Heat and moisture production in pullet barns

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Glennon, C. R., McQuitty, J. B., Clark, P. C. and Feddes, J. J. R. 1989. **Heat and moisture production in pullet barns.** Can. Agric. Eng. **31**: 227–232. Two commercial barns for rearing pullets for egg production were monitored for 24-h periods during each month of the 18- to 20-wk rearing cycle to ascertain heat and moisture loads within these facilities. One barn was representative of the cage-rearing system and the other of on-floor rearing. Total heat production of the White Leghorn type pullets ranged from 2.3 to 30.5 kJ/(h.bird) over the rearing cycle, while the non-bird latent heat production ranged from 0.6 to 6.4 kJ/(h.bird). Approximately two-thirds of the total heat loss by ventilation was in sensible heat form. The conversion of sensible to latent heat in evaporation of moisture ranged from 12 to 38% of bird sensible heat production over the rearing cycle.

INTRODUCTION

Poultry heat and moisture production data for engineering design purposes are given in a number of widely-used references, including the Associate Committee on the National Building Code (1977), the American Society of Agricultural Engineers (ASAE) Yearbook of Standards (1988) and the Midwest Plan Service Structures and Environment Handbook (1983). These sources, however, do not include data for birds reared for egg production. In addition, there are sufficient differences in bird type and housing and management practices to make extrapolations of existing broiler and layer data, many of which are based on direct or indirect calorimetry, highly questionable for use as criteria in designing environmental control systems in poultry rearing units.

Accordingly, a study was undertaken, the results of which are reported here, to ascertain heat and moisture production rates in two commercial poultry rearing barns over the 18- to 20-wk rearing period. Floor- and cage-rearing systems are both utilized in Alberta, and for comparative purposes, a barn representative of each system was studied.

EXPERIMENTAL FACILITIES

The two pullet barns were selected for monitoring on the basis of feasibility of instrumentation, accessibility, and co-operation of the farmers. The study was conducted during the cool/cold period extending from 23 Sept. 1983 to 13 Apr. 1984. Barns A and B were located within 100 km from Edmonton. Table I lists the management data relevant to the two barns.

Barn A was a double-storey, on-floor pullet unit (Fig. 1). Initially, 5825 d-old chicks were placed in the upper level, with over half of the birds being moved to the lower floor after 6 wk. Only the upper storey of the barn was monitored, since it was representative of a pullet-rearing cycle. The chicks were placed on fresh litter composed of short straw with the litter accumulating throughout the rearing cycle.

Barn B, a single-storey unit (Fig. 2), utilized six rows of double-deck rearing cages. Initially, 14 000 chicks were placed in the lower level of cages. After 6 wk, they were divided evenly among both decks. The droppings accumulated below the cages in shallow concrete pits, 150 to 200 mm in depth, which were scraped mechanically every 10 wk.

Table I. Summary of management data for the two barns

	Barn A	Barn B
Number of birds start/finish	5800/2300†	14 000/13 580
% mortality	8.3	3.0
Strain of birds	HY-Line W-77	Shaver S288
Size of cage (cm^2)	NA	91 × 61
Cage area per bird (cm^2/bird)	NA	24 (450)‡
Bird density (birds/m^2 floor area)‡	24	27
Building construction	Wood-frame Metal roof	Wood-frame Metal roof
Building dimensions (m)	6 × 40 × 2.3	9 × 50 × 2.4
Building exposure factor (kJ/(h.°C.bird)) (18 wk)	0.12	0.13
Waterer type	Fountain waterers	Low-pressure cups
Ration type	Wheat-based	Wheat-based
Protein content (%)	16 - 20	16 - 19
Feed energy (MJ/kg ME)	12.8	11.7
Feeder type	Chain-in-trough	Chain-in-trough
Feedings per day	7	2
Feeder period (min)	5	15
Lighting type	Incandescent	Incandescent
Lights on/off, time	0700/1800	0700/1800
Hours of light	11	11

†3000 birds removed after 6 wk to reduce density.
‡After 6 wk.

