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Backtest type and housing condition of pigs influence energy metabolism¹

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ABSTRACT: The behavioral response of piglets in a backtest early in life seems indicative of their coping strategy at a later age. Coping characteristics may depend on the interaction between backtest classification and housing conditions. We studied whether growth rate and partitioning of energy in adult gilts were related to response in the backtest early in life, and to housing in groups or individual stalls. During the suckling period, female piglets were subjected to the backtest. Each piglet was restrained on its back for 1 min, and the number of escape attempts was scored. Thirty-six high-resisting gilts and 36 low-resisting gilts were selected. After weaning, pigs were housed in 12 groups of six (three high-resisting and three low-resisting). From 7 mo of age onward, 36 gilts out of six groups were housed in individual stalls, whereas the other gilts remained group housed. At 13 mo of age, gilts were housed in clusters of three (three high-resisting or three low-resisting) for an experimental period of 7 d in climatic respiration chambers. Group-housed gilts were

loose housed, and stall-housed gilts were housed in stalls within the chamber. Despite the fact that high-resisting and low-resisting gilts did not differ ($P = 0.269$) in initial BW, low-resisting gilts showed a higher ($P = 0.039$) ADG during the experimental period in association with a higher ($P = 0.043$) energy metabolizability. This suggests that, in line with the theory on coping strategies, high-resisting gilts may have more difficulties in adapting to a change in environment, (i.e., the change from home pen to climatic chamber). Group- and stall-housed gilts differed ($P = 0.001$) in initial BW, with group-housed gilts being heavier. During the experimental period, stall-housed gilts showed lower energy metabolizability ($P = 0.001$), lower energy retention ($P = 0.001$), and a higher energy requirement for maintenance ($P = 0.001$) due to a higher activity-related heat production ($P = 0.001$). This finding suggests that stall housing might have a negative influence on performance and partitioning of energy when animals are adapting to a change in their environment.

Key Words: Backtest, Coping Strategy, Energy Metabolism, Housing, Pigs

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Introduction

Studies in rodents describe two distinct behavioral and physiological response patterns, a proactive or a reactive coping strategy (Bohus et al., 1987; Benus et al., 1991). Coping strategies have also been reported for a number of other species, such as in birds (great tits: Verbeek, 1998; laying hens: Korte et al., 1997, 1999) and pigs (Hessing et al., 1993).

According to Hessing et al. (1993, 1994), an indication for the coping strategy of pigs can be obtained early in life by assessing the degree of resistance displayed in a manual restraint test, known as the *backtest*. A number of studies in growing pigs have demonstrated that the extreme responders in this test—the high-resisting (HR) and low-resisting (LR) animals—differ in a variety of features. High-resisting pigs were more aggressive (Ruis et al., 2000) and had lower baseline salivary cortisol concentrations (Geverink et al., 2002) and lower antibody titers (Schrama et al., 1997b) than LR pigs.

Also in adult gilts, responses to a challenge still seem to be related to backtest classification. Stall-housed HR gilts tended to show more chain biting and a lower heart rate response to feeding than LR gilts (Geverink et al., 2003). The association between backtest response and energy metabolism has not been studied so far. Cronin (1986) reported that the degree of adaptation to tether

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housing by sows influenced both behavior and energy metabolism. Indeed, a possible effect of backtest type could be influenced by the housing system. Previous studies showed that behavioral and immunological responses of LR pigs but not HR pigs depended on the housing system (Bolhuis, 2003; Bolhuis et al., 2003), suggesting that LR pigs, being more dependent on environmental cues than HR pigs, indeed adopt the reactive coping style (Koolhaas et al., 1999). The present experiment was conducted to study the effect of backtest type, housing system, and their interaction on growth rate and partitioning of energy in adult breeding gilts.

