Effects of Diet and Genetics on Production Traits in Response to Repeated Exposure to Heat Stress in Pigs

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Summary and Implications

Hot temperatures negatively impact global livestock production and are a serious financial burden to pig producers. Trends predict that global temperatures will continue to increase, making this a pertinent issue now and in the future. Study objectives were to investigate the effects of genetics and dietary fiber content on growth, feed intake, and feed conversion efficiency in response to repeated exposure to heat stress. A total of 103 finishing barrows from a contemporary commercial line and Yorkshire lines divergently selected for high and low feed efficiency based on residual feed intake (**RFI**) were used in this experiment. All pigs were subjected three consecutive times to a 4-d heat stress (**HS**) load, starting with a 19-d thermal neutral (**TN**) adaptation period and alternated by 7-d TN conditions (see Figure 1). Feed intake, growth and feed conversion efficiency were measured for each period. Heat stress negatively impacted all three production traits, however, pigs from the commercial line were most affected. In addition, during heat stress, pigs from the low RFI (= more efficient) line lost their advantage in feed conversion efficiency over pigs from the high RFI line. This supports the hypothesis that pigs with a high genetic propensity for lean tissue accretion are more susceptible to heat stress. However, our results also indicated that the effect of heat stress on feed intake, growth rate, and feed conversion efficiency was not significantly influenced by the amount of fiber in the diet (at constant energy density).

Introduction

Heat stress accounts for over $900 million loss in the U.S. swine industry annually due to poor reproduction, slow growth and reduced feed efficiency, making it one of the costliest issues in the US pork industry today. Because trends in global warming predict increased temperatures and extreme summer conditions in most pig producing areas in the US, these detrimental effects will likely become even more of an issue in the future. Therefore, there is an urgent need to understand the effects of genetics and dietary management practices on heat stress induced losses in production efficiency. Periods of heat stress often repeat themselves over time, cycling between heat stress and thermoneutral periods.

A pig's thermal comfort zone in which it performs best is determined by the balance between external heat load and endogenous heat production. Endogenous heat production is determined by metabolic rate and, thus, high producing animals are expected to be more susceptible to heat stress. In addition, an increase in the use of co-products in swine diets increases the concentration of dietary fiber. Because fiber has a higher heat increment of feeding, it can be hypothesized that pigs fed increasing fiber are more susceptible to heat stress.

Study objectives were to investigate the effects of genetics and dietary fiber content on growth, feed intake, and feed conversion efficiency in response to repeated exposure to heat stress.

Materials and Methods

A total of 103 finishing barrows were used in this experiment: 35 barrows from a contemporary commercial line, 36 Yorkshire barrows from a line selected for low RFI (efficient pigs) and 32 Yorkshire barrows from a line selected for high RFI (inefficient pigs). Pigs were located in one of two rooms and feed and water were provided *ad libitum* during the entire experiment. Within each room and line, individuals were randomly allocated to two dietary treatments: a diet with low fiber vs a diet with high fiber; both diets had a similar energy content and were formulated to meet or exceed the predicted requirements for finishing pigs for energy, essential amino acids, protein, minerals and vitamins.

Figure 1. Experimental design.

All pigs where subjected three separate times to a 4-d HS load that was preceded by a 19-d TN adaptation period and alternated by 7-d TN conditions as demonstrated in **Figure 1**. Feed intake (**FI**) was measured daily throughout the experiment. Body weights (**BW**) were obtained on d 1, 8, and 19 of TN1, and at the end of HS2 (d 23), TN3 (d 30), HS4 (d 34), TN5 (d 41), HS6 (d 45) and TN7 (d 52). Average daily body weight gain (**BWG**) and feed intake were calculated for each period. Feed conversion efficiency (**FCE**) was calculated as BWG/FI (note that this is the inverse of feed conversion ratio). Additionally, 10^{th}-rib back fat thickness (BFT) was measured via ultrasound scan at the end of period TN1 and TN7 (d 19 and 52, respectively).

