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RESEARCH ARTICLE

The Relationship between Body Temperature and Egg Production Determined by a Thermal Camera in Laying Hens

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ABSTRACT

This study was carried out to investigate the culling of low-producing hens from a laying flock by objective methods. A total of 16 commercial laying hybrid breeds (Lohmann White and Lohmann Brown) at 60 weeks of age were used in this study. The body temperature of the hens used during the trial period was obtained from the head and foot regions with the help of a thermal camera, and their egg production was associated with these values. Considering egg production, the differences between the hybrids were statistically significant (P < 0.001). In terms of temperature values taken from the morning foot section, the differences between the hybrids were not statistically significant (P > 0.05) during the experimental period. Considering the temperature values taken in the afternoon, the differences between the hybrids were statistically significant (P < 0.01). ROC analysis was utilized to determine the relationship between egg production and body temperature. According to the results of the test, the critical point between the temperature of the morning (head region) and the egg yield was determined. Accordingly, the hens with a temperature higher than 38.3 °C were laying more eggs than those with a temperature lower than 38.3 °C. The trial lasted 16 weeks, and in conclusion, we can infer from the experiment conducted during this study that the temperature value taken from the head section in the morning by a thermal camera may be used to identify the low producing hens in laying flocks.

Introduction

In earlier times of egg production, hen eggs were produced using purebred stocks, and the average egg yield per laying hen was 100 eggs. Today, purebred hen lines have been replaced by hybrid layers, which are characterized by a very high genetic capacity (Leenstra et al., 2016; Thiruvenkadan et al., 2010)

As a result, standard hen breeds, raised either for eggs or dual purposes (meat and eggs), have been displaced by commercial hybrids. Modern hybrid layers have an average annual egg yield of more than 300 eggs per hen (Dudde et al., 2000).

Profitable economic production requires the culling of non-productive and low-producing animals from a flock. Thereby, more feed and space are provided to the remaining productive birds in the flock.

High feed costs oblige culling to be practiced on a regular basis in layer hen flocks. If not culled, non-productive animals, which do not lay eggs but consume feed, reduce the profit of the commercial operation. The culling of low-producing hens

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reduces not only egg production costs but also disease incidence. These issues are directly related to flock performance, and therefore, to profit margin. The culling of non-productive animals on a level of 2% of a flock resulting in a 2% increase in egg production clearly demonstrates the significance of culling for egg farms (Altahat et al., 2012).

Current methods used to cull non-productive hens generally involve a subjective assessment. Non-productive animals are culled based on the individual inspection of their head (comb, wattles, eyes, eye rings, and beak), abdomen, pubic bones and vent (Oleforuh-Okoleh, 2011).

When hens produce eggs, they divert the yellow color of certain parts of their body to the egg yolk. Thus, bleaching of certain body parts is a good indicator of egg production. This type of color loss is distinctly visible in yellow-skinned breeds, such as White Leghorns. However, bleaching is less visible, and therefore, more difficult to detect in white-skinned breeds (Claybaugh, 1947).

A thermal imaging camera detects the surface temperature of an object and provides a thermographic schematic representation of an organism. Thermal imaging cameras are used in various areas, including among others, industry, construction, policing, rescue operations, border patrol and human and veterinary medicine (Stewart et al., 2005; McCafferty et al., 2011).

The literature review has shown that, to date, culling practices aimed at increasing the egg yield of layer hens have been performed mostly using subjective methods.

Generally, high-producing layer hens have high body temperatures due to their high metabolic rate. On the other hand, low-producing birds and broody hens have relatively lower body temperatures (Kadono et al., 1981).

In view of this information, this study was designed to develop a more objective method for the culling of low-producing hens in egg farms with the use of thermal cameras.

Materials and Methods

Animal Material

This study was conducted at the layer hen premises of the Food and Livestock Research and Application Centre of Atatürk University. The animal material comprised sixteen 60-week-old hybrid layers of the Lohmann White and Lohmann Brown breeds. The trial was continued for a period of 16 weeks. The building, in which the birds were housed, was equipped with three blocks and two rows of 3-storey battery cages. To ensure a uniform impact of the prevailing environmental factors on the birds, the animals were randomly allocated to cages located on the same aisle and on the same floor. Eight hybrid layers of the Lohmann White (LW) genotype and eight hybrid layers of the Lohmann Brown (LB) genotype were housed individually in separate cages. The cages measured 62.5 cm in width, 60 cm in length and 51 cm in height. Each cage was assigned a unique number to determine the daily egg yield of each animal.

