Effects of dietary fiber on performance of multiparous lactating sows in a tropical climate

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ABSTRACT: Sixty-two multiparous Large White sows were used to determine the effect of dietary fiber level on lactation performance according to season under conditions of a humid tropical climate. This experiment was conducted in Guadeloupe (West French Indies, lat 16°N, long 61°W) between October 1999 and January 2001. Two seasons were distinguished a posteriori from climatic measurements parameters continuously recorded in the farrowing room. During the warm season, ambient temperature and relative humidity averaged 25°C and 86.8%, respectively. The corresponding values for the hot season were 27.5°C and 83.5%. Experimental diets fed during lactation were a control diet (C; 14% neutral detergent fiber) and a high-fiber diet (HF; 20% neutral detergent fiber) obtained by substitution of wheat middlings by wheat bran. The two diets were formulated to provide the same ratios between essential amino acids and lysine and between lysine and net energy. No interaction between season and diet composition was found for all criteria studied. Over the 28-d lactation, average daily feed intake (ADFI) was lower and body weight loss was higher (P < 0.001) during the hot season compared to the warm season (3,447 vs 4,907 g/d and 33 vs 17 kg, respectively). The number of stillborn piglets was higher (P < 0.05) during the hot season than during the warm season (2.0 vs 1.1 piglets, respectively). Litter growth rate and mean BW of piglets at weaning were reduced (P < 0.01) during the hot season vs the warm season (2.1 vs 2.3 kg/d and 7.7 vs 8.3 kg, respectively). The ADFI was similar for both diets and digestible energy (DE) intake tended to be lower (P = 0.06) with the HF diet (54.9 vs 59.3 MJ of DE/d for C sows) in relation with its lower DE concentration. The body weight loss was greater (P < 0.01) for HF sows than for C sows (30 vs 21 kg). Compared with the C diet, the HF diet increased (P < 0.05) litter growth rate and piglet body weight at weaning (2.3 vs 2.1 kg/d and 8.3 vs 7.7 kg/d for HF vs C, respectively). Season and diet composition did not affect the weaning-to-estrus interval. In conclusion, the hot season in humid tropical climates, which combines high levels of temperature and humidity, has a major negative effect on the performance of lactating sows.

Key Words: Feed Intake, Fiber, Lactation, Sows, Tropical Climate

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Introduction

Numerous studies have reported that when ambient temperature rises above the upper limit of the zone of thermal comfort (22°C; Quiniou and Noblet, 1999), daily feed intake in lactating sows is severely reduced, with subsequent negative consequences on milk production (Black et al., 1993; Quiniou and Noblet, 1999). Most of these results were obtained with several levels of ambient temperature kept constant over the day and at a low relative humidity. However, in practical conditions, ambient temperature and relative humidity in farrowing houses can fluctuate over the day and over the year or successive seasons, especially in tropical countries. From that point of view, very little has been published concerning the effect of season in tropical climate on performance of lactating sows.

In Guadeloupe Island, and more generally in several tropical countries, milling byproducts are used in pig feeds. The potential of these high-fiber ingredients has been demonstrated in restrictively fed pregnant sows for improving health status and animal welfare (Ramonet et al., 1999). This interest is emphasized by the greater ability of sows to digest dietary fiber relative to growing pigs (Noblet and Le Goff, 2001). However,
Table 1. Main characteristics of seasons\(^a\)

<table>
<thead>
<tr>
<th>Item</th>
<th>Warm</th>
<th>Hot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature, °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>21.7</td>
<td>24.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>29.9</td>
<td>32.3</td>
</tr>
<tr>
<td>Mean</td>
<td>25.0</td>
<td>27.5</td>
</tr>
<tr>
<td>Relative humidity, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimal</td>
<td>66.4</td>
<td>61.7</td>
</tr>
<tr>
<td>Maximal</td>
<td>97.6</td>
<td>96.5</td>
</tr>
<tr>
<td>Mean</td>
<td>86.8</td>
<td>83.5</td>
</tr>
<tr>
<td>Time T &gt; 25°C and RH &gt; 85%, %(^b)</td>
<td>10.9</td>
<td>26.4</td>
</tr>
</tbody>
</table>


\(^b\)Percentage of time when ambient temperature and relative humidity were above 25 °C and 85%, respectively.