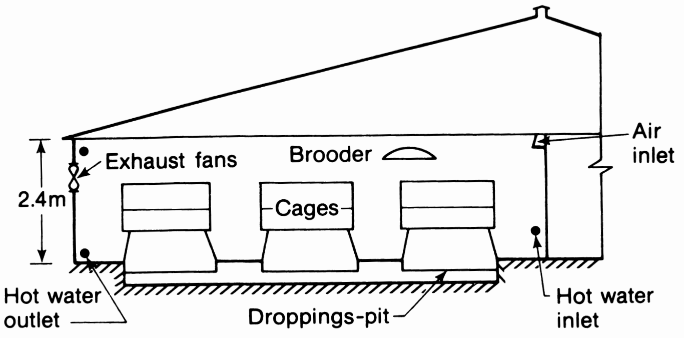

Figure 1. Schematic elevation of on-floor pullet rearing unit (Barn A).

Both rearing barns used exhaust ventilation systems, with all fans being located on one side of each barn. Fresh air was introduced directly into Barn A through an intermittent, slotted, air inlet located under the eaves on the same side of the barn

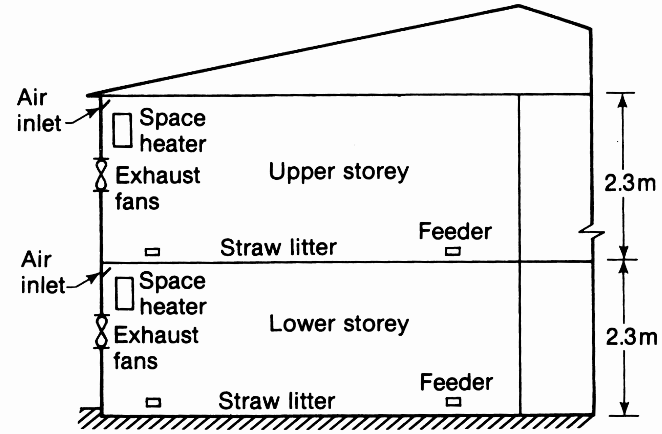

Figure 2. Schematic elevation of caged pullet rearing unit (Barn B).

as the exhaust fans (Fig. 1). In Barn B, fresh air was drawn into the attic via roof vents, and then into the barn through a continuous-slot, air inlet situated along the opposite wall of the room from the exhaust fans (Fig. 2). This inlet was covered with a burlap hanger that directed the air towards the floor.

In Barn A, three variable-speed, 510-mm-diameter fans were spaced equally along the length of the building. Two of the variable-speed control units, nearest to the south wall, were operated by the same thermostatic controller. The third fan in this unit was operated by a separate controller. All three fans were located 1.7 m above floor level, while all utilized anti-back draft louvers. Ventilation in Barn B ws provided by four, 510-mm-diameter, two-speed fans spaced equally along the length of the barn. The fans, shrouded on the outside, were located 1.7 m above floor level, each operated by a separate thermostatic controller.

Both barns utilized black-steel pipe for circulating hot water as a source of supplemental heat. In Barn A, hot water was circulated through one loop of 51-m internal diameter, white-painted, steel pipe mounted 200 mm from the ceiling along the exposed length of the building. A fan-operated space heater was incorporated within the hot-water loop to provide additional heating. Clear spacings between the pipes and between the pipes and the wall were 75 mm and 160 mm, respectively, the total length of pipe being 50 m. In Barn B, a 67-mm internal diameter, black-steel pipe was situated along the perimeter of the room, mounted 600 mm and 60 mm from the floor and wall, respectively (Fig. 2). The total length of the pipe was 128 m. The hot-water boiler in each barn was controlled by a single thermostat. In addition to hot-water heating, Barn B utilized four natural-gas-fired brooders, mounted 300 mm from the ceiling (Fig. 2), to maintain a comfortable thermal environment during the first week of the rearing cycle.

