2011

Technical Note: Heat and Moisture Production of W-36 Laying Hens at 24°C to 27°C Temperature Conditions

H. Justin Chepete
Iowa State University

Hongwei Xin
Iowa State University, hxin@iastate.edu

Luciano B. Mendes
Iowa State University

Hong Li
University of Delaware

Technical Note: Heat and Moisture Production of W-36 Laying Hens at 24°C to 27°C Temperature Conditions

Abstract

This study was conducted to quantify heat and moisture production (HMP) of W-36 laying hens in their prime laying phase (27 to 33 weeks of age) using four large-scale indirect animal calorimeters. Two experiments were conducted involving two groups of hens. The hens were exposed to conditions of 24°C to 27°C and concomitant relative humidity (RH) of 45% to 65% for six weeks. In each experiment, a total of 216 laying hens were used, with 54 hens housed in each of the four calorimeters at the cage stocking density of 435 cm2 hen-1 (67 in.2 hen-1) that was typical of industry practice. Total heat production (THP), room-level latent heat production (LHP), and room-level sensible heat production (SHP) were expressed as daily time-weighted average (TWA), with an average of 16 h light and 8 h dark. The results showed that HMP was similar for the 24°C to 27°C temperature range. THP, LHP, and SHP, in W kg-1 (mean ±SE) were, respectively, 6.1 ±0.3, 2.3 ±0.2, and 3.8 ±0.1 for the daily TWA; 6.5 ±0.3, 2.4 ±0.2, and 4.1 ±0.1 for the light period; and 5.4 ±0.3, 2.2 ±0.2, and 3.2 ±0.1 for the dark period. The HMP data contribute to the design and operation of ventilation systems in modern laying hen housing.

Keywords

Heat and moisture production, Indirect calorimeter, Laying hens

Disciplines

Agriculture | Bioresource and Agricultural Engineering

Comments

This article is from *Transactions of the ASABE* 54, no. 4 (2011): 1491–1493.

TECHNICAL NOTE:

HEAT AND MOISTURE PRODUCTION OF W-36 LAYING HENS AT 24°C TO 27°C TEMPERATURE CONDITIONS

H. J. Chepete, H. Xin, L. Mendes, H. Li

ABSTRACT. *This study was conducted to quantify heat and moisture production (HMP) of W-36 laying hens in their prime laying phase (27 to 33 weeks of age) using four large-scale indirect animal calorimeters. Two experiments were conducted involving two groups of hens. The hens were exposed to conditions of 24°C to 27°C and concomitant relative humidity (RH) of 45% to 65% for six weeks. In each experiment, a total of 216 laying hens were used, with 54 hens housed in each of the four calorimeters at the cage stocking density of 435 cm² hen⁻¹ (67 in.² hen⁻¹) that was typical of industry practice. Total heat production (THP), room-level latent heat production (LHP), and room-level sensible heat production (SHP) were expressed as daily time-weighted average (TWA), with an average of 16 h light and 8 h dark. The results showed that HMP was similar for the 24°C to 27°C temperature range. THP, LHP, and SHP, in W kg⁻¹ (mean ±SE) were, respectively, 6.1 ±0.3, 2.3 ±0.2, and 3.8 ±0.1 for the daily TWA; 6.5 ±0.3, 2.4 ±0.2, and 4.1 ±0.1 for the light period; and 5.4 ±0.3, 2.2 ±0.2, and 3.2 ±0.1 for the dark period. The HMP data contribute to the design and operation of ventilation systems in modern laying hen housing.*

Keywords. *Heat and moisture production, Indirect calorimeter, Laying hens.*

Heat and moisture production (HMP) rates of animals and their surroundings are the basis for effective design and operation of environmental control systems for animal production facilities. HMP rates are influenced by animal genetics, nutrition, housing style, equipment, and management practices, all of which have witnessed significant advancement over the years (Reece and Lott, 1982a, 1982b; Gates et al., 1996; Xin et al., 1998). Photoperiod has been shown to have significant impacts on HMP of poultry (Riskowski et al., 1977; Zulovich et al., 1987; Xin et al., 1996). The W-36 laying hen strain is common in U.S. egg production due to its high livability and productive potential (Hy-line, 2009-2011).