The increase in dietary fiber level is associated with a reduced energy content of the feed, which can be detrimental in lactating sows, for which energy intake has to be maximized. Moreover, such diets induce a higher heat production (Noblet et al., 1989; Ramonet et al., 2000) and consequently, it can be hypothesized that feeding high-fiber diets under tropical climate conditions may accentuate the negative effect of high temperatures on performance of lactating sows.

The first objective of this study was to investigate the effect of season under tropical climate on performance by lactating sows and their litters. The second objective was to determine the effect of an increased dietary NDF level on performance of lactating sows raised in tropical climate conditions.

Materials and methods

Experimental Design

Sixty-two lactation Large White sows in 10 successive replicates of six to eight animals were used in a trial conducted at the experimental facilities of INRA in Guadeloupe (lat 16°N, long 61°W), an area characterized as having a humid, tropical climate. The data covered the period between October 1999 and January 2001, and two seasons were determined a posteriori from climatic measurements: a warm season (25.0 °C on average) and a hot season (27.5 °C on average; Table 1). Within each replicate, sows were allocated to two experimental diets differing in dietary fiber content (C and HF for control and high-fiber diets, respectively). The C diet was based on corn, soybean meal, and wheat middlings. In the HF diet, the wheat middlings and corn fraction were partly replaced by wheat bran. The two diets were designed to supply the same levels of standardized digestible lysine (i.e., 0.80 g/MJ of NE) and the ratios between essential AA and lysine were above those recommended by Dourmad et al. (1991). Chemical composition and nutritional value of diets are presented in Table 2. Diets were offered as pellets. Feeds were prepared for one or two successive replicates and stored in a temperature-controlled room (at 18°C).

Animal Management

Fourteen days before farrowing, sows were moved to open-front farrowing rooms. Ambient temperature, relative humidity, and photoperiod were not controlled and followed those of outdoor conditions. The farrowing room was equipped with pens on a metal-slated floor.
Each pen consisted of a commercial crate for lactating sows (2.1 × 2.2 m) and an infrared light to provide supplemental heat for the piglets. The infrared light was activated on the day of farrowing and was positioned near the rear of sows. Sows were allotted to one of the two dietary treatments according to parity, BW, and backfat thickness on d 100 of gestation. Litter size was adjusted to 10 or 11 piglets by cross fostering within 24 h after farrowing. When the number of available piglets was insufficient, piglets from Large White non-experimental sows were fostered. At birth, piglets were tattooed and the teeth were cut. On the farrowing day (d 0), sows received 1 kg of the standard gestation diet (13.0 MJ of DE/kg, 14% CP, and 0.55% lysine). Feed allowance was progressively increased by 1 kg each day until d 5, and sows were offered feed ad libitum from d 6 onwards. The proportion of the gestation diet decreased regularly over the 3 d postpartum (i.e., 75, 50, and 25% on d 1, 2, 3, respectively); sows were fed only with the C or HF diet on d 4. Sows had free access to water from a low-pressure nipple drinker. At d 14, piglets received an injection of 200 mg of iron dextran, and males were castrated. Creep feed (15.3 MJ of DE/kg, 20% CP, 1.47% lysine) was offered from d 21 of lactation.