Materials and Methods

General Outline of Experimental Design

The experiment consisted of three identical successive replicates. Within each replicate, eight clusters of three 13-mo-old gilts were tested using a 2×2 factorial design with the factors backtest type (high-resisting vs. low-resisting) and housing system (group vs. stall housing). Each cluster of three gilts was housed in a climatic chamber. Four climatic chambers were available, so that within each replicate the eight clusters were tested in two succeeding periods of 7 d.

Animals and Housing

Subjects and housing have been described previously (Geverink et al., 2003). In three identical successive replicates, a total of 72 nulliparous crossbred gilts (Piétrain \times [Large White \times {Duroc \times British Landrace}]), kept in the experimental farm of the Wageningen University, The Netherlands, were studied. They were selected out of a large pool of gilts bred at a commercial farm (Straathof, The Netherlands) on the basis of their response in the backtest (adapted from Hessing et al., 1993) at 10 and 17 d of age. For an extensive description and review of the backtest method, see Bolhuis et al. (2003) and Bolhuis (2003), respectively.

The test was performed in the corridor next to the home pen. A piglet was gently removed from its pen and put on its back on a farrowing mat on a table. It was restrained in this supine position for 60 s by placing one hand over the throat and the other loosely on the hind legs. The number of escape attempts (i.e., series of struggles of the hind limbs) was scored. A piglet making more than two escape attempts in each test was classified as a high resister (HR) and when it made less than two escape attempts in each test it was classified as a low resister (LR). Piglets making exactly two escape attempts in one or both tests were not selected for experimentation.

In each replicate, out of the pool of tested gilts 12 HR gilts and 12 LR gilts were selected. They were weaned at 4 wk of age and brought to the experimental farm of the Wageningen University, The Netherlands, at 10 wk of age. Gilts were housed in four groups of six (three

HR and three LR gilts). At 7 mo of age, gilts out of two groups were moved to two identical rooms with individual stalls, with the six gilts within a room (three HR, three LR) originating from the same group. Two groups of six gilts each (three HR, three LR) remained group-housed in separate identical rooms. Two stall-housed gilts in the first replicate (one HR and one LR), one group-housed LR gilt in the second replicate, and one group-housed LR gilt in the third replicate were removed shortly before the experimental period due to various health problems.

Group housing pens (3.80×3.15 m) had 65% solid floor and 35% slatted floor. A metal food trough (3.80 m in length) was fitted at the front of the pen. The animals had access to a nipple drinker in the dunging area and a chain attached to the bar above the trough. Individual stalls were 0.60 m wide and 2.20 m long. They were made of partitions with vertical bars and placed in one row. High-resisting and LR gilts were housed alternately. Each stall had a concrete floor (1.30×0.60 m) in the front and slatted floor (0.90×0.60 m) at the rear end. A metal trough was fitted at the front, with a nipple drinker in the middle. Above the food trough, a chain was attached that was easily accessible to the pig.

For all rooms, an automatically controlled heating and ventilation system was used, set to maintain room temperature at 18°C. Furthermore, the individual stalls had floor heating to compensate for heat loss through the concrete floor.

In addition to natural light, artificial lights were on from 0700 until 1900. Twice daily at 0830 and 1500, the animals were fed a commercial pelleted diet (see Table 1) according to the Dutch standard for breeding gilts (CVB, 1998); from 8 mo of age onward, the amount offered (as-fed basis) was $2 \text{ kg} \cdot \text{gilt}^{-1} \cdot \text{d}^{-1}$. The feed was delivered by hand. After feeding and cleaning out in the morning, fresh straw was provided for the group-housed pigs as bedding on the concrete area and for the stall-housed pigs a handful in the food troughs.

The established principles of laboratory animal use and care were followed as well as the Dutch law on animal experiments which complies with the ETS123 (Council of Europe, 1986) and the 86/609/EEC directive (EEC, 1986). The Wageningen University Animal Care and Use Committee (Wageningen, The Netherlands) approved the experiment.