Feed Material

Throughout the trial, the animals were given water and feed *ad libitum*. The feed provided to the animals was purchased from a commercial feed mill, and its composition is presented in Table 1.

Table 1. Chemical composition of feed

Nutrient	(%)
Dry Matter	88.2
Crude Protein	16.50
Crude Oil	2.20
Crude Ash	11.50
Methionine	0.38
Lysine	0.68

*12000 IU Vitamin A, 35 mg Vitamin E, 5 mg Vitamin K, 80 mg Manganese, 60 mg Iron, 60 mg Zinc, 5 mg copper, 0.20 Cobalt, 0.15 Selenium, 1 mg Iodine are included in 1 kilogram of feed.

Ambient Temperature and Relative Humidity of the Poultry House

The temperature of the poultry house was maintained within a range of 16-24 °C by means of sensors connected to the ventilation and heating systems. The portable air data logger Trotec BZ30® was used for temperature (with 0.1°C sensitivity) and relative humidity (with 0.1% sensitivity) measurements, which were performed on a weekly basis in the morning and evening. The temperature and relative humidity values measured in the poultry house are presented in Table 2.

Table 2. Temperature and humidity of the house

Measurement Time	Temperature (^{0}C)		Humidity (%)	
	Mean	SEM*	Mean	SEM*
Morning	19.78	1.76	45.70	7.64
Afternoon	20.81	1.86	44.25	7.63

* SEM: Standard error of means.

Determination of Various Body Temperatures

The head and foot temperatures of the animals were determined using a thermal camera Testo 855-2® (with < 30 mK at 30°C sensitivity). The measurements were performed on a weekly basis, at 9.30 am and 3.30 pm, on a selected day of the week, throughout the trial period. Measurements were made on the same days. To avoid exposing the animals to stress, thermal images were taken at an approximate distance of 1 meter to the cages.

Statistical Analyses

The data obtained in this study were analyzed using the General Linear Model (GLM) procedure in the Statistical Package for the Social Sciences (SPSS) software (SPSS 19.0). The differences between the groups were determined with Duncan's Multiple Comparison Test. The cut-off values for egg yield and body temperature were determined by receiver operating characteristic (ROC) analysis. The results produced a 95% confidence interval for the area under the ROC curve (AUC).

Mathematical Model:

$Y_{ijk} = \mu + a_i + b_j + (a*b)_{ij} + e_{ijk}$

Y_{ijk} = Value of any of the performance parameters

μ = Population mean

a_i = Effect of the hybrid

b_j = Effect of the week

$(a \times b)_{ij}$ = Interaction between the hybrid (i) and week (j)

e_{ijk} = Random errors

Results and Discussion

The egg yield values determined for the trial groups are presented in Table 3. The differences observed between the hybrid layers for egg yield were significant (P < 0.001). The egg yields of the LB and LW hybrid layers were determined to be 88.05% and 95.08%, respectively. While the impact of the week on egg yield was significant (P < 0.002), the impact of the hybrid x week interaction was found to be statistically insignificant (P > 0.05).

Table 3. Weekly egg production in laying hybrids

LB	$\overline{x}$	LW	$\overline{x}$
1	91.06[a]	1	92.85 [ab]
2	92.85[a]	2	98.21[a]
3	96.42[a]	3	96.42[ab]
4	89.27[a]	4	94.63[ab]
5	98.21[a]	5	100.00[a]
6	96.42[a]	6	98.21[a]
7	89.27[a]	7	92.85[ab]
8	83.91[ab]	8	94.63[ab]
9	94.63[a]	9	100.00[a]
10	91.06[a]	10	92.85[ab]
11	96.42[a]	11	98.21[a]
12	85.71[ab]	12	94.63[a]
13	83.92[ab]	13	94.63[ab]
14	80.35[ab]	14	94.63[a]
15	64.27[b]	15	92.85[ab]
16	74.98[ab]	16	85.70[b]
*SEM	5.25		5.25
Mean	88.05±1.31	Mean	95.08±1.31
**P<			
Hybrid	0.001		
Week	0.002		
Hybrid x Week	0.535		

* Standard error of means, ** Statistical significance.

As it may be seen in Table 3, throughout the trial period, the white hybrid layers displayed an egg yield higher than that of the brown hybrid layers. The analysis of the mean weekly egg yields of both groups showed that the egg yield reached its peak in week 9 (97.31%), and it gradually decreased thereafter to the lowest level in week 15 (78.56%).