Calculations and Statistical Analyses

The DE content was estimated from the chemical composition of the diet according to the equation proposed by Le Goff and Noblet (2001). The daily maximum, minimum, mean, and variance of the ambient temperature and relative humidity were averaged for each replicate. These data were used to split the total experimental period into two seasons through a principal component analysis (PRINCOMP procedure, SAS Inst., Inc, Cary, NC). The effects of season, diet composition, and their interaction on sows and litters performance were tested according to an ANOVA (GLM procedure of SAS). The effect of group was tested within the effect of season. The effect of lactation stage on the daily feed intake was tested as repeated measurements (repeated procedure; GLM of SAS) with temperature and diet composition as main effects, according to the comparison of ADFI to a reference value (ADFI on d 6) and contrasts between adjacent ADFI. The effect of age of piglets on litter BW gain was analyzed according to a multifactorial analysis (split-plot), taking into account the effects of season and diet and the interactions between these main effects. The farrowing rate and number of sows coming into estrus before and after 5 d postweaning were compared using a χ² test (SAS).

Climatic Measurements

The warm season was determined to be between October 1999 and April 2000 and between December 2000 and January 2001, whereas the hot season corresponded to the May to November 2000 period. The average ambient temperature and relative humidity for both periods of the warm season were not different (i.e., 24.8 vs 25.4°C and 86.5 vs 87.6%, respectively). For this reason, the two periods were grouped in the same season in which the average ambient temperature and relative humidity were 25°C and 86.8%, respectively. The corresponding values for the hot season were 27.5°C and 83.5%, respectively (Table 1). The proportion of time when temperature and relative humidity were above 25°C and 85%, respectively, was higher in the hot season (26.4 vs 10.9%). The daily variation of ambient temperature and relative humidity were very similar with minimal and maximal values of temperature at about 0600 and 1300, respectively. Conversely,
Figure 1. Diurnal fluctuations in ambient temperature (solid lines) and relative humidity (dotted lines) in warm (thick lines) and hot (thin lines) seasons.

relative humidity was greatest at the end of the night and least when the ambient temperature was greatest (Figure 1).

Sow Performance

Two sows died 1 d after farrowing during the hot season; dissection indicated that cystitis-pyelonephritis and endometritis caused the deaths. No interaction \((P > 0.10)\) between season and diet composition was found for all criteria studied. Parity number was not affected by season or by diet composition. Lactation length was higher in the warm season than in the hot season (Table 3), but no difference in lactation length was observed between the dietary treatments.

As presented in Table 3, ADFI was affected \((P < 0.001)\) by season; it was lower in the hot season during the whole lactation period and during the ad libitum period (i.e., between d 6 and 27; 3,447 g/d vs 4,907 g/d and 3,842 g/d, respectively). A similar effect was observed for daily DE intake. The ADFI was similar for the C and HF diets, but DE intake tended to be lower \((P = 0.06)\) for sows fed the HF diet in connection with its lower DE content. After farrowing, sows were restrictively fed for 4 d according to the same feeding plan. Consequently, the increase of ADFI was similar for both seasons until d 4 (Figure 2). After d 4, the effect of season on the increase of ADFI was significant \((P < 0.001)\); feed intake increased until d 4 and 6 in hot and warm seasons, respectively. Compared to d 6, ADFI increased progressively with the advancement of lactation at both seasons; the difference was significant \((P < 0.05)\) after d 21.

The lactation BW loss was higher in the hot season than in the warm season (Table 3). In addition, it was higher \((P < 0.01)\) for the HF diet than for the C diet (Table 3). The backfat thickness before farrowing and at weaning were lower for the HF diet \((P < 0.01)\). The backfat thickness loss during lactation tended to be higher \((P = 0.08)\) in the hot season (4.8 vs 3.8 mm). Rectal temperature was higher \((P < 0.001)\) in the hot season than in the warm season (38.6 vs 38.2°C), and it was higher \((P = 0.03)\) for the HF diet (Table 3).