Experimental Period

Housing. At 13 mo of age, gilts were housed for an experimental period of 7 d in climatic respiration chambers. Each group of six gilts was split in two clusters of three HR and three LR gilts. The six stall-housed gilts out of each room were assigned to two clusters of three HR and three LR gilts. The respiration chambers were located in a separate building on the experimental farm. Stall-housed gilts were individually moved to the chambers in a transport box. Group-housed gilts were

Table 1. Composition of diet, g/kg (as-fed basis)

Ingredient	
Tapioca	385.0
Soybean meal	106.0
Molasses	75.0
Wheat bran	63.8
Peas	50.0
Palm kernel expeller	50.0
Lupins	33.3
Maize gluten feed	32.5
Rapeseed, extracted	28.6
Grass meal	25.1
Sunflower seed, extracted	23.2
Maize germ, extracted	21.9
Animal fat	18.8
Linseed	15.0
Sugar beet pulp	13.3
Soybean hulls	12.6
Soybeans, heat treated	12.3
Oats	8.3
CaCO ₃	6.9
Premix ^a	6.6
Monocalcium phosphate	6.1
NaCl	5.6
Phytase	0.1
Analyzed composition	
Dry matter	903
Crude protein	152
GE, MJ/kg	16.5
Calculated main nutrient composition ^b	
Ash	82.95
Crude fat	43.80
Crude fiber	76.01
Starch + sugars	367.98
NE, MJ/kg	8.70

^aSupplied the following per kilogram of diet fed during the experimental period: L-lysine HCl, 0.53 g; DL-methionine, 1.10 g; vitamin A, 7,000 IU; vitamin D₃, 1,400 IU; vitamin E, 12 IU; vitamin B₂, 4 mg; vitamin B₁₂, 15 µg; D-pantothenic acid, 7 mg; niacinamide, 18 mg; folic acid, 1.5 mg; biotin, 100 µg; choline-chloride, 250 mg; Ca, 1.525 g; Fe, 80 mg (FeSO₄·7H₂O); Cu, 10 mg (CuSO₄·5H₂O); Zn 38 mg (ZnSO₄·H₂O); Mn 24 mg (MnO₂); Co, 0.25 mg (CoSO₄·7H₂O); I, 0.4 mg (KI); and Se 0.1 mg (Na₂SeO₃·5H₂O).

^bCalculated nutrient composition is based on the CVB (1998) values of included ingredients.

moved in clusters of three (three HR or three LR gilts) in a transport box to the chambers.

The gilts out of a stall-housing room were housed in one of two large identical, open-circuit, indirect climatic respiration chambers measuring 6 × 4 × 2.2 m (Versteegen et al., 1987). The cluster of three HR gilts was housed in one chamber and the cluster of three LR gilts in the other one. Within a chamber, gilts were housed in individual metabolism stalls measuring 2.5 × 0.85 m. The stalls had a plastisol-coated steel floor (1.7 × 0.85 m) in the front and slatted floor (0.8 × 0.85 m) at the rear end. A metal trough was located at the front, with a nipple drinker in the middle. Above the food trough, the chain from the gilt's home stall was attached so that it was easily accessible.

The gilts out of a group were loose-housed in one of two medium-sized, identical open-circuit, indirect climatic respiration chambers measuring 3.5 × 1.5 × 2 m.

The cluster of three HR gilts was housed in one chamber and the cluster of three LR in the other chamber. The chamber floor consisted of an isolated concrete floor with a top layer of 30 mm of nontoxic asphalt on a 1.5-mm stainless steel floor with a grid (0.45 × 0.90 m) at the rear end. A metal trough (length = 1.5 m), divided in three parts, was located at the front. A nipple drinker was located at the rear of the chamber. Above the food trough, a chain was attached so that it was easily accessible to the gilts.