Table I summarizes the management data for the two barns, including the number of birds housed and stocking densities. The pullets in Barns A and B were fed a commercial wheat-based ration (16-20% protein) with a metabolizable energy content of 12.8 and 11.7 MJ/kg, respectively. The operator in Barn B weighed some of the pullets at random, at regular intervals, to determine if the weights of the birds were close to the target weights specified by the Shaver Commercial Management Guide (1982), and adjusted the quantity of feed to attain the birds' target weights. The operator in Barn A relied solely on the commercial feed producer to provide the required ration. Lighting was provided between 07:00 h and 18:00 h in both barns.

EXPERIMENTAL METHODOLOGY

The equipment utilized in this study to monitor continuously the components for the heat and moisture balance in both units was the data acquisition system developed by Feddes and McQuitty (1977), and adequately described by Feddes et al. (1984, 1985). Each barn was divided into six sections, thirds by length and halves by width, and temperature data were collected from the center of each section, with a high and low level temperature measured at the three center sections. The temperature of the sections closest to each fan were representative of the air being exhausted. Dewpoints were measured at each fan location and at an additional two ambient locations. Hand-held instruments were utilized to check all electronic psychrometric readings for accuracy and to ensure that each sensor location was representative of conditions in that area. A summary of the primary sensors, their locations, and scanning rate, for the two barns is given in Table II.

The exhaust ventilation fans were assumed to introduce all of the exchange air to each barn. Air flow through each operating fan was measured indirectly by monitoring, on a 4-min basis, the output from Hall-effect switches activated by magnets mounted on the fan shafts. These shaft speeds were related to air-flow rate from a shaft speed fan output curve established for the duration of the study. Air flow rates were measured twice during each sampling day in insulated discharge ducts located downstream from each fan. These ducts were constructed to the recommendation set out by Jorgenson (1983). Fan air-flow rates were calculated as the product of the mean air velocity and the duct area. Mean air velocity was determined in each discharge duct with a manual 25-point profile using a thermistor anemometer (Kurtz Instruments, Redlands, CA). The anemometer was calibrated in a small-scale, air-velocity

Table II. A summary of primary sensors, their locations and scanning rate, for the two barns monitored

Sensor type, sensor location and sampling rate	Number of locations	
	Barn A on-floor	Barn B cages
Thermistor: 3 readings/h		
Outside	1	1
Inlet	1	3
High (elevation, m)	3 1.5	4 1.8
Ambient (elevation, m)	9 1.5	8 0.9
Wet-bulb	1	1
Total	15	17
Heat-flux plates: 3 readings/h		
Ceiling	1	1
Floor	0	1
Walls	4	4
Total	5	6
Thermistors: 15 readings/h		
Duct temperatures	3	0
Hot water	2	2
Total	5	2
Sequential dewpoint: 2 readings/h		
Exhaust	3	4
Ambient	2	2
Outside	1	1
Pressure differential, 4-min	1	1
Fan rpm, 4-min	3	4
Water consumption: daily readings	1	1
Doppler flow meter: daily readings	1	1

calibrator (Department of Mechanical Engineering, University of Alberta, Edmonton, AB). During the entire study period, inlet position remained unchanged.

All mean daily ventilation rates were checked with carbon dioxide (CO_2) production and concentration data. Concentrations of CO_2 were measured at the inlet and at the exhaust locations from the same sample the dewpoint was measured. A non-dispersive infrared gas analyzer was used for this purpose (Model 315A, Beckman, Fullerton, CA). The rate of CO_2 production is a function of feed intake and metabolic activity. Carbon dioxide production rates were estimated from the metabolizable feed intake and a respiratory quotient (RQ) value of 1.0 (Feddes and DeShazer 1988). For this RQ value, Brody (1945) suggested that 21.1 L of CO_2 are produced per MJ of metabolizable energy. Feed intake was obtained from the commercial management guides for each strain of pullet (Summers and Leeson 1985).

