/kg $^{3/4}$/day, the energy balance in the present experiment was calculated as follows; at 32.5°C being +25 Cal/kg$^{3/4}$/day and at 35°C being −3Cal/kg $^{3/4}$/day. It was maintained barely at 32.5°C, and was not maintained at 35°C. These data show that White Leghorn hens can be managed at 32.5°C with good efficiency.

A series of experiments has to be performed moreover as for the following matters; the breed difference, and the effect of humidity and wind, the effect of food composition (especially protein, vitamins, minerals, amino acid components and balance, caloric content), egg shell thickness and egg quality. The decrease of body weight may have significance for maintaining egg production for long term. There arise many questions in this experiment for the decrease of body weight observed at above 32.5°C and the comparison of ME at the decreased condition of body weight. It is interesting that how much effect it might have for maintenance of body weight and food intake, if the forced or usual feeding of high caloric content food were done. With regard to this point we intend to confirm by the next experiments for long term.

SUMMARY

In order to investigate the effects of environmental temperature on egg production, food intake and water consumption in laying White Leghorns, this experiment was performed. Fifteen hens (10 of them were 1 year old hens, 5 were 2 years old hens) were kept in the temperature room from 25 to 35°C changing by 2.5°C at each interval during 10–15 days. The results obtained were as follows;

1) The higher the temperature becomes, the lesser food intake was observed. The decreasing rate was 1.6% per Centigrade rise of environmental temperature from 25°C to 35°C. Water consumption increased with the rise of temperature. Each ratio of water consumed per one g of food intake was about 2 times at 32.5°C, and about 3 times at 35°C as much as that at 25°C.

2) Egg production rate was lowest at 35°C, being 73%. Daily egg production was also lowest at 35°C, but food efficiency for egg production, was highest at 35°C, being 61%.

3) Excluding abnormal eggs, net efficiency for egg production was highest at 32.5°C, being 53%, but being 42% at 35°C. Appearing rate of abnormal eggs was attained to 31% at 35°C. Comparing 25°C with 32.5°C, the latter temperature regime had by 15% higher food converting efficiency. The reason for the highest food converting rate for egg production at 32.5°C was discussed.

REFERENCES

1) WARREN, D. C. and SCHNEPEL, R. L.: *Poult. Sci.*, **19**, 69-72 (1940).
2) HUTCHINSON, J. C. D.: *Ibid.*, **32**, 692-696 (1953).
3) WILSON, W. O., MCNALLY, E. and OTA, H.: *Ibid.*, **36**, 1254-1261 (1957).
4) MUELLER, W. J.: *Ibid.*, **40**, 1562-1571 (1961).
5) HUTCHINSON, J. C. D.: in Environmental Control in Poultry Production (CARTER, T. C. ed.), 40 pp., Oliver & Boyd, Edinburgh (1967).
6) BRUCKNER, J. H.: *Poult. Sci.*, **15**, 417-418 (1936).
7) OTA, H.: in Environmental Control in Poultry Production (CARTER, T. C. ed.), 44 pp., Oliver & Boyd, Edinburgh (1967).
8) PAYNE, C. G.: *Ibid.*, pp. 40-54 (1967).
9) ROMJIN, C. and LOKHORST, W.: in Physiology of the Domestic Fowl (HORTON-SMITH and AMOROSO ed.), pp. 211-227, British Egg Marketing Board Edinburgh (1964).
10) CONRAD, R. M.: *Poult. Sci.*, **18**, 327-329 (1939).
11) HURWITZ, S. and GRIMINGER, P.: *Ibid.*, **41**, 499-508 (1962).
12) HUSTON, T. M., JOINER, W. P. and CARMON, J. L.: *Ibid.*, **36**, 1247-1254 (1957).
13) BERMAN, A., HELLER, E. D. and SNAPIR, N.: *Int. J. Biometeor.*, **13**, 265-274 (1969).
14) BERMAN, A. and SNAPIR, N.: *Brit. Poult. Sci.*, **6**, 207-216 (1965).
15) YOUSEF, M. K., HARN, L. and JOHNSON, H. D.: in Adaptation of Domestic Animals (HAFEZ, E. S. E. ed.), 235 pp., Lea & Febiger, Philadelphia (1968).

白レグの産卵，採食，飲水におよぼす環境温度の影響

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白レグ産卵鶏15羽（1年鶏10羽，2年鶏5羽）を供試し，産卵鶏の産卵，採食，飲水におよぼす環境温度（25～35°C, 2.5°C 間隔，各温度感作 10～15日）の影響を，環境調節室内で実験し，次の知見を得た．

1) 採食量は温度上昇と共に減少し，25～35°C において，温度 1 °C あたりの減少率は1.6%であった．飲水量は温度上昇と共に増加し，摂取飼料 1 g あたりの飯水量も急激に増加し，30°C で 25°C の1.5倍，32.5°C で 2 倍，35°C で 3 倍に達した．

2) 産卵率は 35°C において 73%と最低で，一日あたりの卵生産量も最低であったが，飼料消費あた

りの産卵効率は61%と最高であった.

3) 破卵，軟卵をのぞいた正常卵の生産効率は，32.5°Cにおいて53%と最高で，一方35°Cにおいては42%であった. 35°Cでは，破卵，軟卵の出現率が31%にも達した. 32.5°Cでは25°Cを基準にした場合，15%の卵生産効率の増加がみられ，この点について考察した.