Effects of ambient temperature, plumage condition, and housing system on energy partitioning and performance in laying hens, thereby predicting energy intake

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Abstract

Environmental factors, e.g. temperature (T), feather cover (FC), and housing system (HS) affect energy requirements of laying hens. Interaction effects of T (11°C, 16°C, 21°C), FC (100% vs. 50%) and HS (cage vs. floor) on energy partitioning and performance of laying hens were investigated. Six batches of 70 brown layers per batch were applied. Heat production (HP) was determined by indirect calorimetry.
ME-intake increased by 1% for each degree reduction in T. HP was not affected by T in hens with 100% FC, whereas in hens with 50% FC HP linearly increased if T decreased. In floor housing, HP at 16°C and 11°C was 5.8% and 3.0% higher, respectively, than in cages. NE for production (NE_p) was 25.7% higher in cages compared to floor housing. In cages, 24.7% of NE_p was spent on body fat deposition, whereas in floor housing 9.0% of NE_p was released from body fat reserves. ME-intake (kJ/d) was predicted by:
$586\ BW^{0.75} - 7.94\ T + 26.84$ Daily gain $+ 11.36$ Egg mass $- 0.993\ FC - 36.2\ HS$ (0 = cages, 1 = floor; $R^2 = 0.75$). Despite considerable differences among treatments, egg performances were not affected, indicating the adaptive capacity of layers to a broad range of environmental conditions.

Abbreviations: HP, heat production; ME, metabolisable energy;

Introduction

The accurate prediction of feed intake is important to formulate diets for laying hens (Sakomura, 2004). Environmental factors, like ambient temperature, season, and housing system probably affect feed intake of laying hens (Chwalibog and Baldwin, 1995; Roth and Bohmer, 2008). Current equations to predict feed intake of laying hens are largely based on hens in cages (Herremans *et al.*, 1989; Nrc (National Research Council), 1994). However, in Europe conventional cages are phased out from 2012 onwards (Ec, 1999), resulting in a shift to alternative housing systems like free range and outdoor systems. Moreover, beak trimming will be limited or prohibited in the coming years. Locomotion activity in free range systems, variable and in most cases lower ambient temperatures, and reduced plumage conditions in flocks with intact beaks as a consequence of feather pecking (Blokhuis and Van Der Haar, 1989; Damme, 1999) might affect the energy and protein requirements of the hens. The aim of the current study was to study the interaction effects of ambient temperature, plumage condition and housing system on energy partitioning and performance of laying hens, and to develop an equation that predict ME intake based on the results of this experiment.

Material and Methods

In 6 subsequent batches of 90 17 wk old H&N Brown Nick layer hens, obtained from 35-50 wk old breeder flocks, effects of ambient temperature, plumage condition and housing system were assessed by using a 3 x 2 x 2 factorial design with the following factors: Temperature (T): regular (21°C), average (16°C) and low (11°C); Feather cover (FC): 100% vs. 50%; and Housing system (HS): free range vs. caged housed.

Housing systems were chosen, thereby aiming to realize a low (cage) and high (free range) level of physical activity. Housing system was allotted to batch number. Within a batch, plumage condition was allotted to one of two chambers, whereas temperature levels were allotted to subsequent periods within each batch and chamber. In total, this experiment comprised 12 treatments with 3 replicates per treatment (36 observations; 6 batches x 2 chambers x 3 periods/chamber). Before each measuring period, animals were habituated to the housing system during a pre-experimental period of 4 weeks.

At the age of 21 wk, 70 healthy hens out of 90 were divided over two respiration chambers (3.7 x 1.47 m: 5.4 m^2). Total weight of the animals per chamber was standardized by reducing variation in mean body weight (BW) by removing the lightest and heaviest hens. Batches were alternately assigned to cage housing or free range housing. Each batch of 6 wk was subdivided in three periods of 2 wk In each period, one of the three ambient temperature levels was applied. The first wk of each period was used for adaptation of the hens to the new environment. During the second wk of each period observations were performed.