The ventilation rates calculated from the CO_2 data agreed with those measured in Barn B. However for Barn A, there were substantial discrepancies in that the measured ventilation rates were about 50% of those estimated from the CO_2 data. When using the estimated ventilation rates, the calculated heat production of the birds was similar to that in Barn B. The measured air flow rates in the discharge ducts for Barn A were found to be very low. At times all three fans were operating at minimum, such that the shaft speed-fan output relationships became too inaccurate. The total ventilation rate ranged between 430 and 850 L/s. The minimum suggested fan output for this type of fan is about 600 L/s (Prairie Agricultural Machinery Institute 1984). This indicated that the fans were operating outside their recommended performance range.

Heat-flux plates (DeShazer et al. 1982) were used to measure the conductive heat losses from representative structural components of each building. Temperature data and the known thermal characteristics of the building components were used to check the plate outputs. Surface temperatures obtained with an infrared pyrometer, and heat flux measured with a commercial heat-flow meter (Concept Engineering, Old Saybrook, CO) also were used to check the plate outputs.

Supplemental heat in each barn was derived from water-temperature differentials between the inlet and outlet of the black-steel pipe and water flow-rate. Thermistors were placed on the inlet and outlet pipes inside the barn and wrapped in thermal insulation in order to measure the water temperatures. The thermal mass of the heating system was accounted for in the derivation. The flow rate of heating water within these pipes was measured with an ultrasonic Doppler flow-meter (Polysonics Flowmeter, Houston, TX). In Barn B, thermistors were placed directly over the brooders, to indicate if the brooders were on or off during the first monitoring period. The heating capacity of these brooders was determined by measuring the rate of gas use with a commercial gas meter (Branchard Engineering Ltd., Edmonton, AB) and obtaining the energy content of the gas from the local supplier.

Water consumption was measured on a daily basis by a water meter (Neptune Meters, Toronto, ON). Pressure differential across the shell of the building was also measured. A summary of operating data for Barns A and B are given in Tables III and IV, respectively.

Data recording and processing

The conditioned output signals from each instrument were read by a micro-processor-controlled data logger located in a mobile laboratory and recorded on a paper-tape punch throughout each monitoring period. Using a computer program developed within the Department of Agricultural Engineering, the data were converted into engineering units and processed such that each component of the building heat balance was calculated on an hourly basis.

Ambient conditions during monitoring

Temperature data from this study were compared to recommended temperatures from the Hy-Line W-77 Commercial Management Guide (1982), and the Shaver S288 Commercial Management Guide (1982) for pullets in Barns A and B, respectively. Recommendations for Barn A were an initial temperature 30-32°C and a reduction of 3°C every week until 21°C was reached. Barn B was to start at 28-31°C and reduce 3°C

Table III. Summary of operating data for the five sampling days for barn A (on-floor unit)

	Sample				
	1	2	3	4	5
Number of birds	5752	5733	2447	2397	2365
Age of birds (d)	10	36	61	90	118
Bird target weight (g)†	85	320	620	1020	1270
Ambient RH (%)	36.5	53.7	59.6	51.4	63.8
(range)	(28/45)	(35/68)	(50/78)	(33/75)	(56/79)
Temperature (°C)					
Ambient	28.5	18.3	17.2	15.4	10.5
(range)	(26/32)	(17/21)	(15/20)	(14/19)	(7/14)
High level	29.6	19.4	18.1	16.7	11.0
(range)	(26/33)	(17/23)	(16/21)	(14/20)	(7/14)
Low level	28.2	17.9	16.8	14.9	10.3
(range)	(25/32)	(16/21)	(14/20)	(13/18)	(6/14)
Inlet	13.8	8.3	1.6	−15.9	−8.3
(range)	(7/24)	(2/20)	(−1/8)	(−11/-20)	(−6/-10)
Static pressure differential (Pa)	7	13	7	5	4
Water consumption (mL/(h.bird))	0.2	2.3	2.1	1.7	NA
Time of feeding	0700, 0745, 0900, 1000, 1130, 1345, 1530				

†From Hy-line Commercial Management Guide (1982).