All traits were analyzed with a mixed model with a repeated statement and the fixed effects of genetics, climate, period, diet, and room, the random effect of litter, 'age' as a covariate, and associated interaction effects.

Results

Over the entire experimental period (1-52 d), on average, commercial pigs grew from 59 to 107 kg, low RFI pigs from 81 to 108 kg, and high RFI pigs from 81 to 112 kg. Average BFT between TN1 and TN7 was lower in commercial pigs (13.4 ± 0.65 mm) than in low (20.0 ± 0.61 mm) and high RFI pigs (20.4 ± 0.652 mm; $P < 0.0001$). Commercial pigs were lighter than low and high RFI pigs until d 41 ($P < 0.001$).

Figure 2 presents the daily FI (kg/d) least squares means for each line in each climate. FI in HS was lower than in TN in all three lines ($P < 0.0001$). Commercial pigs ate more than pigs of the low and the high RFI line ($P < 0.0001$). FI from individual pigs in each period was significantly positively correlated with FI in each other period ($r = 0.37$ to 0.76, $P < 0.0001$). Pigs fed a low fiber diet tended to eat more than pigs fed the high fiber diet, but the response in FI to heat stress was not significantly affected by diet.

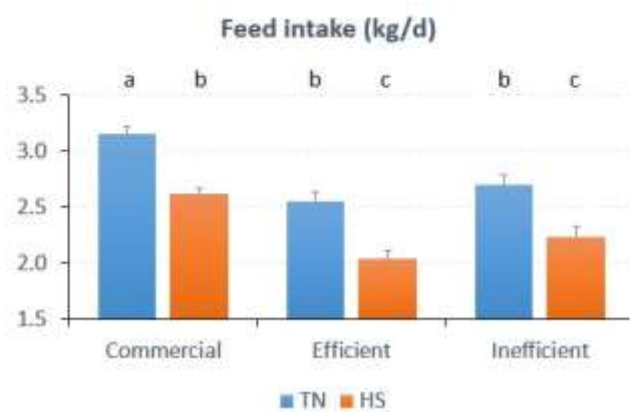

Figure 2. Daily feed intake least squares means for each line in thermoneutral (TN) and heat stress (HS) periods. Columns with different letters are significantly different from each other ($P < 0.05$).

Figure 3 presents the least squares means of daily BWG for each line in each climate. BWG was lower in HS than in TN in commercial ($P < 0.0001$), low ($P < 0.001$), and high RFI pigs ($P = 0.069$). In TN, commercial pigs grew faster than low and high RFI pigs ($P < 0.001$) but the differences between the lines disappeared under HS. With the exception of adaptation period TN1a, pigs that grew faster in one TN period also did so in the other TN periods ($r = 0.12$ to 0.46), and this was significant between TN3 and TN5, and between TN5 and TN7 ($P < 0.01$). Animals with a higher BWG in HS4 also had a higher BWG in HS6 ($r = 0.43$, $P < 0.01$). Animals that grew faster in TN grew slower in the subsequent HS period and vice versa ($P < 0.05$). Pigs fed the low fiber diet grew faster (0.683 ± 0.022 kg/d) than pigs fed the high fiber diet (0.548 ± 0.032 kg/d; $P < 0.05$), but response to HS was not significantly affected by diet.

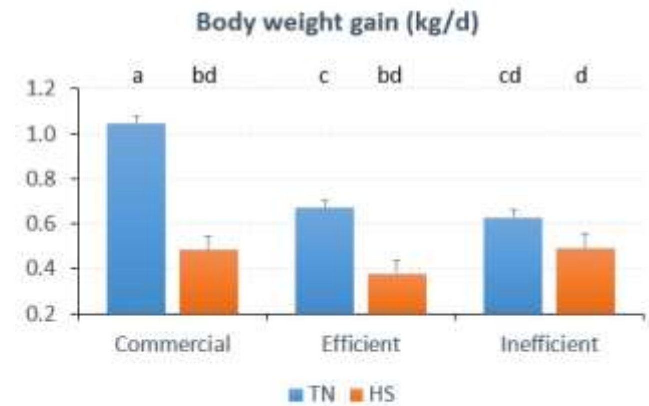

Figure 3. Daily body weight gain least squares means for each line in thermoneutral (TN) and heat stress (HS) periods. Columns with different letters are significantly different from each other ($P < 0.05$).