In all four chambers, environmental temperature was kept constant at 20°C. Relative humidity was maintained at approximately 65%. Air velocity was <0.2 m/s. Animals were exposed to 12 h of light and 12 h of dimness. Artificial lights were on from 0700 until 1900, and, during the night (1900 to 0700), a 25-W bulb lit each medium-sized chamber and two 25-W bulbs each large chamber to create dimness. Sensors to measure climatic conditions and gas flow were calibrated every 6 mo, and sensors to measure gas concentrations were calibrated daily.

Feeding. During the experimental period, gilts were fed the same commercial pelleted diet and the same amount (2 kg·gilt⁻¹·d⁻¹) as before in the home pen. Determined GE and CP content of the diet were 16.5 kJ/g and 15.2%, respectively (as-fed basis). Pigs received their daily feed in two similar portions at 0800 and 1430. From 3 d before the experimental period until the end of the experimental period, altrenogest (Regumate Pig, Hoechst Roussel Vet, Brussels, Belgium) was added to the morning feed (20 mg·gilt⁻¹·d⁻¹) to suppress estrus. After morning feeding, straw was supplied in the food troughs (30 g·gilt⁻¹·d⁻¹). During a period of 3 d before the experimental period, gilts already received straw in these exact portions. Determined GE and CP content of the straw were 15.5 kJ/g and 3.7%, respectively.

Measurements. Experimental unit for all measurements was the cluster of three gilts in a chamber. All gilts were weighed at the start and end of the experimental period. For each cluster, the mean ADG and metabolic BW (kg^{0.75}) were calculated.

Energy and nitrogen balances per cluster were measured during the experimental period. Manure (mixed feces plus urine) was collected quantitatively per cluster and sampled for energy and nitrogen analysis. Gross energy values were determined by adiabatic bomb calorimetry (IKA-C700, Janke and Kunkel GmbH & CoKG, Staufen, Germany), and N content was determined by the Kjeldahl method (ISO, 1979). Metabolizable energy intake per cluster was calculated from energy content of feed, straw, manure and methane (Wenk et al., 2001):

$$ME_{\text{feed+straw}} = GE_{\text{feed+straw}} - (GE_{\text{manure}} + GE_{\text{methane}})$$

The metabolizability of energy, **m(E)**, from food and straw was calculated as the ratio between ME and GE (Wenk et al., 2001):

$$m(E) = ME_{\text{feed+straw}}/GE_{\text{feed+straw}}$$

Exchange of oxygen, methane, and carbon dioxide was determined at 9-min intervals as described by Verspagen et al. (1987). The respiratory quotient (**RQ**), the ratio of carbon dioxide produced to oxygen consumed, was determined. Exchange of oxygen, methane, and carbon dioxide was used to calculate heat production (**H_{tot}**) using the equation of Brouwer (1965):

$$H_{\text{tot}} = 16.18 \times O_2 + 5.02 \times CO_2 - 2.17 \times CH_4$$

During the last 6 d of the experimental period, **H_{tot}** was measured. Total energy retention (**ER**) was calculated by subtracting the average **H_{tot}** of the last 6 d of the experimental period from ME intake. The retention of N was estimated from N in feed, straw, manure, aerial **NH₃** and in **NH₄⁺** of water that condensed on the heat exchanger. Energy retention as protein (**ER_p**) was derived from the N retention:

$$ER_p = N_{\text{retention}} \times 6.25 \times 23.7$$

The value of 23.7 represents the caloric values (kilojoules) per gram of body protein (ARC, 1981). Energy retention as fat (**ER_f**) was calculated from ER and **ER_p** as described by Henken et al. (1991):

$$ER_f = (ER - ER_p)$$

From **ER_p**, **ER_f**, and ME intake, ME required for maintenance (**ME_m**) was calculated as follows:

$$ME_m = ME - (ER_p/0.54) - (ER_f/0.74)$$

where 0.54 and 0.74 are the assumed values for the efficiency of utilization of ME for protein and fat deposition, respectively (ARC, 1981).