Studies have shown that the modern laying hens have higher HMP rates than birds of 20 to 50 years ago (Chepete at al., 2004; Chepete and Xin, 2002). HMP data provide the foundation for proper design, operation, and management of the ventilation system in laying hen houses (Green and Xin, 2009). As such, reliable HMP data that reflect the operational conditions are essential for provision of suitable environmental control components (heating, cooling, and ventilation rate) for the housed birds, and ultimately maximizing productivity of the birds and profitability of the operation.

Submitted for review in September 2010 as manuscript number SE 8780; approved for publication as a Technical Note by the Structures & Environment Division of ASABE in July 2011.

The authors are **Justin H. Chepete, ASABE Member,** Senior Lecturer, Department of Agricultural Engineering and Land Planning, Botswana College of Agriculture, Gaborone, Botswana (former visiting Professor at Iowa State University); **Hongwei Xin, ASABE Fellow,** Professor, and **Luciano Mendes,** former Graduate Research Assistant, Department of Agricultural and Biosystems Engineering, Iowa State University, Ames, Iowa; and **Hong Li, ASABE Member,** Assistant Professor, Department of Bioresources Engineering, University of Delaware, Newark, Delaware. **Corresponding author:** Hongwei Xin, Department of Agricultural and Biosystems Engineering, Iowa State University, Ames, IA; phone: 515-294-4240; fax: 515-294-4250; e-mail: hxin@iastate.edu.

While most of the literature HMP data are for thermoneutral (TN) conditions, commercial poultry barns often encounter a warmer environment during summer. Hence, the objective of this study was to quantify HMP of laying hens in their prime laying phase under environmental conditions typical of commercial production settings. It should be noted that the latent and sensible heat values from this study were for room level (vs. bird level), thereby reflecting the production conditions.

MATERIALS AND METHODS

EXPERIMENTAL CONDITIONS AND HENS

The four indirect animal calorimeters, each measuring 1.5 W × 1.8 D × 1.8 H m, in the Livestock Environment and Animal Physiology (LEAP) Laboratory of Iowa State University were used in the study. Detailed description of the calorimeters system can be found in previous publications (Xin et al., 1996, 1998; Chepete et al., 2004; Green and Xin, 2009). Two experiments were conducted, each involving 216 W-36 laying hens in their prime laying stage at 27 to 33 weeks of age, i.e., six-week measurement period. In both cases, the first week was used for acclimation; hence, the corresponding data were excluded from the final HMP analysis. The hens were exposed to 23.9°C to 25.2°C and 45% to 65% RH in the first experiment and 24.4°C to 27.1°C and 45% to 65% RH in the second experiment. These thermal conditions are typical of commercial production situations. The hens were procured from a commercial laying hen facility in Iowa. Upon arrival at the LEAP laboratory, the birds were divided into four equal groups and randomly allocated to the four chambers, with 54 birds per chamber. Each chamber had a cage rack with nine cages and six hens per cage at an average cage stocking density of 435 cm² (67 in.²) per hen. This cage stocking density was typical of U.S. egg industry production practice. A manure collection pan was placed underneath

  ISSN 2151-0032

each cage. The hens were provided with water and standard commercial laying hen feed *ad libitum*. The lighting regimen was 16 h light and 8 h dark, as used on the commercial farm. At the end of each experiment, the birds were humanely euthanized, as approved by the Iowa State University Institutional Animal Care and Use Committee.

Measured and Calculated Variables

The environment variables measured continuously throughout the measurement period included carbon dioxide (CO_2) and oxygen (O_2) concentrations, ambient temperature, dewpoint temperature, and airflow rate of each chamber. Once a week, 18 hens were sampled from each chamber and weighed to represent the mean body weight of the birds. Manure was removed from each chamber once per week. The data collected in the first 3 d of each week were used in the analysis. This practice was to ensure that the CO_2 produced from manure degradation would be negligible as compared to the amount of respiratory CO_2 production of the hens. From these measured variables, the energetic responses were determined, namely, respiratory quotient (RQ, ratio of CO_2 production to O_2 consumption), total heat production (THP) of the hens, and room-level latent heat production (LHP). The corresponding room-level sensible heat production (SHP) was calculated as the difference between THP and LHP. The detailed calculations for these may be found in the literature (Xin and Harmon, 1996).