Figure 4 presents the daily FCE least squares means for each line in each period. FCE was lower (i.e., poorer) in HS than in NT ($P < 0.001$). In TN only, FCE was better in commercial pigs than in low and high RFI pigs ($P < 0.0001$) and better in low RFI pigs than in high RFI pigs ($P < 0.05$). Pigs with a higher FCE in TN7 had a lower FCE in HS4 ($r = -0.52$, $P < 0.001$) and a higher FCE in TN5 ($r = 0.33$, $P < 0.05$). In addition, similar to BWG, animals with a higher

FCE in periods 1c, 2, 3, 4, 5, and 6 had a lower FCE in the following periods 2, 3, 4, 5, 6, and 7, respectively ($r = -0.41$ to -0.55, $P < 0.001$). FCE was not significantly different between pigs fed high or low fiber diets.

Discussion

When heat dissipation is maximum, and activity is reduced to resting levels, animals have no other option than to reduce metabolic functions to further decrease heat production in order to maintain thermal homeostasis. Along with other physiological processes this can be accomplished by reducing the heat increment of feeding through a reduction in feed intake, and by reducing heat production resulting from tissue accretion, in particular that related to lean tissue growth. Thus, pigs that have a high genetic propensity for lean growth accretion are expected to be more susceptible to heat stress.

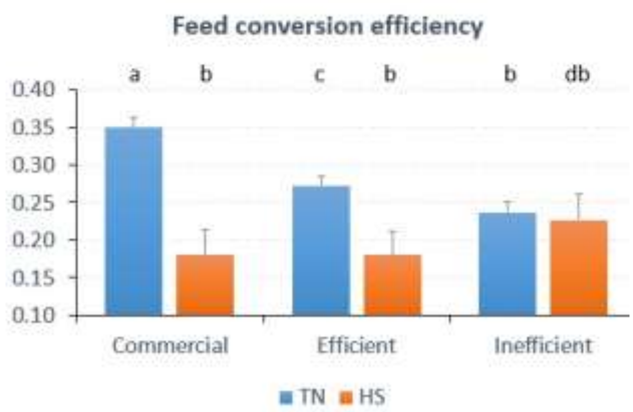

Figure 4. Feed conversion efficiency (kg gain/kg feed) least squares means for each line in in thermoneutral (TN) and heat stress (HS) periods. Columns with different letters are significantly different from each other ($P < 0.05$).

Our results show that growth rate, feed intake, and feed conversion efficiency were all depressed in pigs during heat stress. Heat stress suppressed feed intake to a similar degree in all three genetic lines. However, commercial pigs, which had considerably higher lean tissue growth rate and better feed conversion efficiency during TN than the other two lines, lost their superiority in both traits under HS, and pigs from the line selected for low RFI also lost its advantage in feed conversion efficiency over pigs from the high RFI line. In addition, independent of line, animals that grew faster and had higher feed conversion efficiency during TN were most penalized during the subsequent period of heat stress, whereas animals with a lower performance in both traits in a thermoneutral environment appeared to be more resilient.

Because the amount of heat liberated during digestion, absorption and assimilation is greater on a high fiber diet than on a traditional low-fiber diet, we expected that pigs fed high fiber diets are more susceptible to heat stress. However, our results indicate that response to heat stress in feed intake, growth rate, and feed conversion efficiency was not significantly affected by the fiber content of diets formulated in this experiment.

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