Table IV. Summary of operating data for the six sampling days for barn (cage unit)

	Run number					
	1	2	3	4	5	6
Number of birds	13 776	13 668	13 643	13 616	13 596	13 580
Age of birds (d)	6	35	63	93	113	134
Bird target weight (g)†	80	440	670	910	1080	1250
Ambient RH (%)	43.0	46.0	41.0	45.6	47.9	38.7
(range)	(32/65)	(34/56)	(26/63)	(28/67)	(28/67)	(18/58)
Temperature (°C)						
Ambient	24.4	22.4	20.3	17.1	16.4	18.6
(range)	(23/26)	(21/24)	(18/23)	(15/20)	(14/23)	(13/25)
High level	24.4	22.7	19.9	16.6	16.9	19.2
(range)	(23/26)	(22/24)	(17/23)	(15/20)	(15/23)	(19/25)
Low level	24.2	22.0	19.8	16.3	16.4	18.3
(range)	(23/25)	(21/23)	(17/23)	(15/19)	(14/23)	(14/25)
Inlet	−4.6	3.1	3.9	1.4	3.2	6.7
(range)	(−9/-4)	(−1/5)	(−1/7)	(−2/3)	(−1/9)	(−3/13)
Static pressure differential (Pa)	31	1	3	2	5	6
Date of manure removal	28 Nov.		24 Jan.		21 Mar	
Water consumption (ml/(h.bird))	1.3	3.1	18.0‡	7.0	6.5	9.8
Time of feeding			0830	1430		

†From Shaver Commercial Management Guide (1982).
‡Excessive leakage of waterers.

every week until 15°C was reached. The ambient temperature in both barns was controlled 30-32°C when the chicks were introduced at the start of the rearing cycle. Over the production period, the ambient temperature was reduced to a satisfactory 18°C in Barn B, while in Barn A the temperature was variable and averaged 11°C during the last run (Tables III and IV). Mean hourly temperatures dropped as low as 7°C in Barn A and 13°C in Barn B.

Temperature stratification was an indication of poor air mixing in Barn A. The difference in temperature between the low and high level temperatures averaged almost 1.5°C in Barn A, while, in Barn B, the temperature varied less than 0.5°C. The pressure differentials across the inlets were acceptable in only the first run of Barn B (Table IV). Pressure differentials were as low as 3.9 Pa in Barn A and 1.0 Pa in Barn B, again an indication of poor air mixing.

The recommended inside relative humidities for pullet facilities are a minimum of 50% and a maximum of 75% (Canadian Code for Farm Buildings 1977; ASAE 1988). The measured relative humidities were found to have a mean value of 53% for Barn A and 44% for Barn B. The relative humidity values for each sampling run in Barn B (Table IV) were below the maximum of 80% recommended by Winchell (1982), suggesting that the ventilation rate could have been reduced for humidity control but perhaps at the expense of a decrease in air quality. The relative humidities measured in Barn A (Table III) were above the minimum recommended values throughout the rearing cycle, except for the first sampling day.

RESULTS AND DISCUSSION

Heat losses from the barns were those resulting from air exchange and conductive heat flow through the shell of the building. These losses were offset by the supplemental heating system, some miscellaneous heat sources, including lighting, and the heat output of the birds, which was not measured directly. The latent heat measured in the exchange air included both the latent heat produced by the birds and latent heat converted from sensible heat evaporation of wet surfaces.

Heat balance

The daily mean values for each sampling run over the rearing cycle for ventilation rates, heat losses and heat gains are tabulated in Table V for both barns. The heat lost by ventilation averaged over 90% of the total heat losses and was subject to significant variation as a result of varying ventilation rates.

Supplemental heating (Table V) was required in Barn B for the first week of production only, while in Barn A, supplemental heating was required for up to 14 wk due to colder outside temperatures. The highest supplemental heat requirement was 8.4 kJ/(h.bird), in Barn B, when the birds were in their first week of the growth cycle and when their total heat production was at a minimum.