Data Handling and Analysis

In each experiment, repeated measurements were taken in each chamber, and each of the four chambers constituted a replication. For each week, data collected during the first 3 d were used in the analysis. Within each day, the HMP data were divided into light (16 h) and dark (8 h) periods as well as expressed as daily time-weighted average (TWA). The HMP data were then analyzed using SAS PROC MIXED (SAS, 2008) for the main effects of experiment, age, and photoperiod. The effects were considered significant at $\alpha = 0.05$.

Quality control and assurance standard operational protocols were followed in data collection (e.g., system and instrument calibration, sufficient time of stabilization between sequential sampling of air from each calorimeter chamber) and data analysis (e.g., data completeness within the 24 h measurement period, flagging of questionable readings) to ensure highest quality and integrity of the results.

Results and Discussion

THP, LHP, SHP, and RQ showed no significant differences ($p = 0.85$, 0.12, 0.11, and 0.13, respectively) between the two experiments. Thus, data from both experiments were pooled and are presented in table 1. The hens did not pant nor show any other sign of heat stress in either experiment, indicating that the conditions were within the TN range of the hens.

The TWA THP values in this study ranged from 5.6 to 6.8 W kg^{-1}, averaging 6.1 ±0.3 W kg^{-1} for hens at 28 to 33 weeks of age. The average value compared well with results from recent studies by Green and Xin (2009) and Chepete et al. (2004), who reported average values of 6.5 W kg^{-1} for hens at 39 to 46 weeks of age under 24°C temperature and 7.0 W kg^{-1} for hens at 37 weeks of age under 24.4°C temperature, respectively. The somewhat lower THP for the current study presumably can be attributed to the warmer temperature, ranging from 24°C to 27°C, and is consistent with findings by Green and Xin (2009), who observed a decrease in THP from 6.5 W kg^{-1} at 24°C to 5.6 W kg^{-1} at 32°C. THP was significantly ($p = 0.0001$) affected by bird age and photoperiod in that it was significantly higher in the light period (6.5 ±0.3 W kg^{-1}) than in the dark period (5.4 ±0.3 W kg^{-1}). This outcome was consistent with the literature reports (Green and Xin, 2009; Chepete et al., 2004; Xin et al., 1996; MacLeod and Jewitt, 1984; Riskowski et al., 1977). The higher THP in the light period was attributed to more physical activities, such as feeding, drinking, pecking, and locomotion, as reported by Boshouwers and Nicaise (1985). In this study, a change from light to dark period resulted in an average THP reduction of 22%, as compared with the literature report of 24% to 35%. When the birds reached 33 weeks of age, the THP values were appreciably higher than those at younger age (table 1). This outcome presumably arose from birds having reached peak egg production and metabolism. Such a trend had been reported by Chepete et al. (2004) to occur during the post-metabolic peak period for W-36 laying hens.

Table 1. Mean heat production rates and respiratory quotient of W-36 laying hens reared at 24°C to 27°C temperature.[a]

Hen Age (weeks)	Body Mass (kg)	Latent Heat Production (W kg^{-1})[b]			Sensible Heat Production (W kg^{-1})[c]			Total Heat Production (W kg^{-1})[d]			Respiratory Quotient[b],[d]		
		Light	Dark	TWA	Light	Dark	TWA	Light	Dark	TWA	Light	Dark	TWA
28	1.46 (0.04)	2.2 (0.2)	1.9 (0.2)	2.0 (0.2)	3.9 (0.1)	2.9 (0.1)	3.6 (0.1)	6.1 (0.3)	4.8 (0.3)	5.6 (0.3)	0.98	1.00	0.98
29	1.46 (0.04)	2.2 (0.2)	2.1 (0.2)	2.2 (0.2)	3.9 (0.1)	3.0 (0.1)	3.6 (0.1)	6.1 (0.3)	5.1 (0.3)	5.8 (0.3)	1.00	0.99	1.00
30	1.45 (0.04)	2.5 (0.2)	2.3 (0.2)	2.4 (0.2)	4.0 (0.1)	3.2 (0.1)	3.7 (0.1)	6.5 (0.3)	5.5 (0.3)	6.2 (0.3)	0.98	0.97	0.98
31	1.45 (0.05)	2.6 (0.2)	2.5 (0.2)	2.5 (0.2)	4.2 (0.1)	3.1 (0.1)	3.8 (0.1)	6.8 (0.3)	5.6 (0.3)	6.4 (0.3)	1.00	1.00	1.00
33	1.44 (0.05)	2.5 (0.2)	2.2 (0.2)	2.3 (0.2)	4.7 (0.1)	3.7 (0.1)	4.4 (0.1)	7.2 (0.3)	5.9 (0.3)	6.8 (0.3)	1.02	1.03	1.02