Hens were habituated to the climate respiration chambers for 7 d before measurements started. Thereafter, energy balances were assessed per chamber over a 7-d measuring period Exchange of O_2, CO_2 and CH_4 was measured in 9-min intervals, as described by Verstegen *et al.* (1987). Total heat production (HP_{tot}) during the last 6 d of the experimental period was calculated according to the equation of Romijn and Lokhorst (1966):

HP_{tot} (kJ) = 16.20 x O_2 (l) + 5.00 x CO_2 (l). Metabolizable energy (ME) intake was calculated by subtracting the energy content of manure/litter from that of feed plus fresh wood shavings. ME for maintenance (kJ) was calculated as ME intake – ME for protein deposition (kJ)/0.54 – ME for fat deposition (kJ)/0.74 (Romijn and Lokhorst, 1966). Net energy (NE) was calculated by subtracting HP_{tot} from ME. Retention of N (NR) was estimated from N in feed, wood shavings, manure/litter, dust, as well as from aerial NH_3 and NH_4^+ of water that condensed on the heat exchanger. Net energy as protein (NE_p) was calculated as 23.8 x 6.25 x NR, where 23.8 kJ/g was used as the energy content of protein (Van Es, 1979). Net energy as fat (NE_f) was calculated by subtraction of NE_p from NE. Based on the amount of protein and fat deposited in eggs, NEp could be subdivided in net energy as protein in body weight gain (NEp_{BWG}) and in eggs (NEp_{egg}). Likewise, NEf could be subdivided as energy retention as fat in BWG (NEf_{BWG}) and in eggs (NEf_{egg}).

Results

In hens with an intact plumage, total heat production (HP_{tot}) was not affected by T, whereas HP_{tot} linearly increased in hens with a 50% FC, from 637.6 $kJ.kg^{0.75}.d^{-1}$ at 21^0C to 691.0 $kJ.kg^{0.75}.d^{-1}$ at 11^0C (Figure 1). At 21^0C, HP_{tot} was not affected by HS, whereas HP_{tot} in the free range system was increased by 5.8% and 3.0% at 16^0C and 11^0C, respectively, compared to the cage system (data not shown).

Remarkably, Ambient temperature (T) did not significantly affect any performance parameter (Table 1), although feed intake tended to increase with decreasing T (P = 0.074) from 114.5 g/d at 21^{0}C to 119.4 g/d at 11^{0}C. ME intake tended (P = 0.054) to increase by 9.9% from 858.1 kJ.kg$^{0.75}$.d^{-1} at 21^{0}C to 942.8 kJ.kg$^{0.75}$.d^{-1} at 11^{0}C. Hens with 50% FC consumed 8 g.d^{-1} more feed (P=0.010), had a 5% higher FC (P=0.011) and gained 0.5 g/d more BW (P=0.028) than hens with 100% FC. Daily gross energy (GE) intake of hens with 50% feather cover (FC) increased by 64 kJ.kg$^{0.75}$, compared to the hens with the 100% FC (1340 vs. 1404 kJ). Removing 50% of feathers resulted in a 55.6 kJ (6.3%) increase of ME intake (881.6 vs. 937.2 kJ.kg$^{0.75}$.d^{-1}) compared to the 100% FC treatment (589.6 vs. 619.5 kJ.kg$^{0.75}$.d^{-1}). Daily GE intake of the free range hens increased with 380 kJ.kg$^{0.75}$ (32%) compared to the cage housed hens (1182 vs. 1562 kJ), but HS did not affect feed and ME intake. NE for production was 60.7 kJ.kg$^{0.75}$.d^{-1} (25.7%) higher in hens housed in cages compared to hens housed in the free range system (236.2 vs. 296.9 kJ.kg$^{0.75}$.d^{-1}). Egg performance of the hens was not affected by HS. Based on the variables of this experiment, the following equation was developed to estimate expected metabolizable energy (ME) intake of laying hens:

$$ME\ (kJ/d) = 586\ W^{0.75} - 7.94\ T + 26.84\ \Delta W + 11.36\ EE - 0.993\ FC - 36.2\ HS$$

where: W = body weight (kg); T = ambient temperature (^{0}C); ΔW = change in body weight (g/d); EE = egg mass (g/d); FC = Feather Cover (%), and HS = Housing System (0 = cage housing, 1 = free range housing) (R^2 = 0.75).