Table V. Daily mean ventilation and heat balance data for each sampling day during pullet rearing in barns A and B

Bird age (d)	Ventilation rate (L/(s.bird))	Heat balance terms (kJ/(h.bird))			
		Vent	Building	Supplemental	Bird
Barn A					
10	0.08	9.4	0.7	3.0	7.1
36	0.15	10.8	0.5	1.0	10.3
61	0.20	23.5	1.4	1.2	23.7
90	0.18	34.0	3.1	2.4	34.7
118	0.24	30.4	1.9	0.0	32.3
Barn B					
6	0.05	8.6	2.1	8.4	2.3
35	0.09	11.7	1.6	0.0	13.3
63	0.19	17.8	1.4	0.0	19.2
93	0.33	26.0	1.2	0.0	27.2
113	0.36	26.6	1.1	0.0	27.7
134	0.42	29.4	1.1	0.0	30.5

The daily total heat production rates (Table V) increased throughout the production cycle from 2.3 to 30.5 kJ/(h.bird), (6-134 d) in Barn B and 7.1 and 32.3 kJ/(h.bird), (10-118 d) in Barn A. A plot of heat production vs. time indicates the similarity between the birds in Barns A and B. The figure of 34.7 kJ/(h.bird) for Barn A appeared to be an outlier value. Heat production data have been reported by Ota and McNally (1961), DeShazer et al. (1969, 1970), Olson et al. (1974), Riskowski et al. (1977), and Feddes et al. (1985), using both calorimetric and commercial studies of laying hens with which to compare the results of this study. The data obtained in this study appear to be in line with previous studies of mature layers of similar type when compared on a bodyweight basis (Tables III and IV).

Metabolic rate and bird total heat production undergo diurnal fluctuations, attributed to the fact that birds are sitting or inactive at night with a 20–40% lower heat output (DeShazer et al. 1970). The overall mean reduction in bird total heat production from day to night was found to be 16 and 27% for Barns A and B, respectively (Table VI). The difference in reduction between the two barns may be due, in part, to the greater huddling capability of the birds in Barn A as observed. The mean reduction of 27% found in Barn B compared reasonably well with the data of Riskowski et al. (1977) who reported a reduction of 22% for layers on a 14-h lighting schedule. Feddes et al. (1985) found a mean reduction of 17% for caged layers in three barns under winter conditions. Bird densities, lighting schedule, and feed intake varied in these studies.

An equation that best describes the relationship between bird age and total heat production for growing pullets is as follows:

$$Y = 0.82\, X^{0.76} \qquad (R^2 = 0.94) \tag{1}$$

where Y = total heat production (kJ/(h.bird)) and X = age of the birds (wk).

One of the values for Barn A was considered to be an outlier and was not included in the determination of Eq. 1.

Bird sensible and latent heat

The amount of moisture removed by ventilation comprised the total moisture released by the birds through respiration and by evaporation from the litter/stored droppings and wet surface areas. The daily mean moisture production rates exposed as latent heat ranged from 3.6 to 9.7 kJ(h.bird) (10-118 d), and from 1.1 to 10.0 kJ/(h.bird) (6-134 d) for Barns A and B, respectively.

On a bodyweight basis, the moisture production rate was 4.7 and 3.2 g/(h.kg) in Barns A and B, respectively, excluding the first data point from Barn B when the birds were of little weight. These values were between the mean 6.53 g/(h.kg) reported for broiler chicks of the same age by Longhouse et al. (1968), Deaton et al. (1969) and Feddes et al. (1984) and 2.05 g/(h.kg) for mature layers reported by DeShazer et al. (1969), Olson et al. (1974), Riskoswki et al. (1977), and Feddes et al. (1985).

In general, the moisture load in Barn A was higher than in Barn B. Except for two sampling days in Barn B, non-bird moisture production was greater than 3 kJ/(h.bird) whereas in Barn A the moisture production increased over the rearing cycle, yielding an average value of 4 kJ/(h.bird).

The ratio of latent heat removed by ventilation to the total heat removed remained relatively constant for both barns. These values ranged from 0.38 to 0.16 and from 0.33 and 0.15, respectively (Table VII). These means fall midway between the ratio of 0.49 reported by Feddes et al. (1984) for broilers under winter conditions and 0.26 for mature layers (Feddes et al. 1985). Thus, approximately two-thirds of the total heat loss by ventilation was in sensible heat form.