[a] Results are averages of two experiments with a total of four chambers used per experiment. TWA = time-weighted average. Numbers in parentheses are standard errors of the means (SEM).
[b] The difference between light and dark values was not significant ($p = 0.78$ to 0.92).
[c] The difference between light and dark values was significant ($p = 0.0001$).
[d] SEM = 0.02. Moisture production (MP, g kg^{-1} h^{-1}) = $3600 \times LHP/h_{fg}$, where h_{fg} is latent heat of vaporization (kJ kg^{-1}) evaluated at the mean temperature between T_a and core body temperature of the hen (41°C).

The room LHP values were higher in the light period than in the dark period, although the differences were not significant ($p = 0.92$). LHP magnitude is influenced by the sources of moisture within a room, such as the amount of manure accumulation, manure moisture content, and possible water leakage from drinkers. The TWA LHP ranged from 2.0 to 2.5, averaging 2.3 ±0.2 W kg^{-1}. The studies by Green and Xin (2009) and Chepete et al. (2004) reported room-level LHP of 3.5 W kg^{-1} (39 to 46 week old hens) and 3.3 W kg^{-1} (37 week old hens). The lower room-level LHP for the current study, as compared to the previous studies, could have been caused by differences in the amount of accumulated manure in the manure pan, moisture content in the manure, and possible leakage of drinking water. Expressed as a percentage of THP, LHP ranged from 35% to 40%, averaging 38%. Chepete et al. (2004) reported a range of 29% to 55%, averaging 45% for laying hens at 21 to 64 weeks of age housed at 24°C. Moisture production (MP, g kg^{-1} h^{-1}) may be derived from the LHP using the relationship shown in table 1.

The SHP was 4.1 ±0.1W kg^{-1} during the light period and significantly decreased to 3.2 ±0.1 W kg^{-1} (a 28% reduction) during the dark period ($p = 0.0001$). This reduction was presumably caused by the reduced physical activities of the hens during the dark period. The magnitude of reduction was consistent with the literature values (Riskowski et al., 1977; Feddes et al., 1985; Li et al., 1991; Xin et al., 1996). The TWA SHP in the current study ranged from 3.6 to 4.4, averaging 3.8 ±0.1 W kg^{-1}. Green and Xin (2009) and Chepete et al. (2004) reported average room SHP of 3.1 W kg^{-1} for 39 to 46 week old hens and 3.7 W kg^{-1} for 37 week old W36 hens, respectively. The authors also reported 11% to 15% SHP reduction when switching from light to dark.

The TWA RQ ranged from 0.98 to 1.02, averaging 1.00 ±0.02, whereas it averaged 1.00 ±0.02 and 0.99 ±0.02 W kg^{-1} during the light and dark periods, respectively. The light and dark period values were not significantly different ($p = 0.78$). The RQ values suggest that the birds were well fed and used carbohydrates as their main source of energy (Sturkie, 1954; Mori, 1968). RQ for laying hens under TN conditions have been reported to be 0.91 (Chepete et al., 2004) and 0.92 (Ketelaars et al., 1985).

Conclusions

Total heat production rate (THP), room-level latent heat production rate (LHP), and room-level sensible heat production rate (SHP) of W-36 laying hens (28 to 33 weeks of age) under 24°C to 27°C temperature conditions were quantified. The conclusions and highlights of the study are as follows:

- The laying hens showed similar heat production responses for the temperature range, indicating that 24°C to 27°C is within the thermoneutality of the birds.
- Daily THP, LHP, and SHP, in W kg^{-1} (mean ±SE) were 6.1 ±0.3, 2.3 ±0.2, and 3.8 ±0.1, respectively. THP and SHP during the light hours of the day were significantly (17% to 22%) higher than during the dark hours of the day (6.5 vs. 5.4 W kg^{-1} THP; 4.1 vs. 3.2 ±0.1 W kg^{-1} SHP).
- Results from this study confirm and complement existing literature data on heat and moisture production rates of laying hens that may be used in the design and operation of ventilation systems for modern laying hen housing.