The head temperatures of the animals that were measured in the morning are given in Table 4. It was determined that the differences between the white and brown hybrid layers for the morning head temperatures were significant (P < 0.001).

Table 4. Weekly morning head temperature in laying hybrids

LB	$\overline{x}$	LW	$\overline{x}$
1	37.86[a]	1	38.04[ab]
2	37.36[ab]	2	38.13 [ab]
3	37.44[ab]	3	38.10 [ab]
4	36.73[b]	4	38.15 [ab]
5	37.70[ab]	5	38.38 [ab]
6	37.63[ab]	6	38.54 [ab]
7	37.44[ab]	7	38.93 [ab]
8	38.15[a]	8	38.89 [ab]
9	37.88[a]	9	38.34 [ab]
10	37.99[a]	10	38.13 [ab]
11	37.40[ab]	11	38.49 [ab]
12	37.48[ab]	12	38.06 [ab]
13	37.81[a]	13	37.91 [ab]
14	38.15[a]	14	38.23 [ab]
15	38.15[a]	15	39.35 [a]
16	37.36[c]	16	33.83[c]
*SEM	0.300		0.300
Mean	37.46±0.07	Mean	38.09±0.07
**P<			
Hybrid	0.001		
Week	0.001		
Hybrid x Week	0.086		

* Standard error of means, ** Statistical significance.

To the authors' knowledge, to date, no scientific report has been demonstrated on the correlation of various body temperatures with production yields. Thus, the correlation of body temperature with yield has been addressed for the first time in this study. As there is no previous study that can be used for data comparison, the discussion of this manuscript will be founded mainly on the parameters investigated in this study. These parameters shall pave the way for future research to be conducted in this issue.

The highest head temperatures were measured in the LW hybrids. The mean head temperatures measured in the brown and white hybrid layers were 37.46 °C and 38.09 °C, respectively. The impact of the week on body temperature was found to be significant (P < 0.001). This result confirmed the hypothesis upon which this study was based, for, as high-producing layer hens are known to have a high metabolic rate, their body temperature would be expected to be higher. Hence, in this study, the LW hybrids, which had a higher egg yield, were determined to have higher head temperatures. On the other hand, the effect of the hybrid x week interaction was found to be insignificant (P > 0.05).

In this study, the mean value of the morning head temperatures measured throughout the trial period was determined as 37.79°C ± 1.32°C.

The foot temperatures measured in the trial groups in the morning are presented in Table 5.

No significant difference was detected between the LW and LB hybrids for the foot temperatures measured in the morning. The mean foot temperatures measured in the brown and white hybrids were 37.77 °C and 33.74 °C, respectively. Furthermore, the effect of the hybrid x week interaction was found to be statistically insignificant, and significant differences were determined only for the different weeks.

Table 5. Weekly morning foot temperature in laying hybrids

LB	$\overline{x}$	LW	$\overline{x}$
1	34.63	1	34.69
2	33.80	2	35.03
3	33.56	3	33.84
4	32.00	4	30.59
5	32.54	5	33.74
6	33.21	6	32.00
7	29.90	7	30.70
8	35.38	8	35.20
9	33.54	9	34.67
10	33.63	10	33.35
11	34.58	11	32.94
12	32.45	12	31.48
13	33.65	13	35.70
14	35.96	14	34.10
15	36.29	15	36.04
16	35.26	16	35.94
*SEM	0.87		0.87
Mean	37.77±0.022	Mean	33.74±0.022
**P<			
Hybrid	0.944		
Week	0.001		
Hybrid x Week	0.714		

* Standard error of means, ** Statistical significance.

The morning foot temperatures were observed to be higher in the LB hybrids in comparison to the LW hybrids. In the LB and LW groups, the morning foot temperatures were the highest in week 15 (36.17 °C) and the lowest in week 7 (30.30 °C). The mean value of the morning foot temperatures measured throughout the trial period was determined to be 33.75 C° ± 2.86°C.

The head temperatures measured in the trial groups at noon are presented in Table 6.