Physical activity was monitored continuously with two radar devices per chamber as described in Verspagen et al. (1987) and recorded in the same 9-min intervals as **H_{tot}**. The frequency of reflected radar waves, emitted by the devices, is changed when the animals underneath are moving (Doppler effect). This change in frequency is converted to electrical pulses and recorded in the same 9-min intervals as **H_{tot}**. Linear regression with **H_{tot}** and activity then calculates the energetic value of one activity pulse. The estimated regression coefficients of **H_{tot}** and the activity counts were used to calculate the heat production related to physical activity (**H_{ac}**) for each 9-min period as described by Heetkamp et al. (1995). The heat production not related to physical activity (**H_{cor}**) was derived by subtracting **H_{ac}** from **H_{tot}**.

Statistical Analyses

Experimental unit for all measurements was the cluster of three gilts in a chamber because measurements

could only be done for the whole chamber and not for individual gilts. Therefore, per replicate, $n = 2$ for each treatment (group-housed HR, group-housed LR, stall-housed HR, stall-housed LR), resulting in $n = 6$ per treatment for the whole experiment. Due to a technical problem, incorrect activity figures were registered during the first replicate in stall-housed animals. Therefore, for both stall-housed HR and LR gilts, $n = 4$ with regard to **H_{ac}** and **H_{cor}**.

The data on **GE**, **ME**, **ER**, **ER_p**, **ER_f**, **ME_m**, **H_{tot}**, **H_{ac}**, and **H_{cor}** were expressed in kilojoules per kilogram of metabolic BW per day. The metabolic BW used in the calculation of these data was the average of beginning and ending metabolic BW.

Energy and N balance traits, ADG, metabolic BW, and body weight at the start of the experimental period were evaluated by analysis of variance using the GLM procedures of SAS (SAS Inst. Inc., Cary, NC). Factors in the analysis were “backtest type” (HR vs. LR), “housing” (group housing vs. stall housing), and “replicate” (1 to 3):

$$Y_{ijk} = \mu + \text{replicate}_i + \text{housing}_j + \text{type}_k + (\text{housing} \times \text{type})_{jk} + e_{ijk}$$

where Y_{ijk} = a specific trait of a cluster of animals at replicate i , housing system j and backtest type k ; μ = overall mean, replicate_i = fixed effect of replicate i ($i = 1, 2, 3$), housing_j = fixed effect of housing system j ($j = 1, 2$), type_k = fixed effect of backtest type k ($k = 1, 2$). Preliminary analysis showed no effect of period within replicate (1 vs. 2) so this factor was not included in the final model. Because group-housed gilts were housed in medium-sized and stall-housed gilts in large cells, cell size and housing system were constrained. However, as all sensors to maintain climatic conditions and equipment for measurement of heat production and energy balance were calibrated, it was assumed that cell size did not influence the results.

Results and Discussion

No interactions between backtest type and housing system were detected (see Table 2); thus, only the main effects of backtest type or housing system will be discussed.

Effects of Back Test Type on Growth Rate and Partitioning of Energy. High-resisting and LR gilts did not differ ($P = 0.269$) in body weight at the start of the experimental period (Table 2). Previous research (Geverink et al., 2002) did not detect BW differences at 2 to 7 mo of age either between HR and LR gilts. However, during the experimental period, LR gilts showed a higher ($P = 0.039$) ADG than HR gilts (Table 2). This was paralleled by a higher ($P = 0.043$) energy metabolizability (ME/GE) in LR gilts, which caused a tendency for a higher ME intake ($P = 0.098$). The difference in energy metabolizability between HR and LR gilts did not lead to differences in heat production or **ME_m**. Low-

Table 2. Least squares means of growth rate and partitioning of energy in HR and LR gilts housed in groups or stalls^a