Acknowledgements

Funding for the study was provided by the Iowa Egg Council and is acknowledged with gratitude.

References

Boshouwers, F. M. G., and E. Nicaise. 1985. Automatic gravimetric calorimeter with simultaneous recording of physical activity for poultry. *British Poultry Sci.* 26(4): 531-541.

Chepete, H. J., and Xin. H. 2002. Heat and moisture production of poultry and their housing systems: Literature review. *Trans. ASHRAE* 108: 448-446.

Chepete, H. J., H. Xin, M. C. Puma, and R. S. Gates. 2004. Heat and moisture production of poultry and their housing systems: Pullets and Layers. *Trans. ASHRAE* 110: 286-299.

Feddes, J. J. R., J. B. McQuitty, and P. C. Clark. 1985. Laying hen and moisture production under commercial conditions. *Canadian Agric. Eng.* 27(1): 21-29.

Gates, R. S., D. G. Overhults, and S. H. Zhang. 1996. Minimum ventilation for modern broiler facilities. *Trans. ASAE* 39(3): 1135-1144.

Green, A. R., and H. Xin. 2009. Effects of stocking density and group size on heat and moisture production of laying hens under thermoneutral and heat-challenging conditions. *Trans. ASABE* 52(6): 2027-2032.

Hy-line. 2009-2011. Hy-line W-36 commercial management guide. Dallas Center, Iowa: Hy-line International.

Ketelaars, E. H., A. Arets, W. van der Hel, A. J. Wilbrink, and M. W. A. Verstegen. 1985. Effect of housing system on the energy balance of laying hens. *Netherlands J. Agric. Sci.* 33: 35-43.

Li, Y., T. Ito, and S. Yamamoto. 1991. Diurnal variation in heat production related to some physical activities in laying hens. *British Poultry Sci.* 32(4): 821-827.

MacLeod, M. G., and T. R. Jewitt. 1984. Circadian variation in the heat production rate of the domestic fowl, *Gallus domesticus*: Effects of limiting feeding to a single daily meal. *Comparative Biochem. and Physiol.* 78A(4): 687-690.

Mori, K. 1968. Changes of oxygen consumption and respiratory quotient in tissues the tissues of oysters during the stages of sexual maturation and spawning. *Tohoku J. Agric. Res.* 19(2): 136-143.

Reece, F. N., and B. D. Lott. 1982a. Heat and moisture production of broiler chickens during brooding. *Poultry Sci.* 61(3): 661-666.

Reece, F. N., and B. D. Lott. 1982b. The effect of environmental temperature on sensible and latent heat production of broiler chickens. *Poultry Sci.* 61(8): 1590-1593.

Riskowski, G. L., J. A. DeShazer, and F. B. Mather. 1977. Heat losses of White Leghorn laying hens as affected by intermittent lighting schedules. *Trans. ASAE* 20(4): 727-731.

SAS. 2008. *SAS User's Guide: Statistics.* Ver. 9.2. Cary, N.C.: SAS Institute, Inc.

Sturkie, P. D. 1954. *Avian Physiology.* Ithaca, N.Y.: Comstock Publishing Associates.

Xin, H., and J. D. Harmon. 1996. Responses of group-housed neonatal chicks to posthatch holding environment. *Trans. ASAE* 39(6): 2249-2254.

Xin, H., J. L. Sell, and D. U. Ahn. 1996. Effects of light and darkness on heat and moisture production of broilers. *Trans. ASAE* 39(6): 2255-2258.

Xin, H., H. J. Chepete, J. Shao, and J. L. Sell. 1998. Heat and moisture production and minimum ventilation requirements of tom turkeys during brooding-growing period. *Trans. ASAE* 41(5): 1489-1498.

Zulovich, J. M., H. B. Manbeck, and W. B. Roush. 1987. Whole-house heat and moisture production of young floor brooded layer pullets. *Trans. ASAE* 30(2): 455-458.