Table VI. Summary of heat balance data during day and night for the two barns — overall mean measured values

	Barn A		Barn B	
	Day	Night	Day	Night
Ventilation heat loss (kJ/(h.bird))	23.9	19.3	23.5	17.2
Bird total heat gain (kJ/(h.bird))	22.5	18.9	23.5	17.2
Percentage reduction day to night (%)	16		27	
Supplemental heat (kJ/(h.bird))	2.2	1.6	1.5	1.4

Table VII. Total, latent and sensible heat production of the pullets in barns A and B

Bird age (d)	Total heat	Sensible heat	Total latent	Bird latent†	Building latent	Total latent/ total heat	Sensible heat converted (%)
	kJ/(h.bird)						
Barn A							
10	7.1	3.5	3.6	1.5	2.1	0.51	38
36	10.3	6.0	4.3	2.0	2.3	0.42	28
61	23.7	14.3	9.4	3.0	6.4	0.40	31
90	34.7	25.0	9.7	4.5	5.2	0.28	17
118	32.3	22.6	9.7	5.5	4.2	0.30	16
Barn B							
6	2.3	1.2	1.1	0.5	0.6	0.48	33
35	13.3	7.9	5.4	2.0	3.4	0.41	30
63	19.2	12.3	6.9	3.3	3.6	0.36	23
93	27.2	19.0	8.2	4.5	3.7	0.30	16
113	27.7	19.5	8.2	5.5	2.7	0.30	12
134	30.5	20.5	10.0	6.4	3.6	0.33	15

†Estimated from calorimetric data (DeShazer et al. 1970; van Kampen 1976; Longhouse et al. 1968)

The building total, latent and sensible heat production measured in Barns A and B for each run are given in Table VII. The sensible heat production ranged from 3.5 to 22.6 kJ/(h.bird) (10-118 d) and from 1.2 to 20.5 kJ/(h.bird) (6-134 d) for Barns A and B, respectively. The building sensible heat produced increased with bird age and was influenced by ambient temperatures and relative humidity in both barns.

To estimate the moisture evaporated from within the building, calorimetric moisture production data of DeShazer et al. (1970) and Van Kampen (1976) for laying birds, and of Longhouse et al. (1968) for broilers, were used. The values found by these authors, based on bodyweight, were averaged to a value of 4.9 kJ/(h.kg), adjusted for bird weight, and termed as bird latent heat. The bird latent heat was subtracted from the measured total latent heat to give an approximation of the amount of sensible heat conversion that had occurred (Table VII). The conversion ranged from 38 to 16% (10-118 d) and 33 to 15% (6–134 d) for Barns A and B, respectively, and decreased with increasing bird age and decreasing ambient temperature for both barns. The percentage of bird sensible heat converted to building latent heat averaged 26 and 22 for Barns A and B, respectively.

Feddes et al. (1984), 1985) determined that the percentage of bird sensible heat converted to latent heat in broiler and layer barns averaged 42 and 7%, respectively, with the differences due in large part to differences in temperature and ambient vapor pressures.

SUMMARY AND CONCLUSIONS

Based on the results obtained in this study, the following summary of results and related conclusions were drawn.

1. Total heat production of the pullets agreed with heat production for mature layers of similar type, ranging from 2.3 to 30.5 kJ/(h.bird) over the production cycle.
2. Pullet total heat production can be described as a power function of bird age (Eq. 1) ($R^2 = 0.94$).
3. Total heat production underwent diurnal changes with a 16 and 27% reduction at night in the on-floor and cage system, respectively.
4. Latent heat represented 37% of the total heat production in the barns studied.
5. Mean moisture production rates were 4.0 and 2.9 kJ/(h.bird) for on-floor and cage system, respectively. The production rates for the on-floor system increased over the rearing cycle while the rates for the cage system were constant.
6. The mean percentage conversion of bird sensible to latent heat was 26 and 22 in the on-floor and cage system, respectively.
7. Exhaust air removed in excess of 90% of the total heat losses from both barns, with significant variation due to diurnal fluctuations and management differences.

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