Trait	Group housing		Stall housing		SEM	P-value		
	HR	LR	HR	LR		Type	Housing	Type × Housing
No. of groups	6	6	6	6	—	—	—	—
No. of pigs	18	16	17	17	—	—	—	—
Initial body wt, kg	177.3	173.6	166.2	163.7	3.38	0.269	0.001	0.532
ADG, kg/d	0.79	1.14	0.02	0.29	0.140	0.039	0.001	0.785
Metabolic BW, kg	49.1	48.5	46.3	46.0	0.55	0.460	0.001	0.884
GE intake, kJ·kg ^{-0.75} ·d ⁻¹	681	689	721	728	8.8	0.423	0.001	0.949
ME:GE, %	78.6	79.6	75.0	75.7	0.40	0.043	0.001	0.763
ME intake, kJ·kg ^{-0.75} ·d ⁻¹	535	548	540	551	6.6	0.098	0.517	0.860
Respiratory quotient	0.95	0.96	0.93	0.93	0.004	0.365	0.001	0.698
Heat production, kJ·kg ^{-0.75} ·d ⁻¹								
Total (H _{tot})	411	406	457	456	8.9	0.728	0.001	0.841
Activity-related (H _{ac}) ^b	67	64	111	100	8.1	0.359	0.001	0.649
Non-activity-related (H _{cor}) ^b	344	342	343	337	4.3	0.388	0.509	0.558
Retention, kJ·kg ^{-0.75} ·d ⁻¹								
Total energy (ER)	124	141	83	95	7.7	0.074	0.001	0.710
Protein (ER _p)	37	43	33	40	3.2	0.074	0.323	0.870
Fat (ER _f)	87	99	50	55	6.3	0.194	0.001	0.588
ME for maintenance (ME _m), kJ·kg ^{-0.75} ·d ⁻¹	349	335	411	403	12.0	0.353	0.001	0.837

^aHR = high resisting; LR = low resisting.

^bBecause of a technical problem, incorrect activity figures were registered during the first replicate in stall-housed animals. Therefore, for both stall-housed HR and LR gilts, n = 4 with regard to H_{ac} and H_{cor}.

resisting gilts showed a tendency for a higher ($P = 0.074$) energy retention as protein (Table 2). Because protein is retained in association with three times its weight of water, this probably accounts for the observed difference in ADG.

The growth rate and partitioning of energy measured during the experimental period may not reflect the situation in the home pen. Moving the gilts to the chambers and housing them in an environment different from the home pen imposes a challenge that may take some days to adapt to. In piglets, it was observed that introduction into the chambers caused an increased energy requirement for maintenance or a decreased availability of energy (see review by Schrama et al., 1997a). In our experiment, differences between HR and LR gilts in metabolizability were reflected in ADG and tended to be reflected in energy retention but not in maintenance. This suggests that reallocation of the available energy over maintenance and production processes may differ between piglets and adult pigs. Furthermore, a change in environment may affect energy metabolism differently in animals with diverging coping styles. The coping style concept implies that proactive animals are advantageous in stable situations, whereas reactive copers are more successful in a changing environment (Van Oortmerssen et al., 1985; Benus et al., 1991; Koolhaas et al., 1999). Furthermore, when animals have difficulties in adapting to environmental conditions, the possible consequences, such as stress-related pathologies or abnormal behavior patterns, may depend on individual coping styles (Bolhuis et al., 2003). The results of the current study suggest that housing the ani-

mals for 7 d in the respiration chambers affected HR and LR gilts differently, as they showed a difference in metabolizability and ADG although initial body weight did not differ between backtest types. Low-resisting gilts seem to adapt more easily to a change in environmental conditions, which is in line with the suggestion of Hessing et al. (1994) and Koolhaas et al. (1999) that LR pigs adopt a reactive coping style.