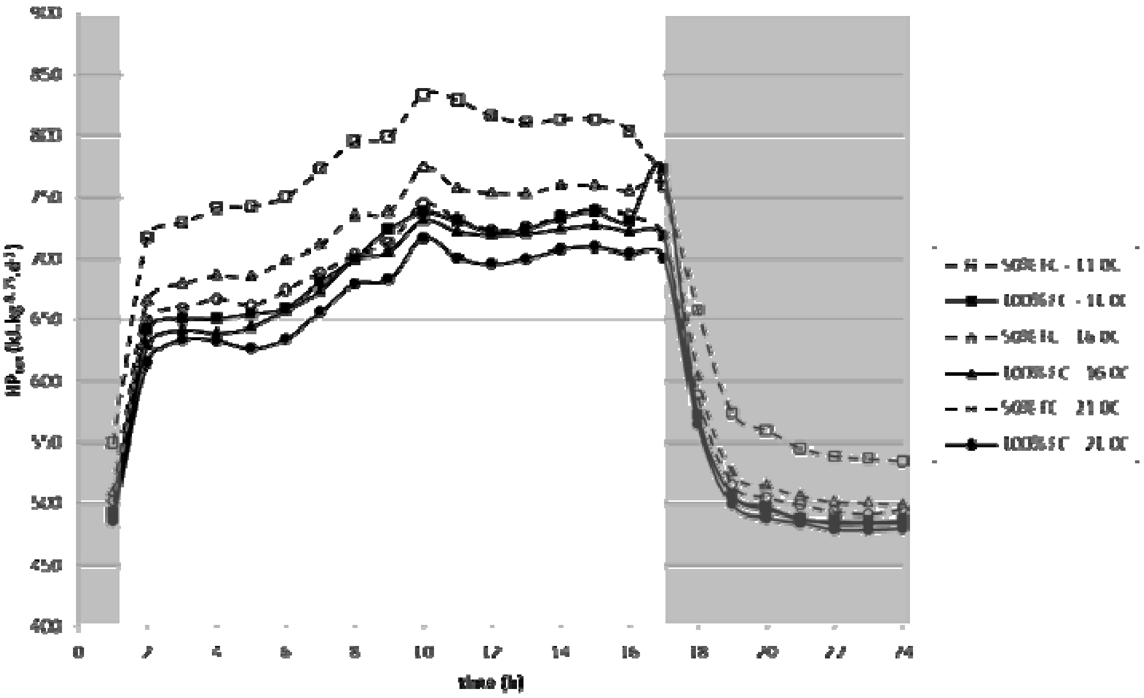

Figure 1 Hourly means of total heat production (HP_{tot}, SEM = 11.2) of hens with 50% FC (dotted lines, open symbols) or 100% FC (solid lines, closed symbols) at ambient temperature levels of 11^{0}C (squares), 16^{0}C (triangles), or 21^{0}C (circles). The dark period is indicated by a shaded background.

Table 1. Effects of ambient temperature (T), feather cover (FC), and housing system (HS) and their interaction on feed intake ($g.d^{-1}$), FCR, daily gain (g/d), GE intake, ME intake, HP_{tot} and NE for Production (in $kJ.kg^{0.75}.d^{-1}$) of 21-26 wk old H&N Brown Nick laying hens

	Feed intake ($g.d^{-1}$)	FCR (kg/kg)	Daily gain (g/d)	GE intake Feed/litter	ME intake	HP_{tot}	NE Prod.
Main effect T.							
T = 11^{0}C	119.3	2.21	2.6	1404	942.8	655.2	281.0
T = 16^{0}C	118.7	2.13	2.2	1379	927.3	641.8	286.0
T = 21^{0}C	114.5	2.07	1.4	1334	858.1	625.3	232.7
SEM	2.14	0.04	0.55	28.39	24	7.2	18.68
Main effect FC							
100%	113.6^b	2.05^b	1.8^b	1340^b	881.6^b	619.5	258.2
50%	121.4^a	2.15^a	2.3^a	1404^a	937.2^a	662.0	275.0
SEM	1.49	0.036	0.38	17.76	15.5	8.15	10.91
Main effect Housing							
Cage	119.4	2.11	2.3	1182^b	927.4	630.7	296.9^a
Free range	115.6	2.09	1.9	1562^a	891.4	650.8	236.2^b
SEM	1.83	0.049	0.53	22.99	19.2	8.15	14.02
***P*-values**							
T.	0.074	0.158	0.253	0.496	0.054	**<0.001**	0.097
FC	**0.010**	**0.013**	**0.028**	**0.015**	**0.023**	**<0.001**	0.165
HS	0.309	0.689	0.578	**<0.001**	0.294	**0.045**	**0.043**
T. * FC	0.459	0.3	0.583	0.102	0.226	**0.005**	0.759
T. * HS	0.63	0.269	0.855	0.978	0.791	**0.040**	0.708
FC * HS	0.742	0.619	0.397	0.437	0.873	0.632	0.396
T. * FC * HS	0.582	0.957	0.608	0.389	0.936	0.636	0.848

Conclusions

Decreasing ambient temperature increased ME intake and HP_{tot}, while egg performances were not affected. Defeathering of hens resulted in increased feed intake, FCR, and HP, and in a decreased daily gain, whereas egg performances were not affected. In free range housing the NE for production was reduced, whereas HP_{tot} was increased, compared to cage housing. Housing system did not affect egg performances. These results indicate the importance of maintaining FC for laying hens, especially in cold conditions, to prevent heat loss. Despite rather extreme differences between treatments, rate of lay, egg weight and egg mass were not affected, indicating the adaptive capacity of laying hens to a broad range of environmental conditions.

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