Table 6. Weekly afternoon head temperature in laying hybrids

LB	$\overline{x}$	LW	$\overline{x}$
1	38.09[bc]	1	38.89 [ab]
2	38.35 [bc]	2	39.30a
3	37.61 [bc]	3	38.34 [ab]
4	37.49[c]	4	38.48 [ab]
5	37.61 [bc]	5	38.21 [ab]
6	37.69 [bc]	6	38.44 [ab]
7	38.25 [bc]	7	38.64 [ab]
8	39.09a	8	39.03 [ab]
9	37.89 [bc]	9	38.74 [ab]
10	37.80 [bc]	10	38.91 [ab]
11	37.79 [bc]	11	38.45 [ab]
12	35.76[d]	12	33.41[c]
13	37.68 [bc]	13	38.04 [b]
14	35.56 [bc]	14	33.78 [c]
15	37.91 [bc]	15	38.08 [b]
16	37.91 [bc]	16	38.31[ab]
SEM*	0.26		0.26
Mean	37.65±0.06	Mean	37.93±0.06
**P<			
Hybrid	0.002		
Week	0.001		
Hybrid x Week	0.001		

* Standard error of means, ** Statistical significance.

It was ascertained that, the head temperatures measured at midday throughout the trial period showed significant differences between the white and brown hybrid layers (P < 0.002). The highest midday head temperatures were measured in the white hybrids. The mean midday head temperatures of the brown and white hybrid layers were determined as 37.65 °C and 37.93 °C, respectively.

The mean midday head temperatures of the LB and LW groups were highest in week 9 (39.06 °C) and the lowest in week 12 (34.59 °C). The effect of the hybrid x week interaction was significant for the midday head temperatures. The analysis of the midday head temperatures showed that, while the values gradually increased over the weeks in the LW, the values slightly decreased in the LB. The mean value of the midday head temperatures measured throughout the trial period was determined as 37.79 °C ± 1.49 °C.

The midday foot temperatures measured in the LB and LW groups are presented in Table 7.

Table 7. Weekly afternoon foot temperature in laying hybrids

LB	$\overline{x}$	LW	$\overline{x}$
1	37.21[ab]	1	37.06 [a]
2	37.04 [abc]	2	36.23 [a]
3	34.25 [defg]	3	31.87 [a]
4	34.53 [defg]	4	34.57 [a]
5	34.54 [defg]	5	34.76 [a]
6	34.01 [efg]	6	34.79 [a]
7	35.55 [cde]	7	33.01 [a]
8	37.83 [a]	8	37.46 [a]
9	34.71 [defg]	9	35.99 [a]
10	34.81 [defg]	10	22.69[b]
11	33.49 [fg]	11	33.40 [a]
12	32.93 [g]	12	31.42 [a]
13	35.18 [de]	13	33.44 [a]
14	33.18 [g]	14	32.14 [a]
15	35.74 [bcd]	15	35.19 [a]
16	35.04 [def]	16	35.50 [a]
*SEM	1.38		1.38
Mean	35.00±0.34	Mean	33.71±0.34
**P<			
Hybrid	0.011		
Week	0.001		
Hybrid x Week	0.002		

* Standard error of means, ** Statistical significance.

As it may be seen in Table 7, the brown and white hybrid layers displayed highly significant differences for the foot temperatures measured at midday (P<0.01). The mean foot temperatures measured at midday in the brown and white hybrids were 35.00°C and 33.71 °C, respectively.

Similar to the case with the morning foot temperatures, the midday foot temperatures were the highest in the LB hybrids. A general assessment revealed that the head temperatures were higher in the LW hybrids, and the foot temperatures were higher in the LB hybrids. The impacts of the week on the midday foot temperatures and the hybrid x week interaction for the midday foot temperatures were determined to be significant (P < 0.002). The mean value of the midday foot temperatures measured throughout the trial

period was determined as 34.41°C ± 4.51°C.

In this study, regression equations were established for the egg yields of the hybrid layers and their various body temperatures measured at different times of the day. The strongest correlation (r = 0.05) was determined in the regression equation established for the morning head temperature and egg yield of the LW hybrids (Y = 47.06 + 1.26 X).