Effects of Housing System on Growth Rate and Partitioning of Energy. Group-housed gilts were heavier ($P = 0.001$) than stall-housed gilts at the start of the experimental period (Table 2). Previous research on the same animals (Geverink et al., 2003) showed that housing gilts in stalls caused a long-term reduction in growth compared to gilts that remained group-housed. A higher ingestion of straw in group-housed gilts than in stall-housed gilts may have been a contributing factor to the weight difference before the experimental period. During that period, group-housed gilts had straw bedding whereas stall-housed gilts only received a handful of straw in the morning. Cole (1990) estimated that sows consumed a maximum of 0.5 kg of straw daily, which would contribute 2 MJ DE/d to the sow's diet. This could theoretically result in a maximum of 80 g/d in gain and thus explain the difference in initial BW. However, also during the experimental period in this study, group-housed gilts showed a higher ($P = 0.001$) ADG than stall-housed gilts (Table 2), although supply of straw was the same in both treatments. As a consequence of the higher initial body weight of group-housed gilts, GE intake per kilogram of metabolic BW was lower than in stall-housed gilts ($P = 0.001$). However,

due to a higher ($P = 0.001$) energy metabolizability (ME/GE), group-housed pigs did not differ ($P = 0.517$) from stall-housed pigs in ME intake per kilogram of metabolic BW. The higher ($P = 0.001$) total energy retention (ER) in group-housed gilts, which was reflected in a higher ADG, was caused by a lower ($P = 0.001$) total heat production. The difference in total retained energy between housing systems ($P = 0.001$) was caused by a difference in fat retention (ER_f, $P = 0.001$). Activity-related heat production (H_{ac}) was higher ($P = 0.001$) in stall-housed gilts. When H_{tot} was corrected for H_{ac}, the non-activity-related heat production (H_{cor}) did not differ between treatments. This indicates that differences in activity level are the major cause of differences in ER and ME_m.

Because the challenge of being moved from home pen housing to housing in climatic chambers may take some days to adapt to, the variables measured are probably not similar to baseline values. Furthermore, the change in environment was not entirely similar for group- and stall-housed gilts. A gilt originating from group housing was housed in a climatic chamber with two instead of five pen mates, which may have caused changes in the social relations between the animals. A gilt originating from stall housing was housed with two instead of five roommates, and had different neighbors. Therefore, part of the differences found between group- and stall-housed animals might be attributed to a different perception of the change in environment. Nevertheless, it is tempting to suggest that the observed differences between group- and stall-housed gilts in metabolism during adaptation to the new environment are due to the housing system during the previous 5 mo. A previous study (Geverink et al., 2003) showed that housing gilts in stalls caused a change in circadian cortisol rhythm, a reduction in growth, and increased stomach wall damage. The current results suggest that the difference between group housing and stall housing in itself may cause a difference in metabolism during adaptation to a changed environment, with most importantly a difference in ME required for maintenance and a change in metabolizability.

It may be that the higher BW and fat retention of the group-housed gilts decreased ME_m. Alternatively, the higher ME_m in stall-housed pigs could indicate that these animals perceive their housing as stressful, as an increased ME_m is generally believed to indicate stress (Schrama et al., 1997a). This is in line with studies that demonstrated higher levels of stereotypies (Morris et al., 1993; Broom et al., 1995; Vieuille-Thomas et al., 1995) and a disruption of endocrinological functions (Barnett et al., 1981; Zanella et al., 1998) for stall-housed sows as compared to group-housed sows. However, other studies showed no differences between stall housing and group housing with respect to abnormal behaviors, endocrinological and immunological functions, or main culling reasons and production results (Von Borell et al., 1992; Stamer and Ernst, 1992; Gjein and Larssen, 1995; Morris et al., 1997). Therefore, the

implications of the presently reported differences in metabolism between group- and stall-housed gilts for welfare merit further research.

Implications

Adult gilts that were classified at a young age as "low resisting" in a backtest showed a higher energy metabolizability during an experimental period of 7 d in climatic respiration chambers than gilts classified as "high resisting." This might suggest that low-resisting gilts adapt better to changing environmental conditions. Growth rate and partitioning of energy during the experimental period also was associated with housing system. Group-housed gilts showed higher energy metabolizability and lower energy requirements for maintenance than stall-housed gilts. Future research should clarify the duration of these differences in metabolism and possible implications for welfare.

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