In order to determine whether or not a significant correlation existed between the morning head temperature and the egg yield in the LB and LW hybrids, an ROC analysis was performed. Accordingly, it was ascertained that the hybrid layers with a morning head temperature of 38.3 °C and above had a relatively higher egg yield, and this difference was found to be statistically significant (Figure 1).
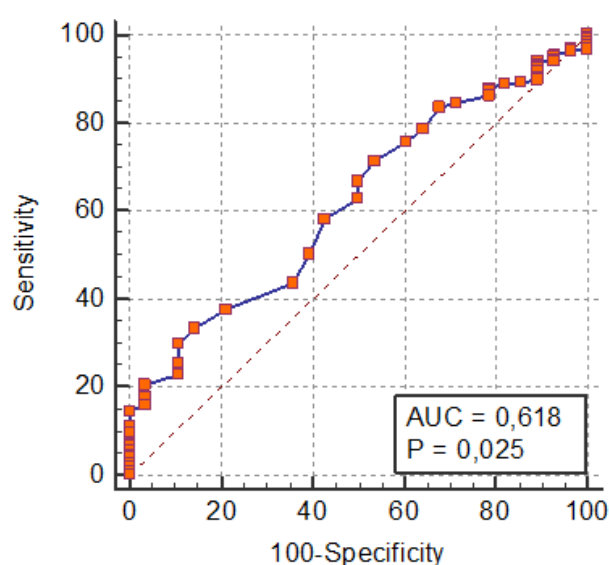
Figure 1. Cutting point corresponding to highest sensitivity and specificity values (morning head temperature-egg yield), AUC= Area under the curve.

The ROC analysis demonstrated that the correlations between the morning foot, midday head and midday foot temperatures and the egg yield were insignificant (P > 0.05). The descriptive statistical data are presented in Table 8.

Table 8. Descriptive statistics of Roc analysis

Descriptive Statistics	MHT	MFT	AHT	AFT
Area under the curve	0.618*	0.544	0.579	0.511
Standard Error	0.053	0.06	0.05	0.05
Confidence limit 95%	0.55-0.68	0.48-0.60	0.51-0.64	0.44-0.57
Z value	2.247	0.752	1.477	0.270

*: P(Area=0.5),
MHT= Morning Head Temperature, MFT= Morning Foot Temperature, AHT= Afternoon Head Temperature AFT= Afternoon Foot Temperature.

Based on the analyses referred to above, it is considered that morning head temperatures would be more useful in determining the correlation between body temperature and egg yield. The greater standard deviation of foot temperatures reduces the precision in determining a correlation between body temperature and egg yield using foot temperature values. Furthermore, it is known that, in hens, conductive heat loss occurs on a higher level in the feet. Moreover, poultry house temperature, and thereby, cage temperature influencing foot temperature may result in the correlation between foot temperature and egg yield being misleading.

Conclusion

In conclusion, it is considered that the morning hours are the best time of the day for measurement of body temperatures intended to be used in establishing a correlation with the production yields of animals.

Acknowledgements

References

Altahat, E., Al-Sharafa, A., and Altarawneh, M., 2012. Factors affecting profitability of layer hens' enterprises. American Journal of Agricultural and Biological Sciences 7(1): 106-113.

Claybaugh, J. H., 1947. EC1490 Seasonal Culling of Growing Stock and Laying Hens. Historical Materials from University of Nebraska-Lincoln Extension 2602. https://digitalcommons.unl.edu/extensionhist/2602

Dudde, A., Krause, E. T., Matthews, L. R., and Schrader, L., 2018. More than eggs - Relationship between productivity and learning in laying hens. Frontiers in Psychology 9: 2000.

Kadono, H., Besch, E. L., and Usami, E., 1981. Body temperature, oviposition, and food intake in the hen during continuous light. Journal of applied Physiology 51(5): 1145-1149.

Leenstra, F., Ten Napel, J., Visscher, J., and Van Sambeek, F., 2016. Layer breeding programmes in changing production environments: a historic perspective. World's Poultry Science Journal 72(1): 21-36.

McCafferty, D. J., Gilbert, C., Paterson, W., Pomero, P. P., Thompson, D., Currie, J. I., and Ancel, A., 2011. Estimating metabolic heat loss in birds and mammals by combining infrared thermography with biophysical modelling. Comparative Biochemistry and Physiology - Part A: Molecular & Integrative Physiology 158: 337–345.

Oleforuh-Okoleh, V. U., 2011. Estimation of genetic parameters and selection for egg production traits in a Nigerian local chicken ecotype. ARPN Journal of Agricultural and Biological Science 6(12): 2006-2009.

SPSS. IBM SPSS statistics for Windows 2010; version 19.0: Armonk, NY: IBM Corp.

Stewart, M., Webster, J. R., Schaefer, A. L., Cook, N. J., and Scott, S. L., 2005. Infrared thermography as a non-invasive tool to study animal welfare. Animal Welfare 14: 319–325.

Thiruvenkadan, A. K., Panneerselvam, S., and Prabakaran, R., 2010. Layer breeding strategies: an overview. World's Poultry Science Journal 66(3): 477-502.