The reproductive performance was measured for a total of 58 sows; two sows did not show estrus before d 15 after weaning. The weaning-to-estrus interval was not affected by season or diet composition and averaged 4.9 d (Table 4). Although treatments had no significant effect on the conception rate \((P = 0.15)\), it was numerically lower in the hot season

Litter Performance

At birth, the litter size and the average piglet BW were not affected by season (Table 5). The mortality at birth was higher \((P < 0.05)\) during the hot season than during the warm season (2.0 vs 1.1 stillborn). Whatever the season, the litter BW gain significantly increased between wk 1 and 2 and between wk 3 and 4, respectively; it was similar for wk 2 and 3 (Figure 3). Over the first 3 wk of lactation, litter BW gain was lower \((P < 0.01)\) in the hot season than during the warm season (1.8 vs 2.1 kg/d); however, it was the same at both seasons \((P > 0.10)\) during the last week of lactation (Table 5). Consequently, litter BW gain between birth and weaning and mean BW of piglets at weaning were higher \((P < 0.05)\) during the warm season than during the hot season (2.3 vs 2.1 kg/d and 8.3 vs 7.7 kg, respectively). The increase in dietary fiber level increased the litter BW gain between wk 1 and 3 (2.1 vs 1.9 kg/d, P < 0.01) and over the whole lactation period (2.3 vs 2.1 kg/d, P < 0.05). As observed for the season effect, litter BW gain during wk 4 was not affected by dietary treatment \((P > 0.10)\), and the mean piglet BW at weaning was higher \((P < 0.05)\) for the HF diet than for the C diet (Table 5).

Discussion

Effect of Season on Sow and Litter Performance

In lactating sows, when ambient temperature exceeds the upper limit of their thermal comfort zone (i.e., 22°C; Black et al., 1993; Quiniou and Noblet, 1999), ADFI is reduced and evaporative heat loss increases markedly; however, it does not prevent an increase in rectal temperature (Quiniou and Noblet, 1999). In our trial, during the warm season, the ambient temperature averaged 25°C and the hourly values of temperature were frequently greater than 22°C (Figure 1), suggesting that sows were heat stressed most of the time. This effect was accentuated during the hot season in connection with the higher average daily temperature (i.e., +2.5°C), which is consistent with the higher rectal temperature. However, the average rectal temperature recorded during the warm and the hot seasons was lower than values measured by Lorschy et al. (1991) and Quiniou and Noblet (1999) at 25 and 27°C (i.e.,
a large range of ambient temperatures, each degree increase in ambient temperature between 25 and 27°C at a relative humidity fluctuating between 50 and 60% resulted in a reduction of feed intake equivalent to 214 g/d or 3.1 MJ of DE/d. In the present study, over approximately the same temperature range and at approximately 85% relative humidity, the corresponding values were more than two times higher (584 g · d⁻¹ · °C⁻¹ and 7.9 MJ of DE · d⁻¹ · °C⁻¹, respectively). These results suggest that the low feed intake of lactating sows kept in tropical climates would be due to the combined effects of high temperature and high humidity. In other words, the high humidity accentuates the effect of high temperature. In growing pigs kept at 28°C, an increase of relative humidity from 45 to 75% resulted in a reduction of 7% of daily feed intake (Granier et al., 1998). To our knowledge, no data are available on the direct effect of relative humidity on performance of lactating sows kept in hot conditions. Nevertheless, it is well established that in pigs, the evaporative heat loss from the lungs through increased respiratory rate is limited when the relative humidity is high (Holmes and Close, 1977). In addition, the lower evaporative critical temperature is lower in lactating sows than in growing pigs (18 to 20°C according to Quiniou and Noblet [1999] vs 23 to 26°C according to Giles and Black [1991]), so that heat stress at a given high temperature is more important in lactating sows. Heat stress will then be further accentuated by high humidity.

Table 3. Effect of season and diet composition on performance of lactating sows over a 28-d lactation (least squares means)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Seasona</th>
<th>Dietb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
<td>Warm</td>
<td>Hot</td>
</tr>
<tr>
<td>No. of sows</td>
<td>36</td>
<td>24</td>
</tr>
<tr>
<td>Duration of lactation, d</td>
<td>28.9</td>
<td>27.9</td>
</tr>
<tr>
<td>Feed intake, g/d</td>
<td>From farrowing to weaning</td>
<td>4,907</td>
</tr>
<tr>
<td>DE intake, MJ/d</td>
<td>From farrowing to weaning</td>
<td>67.0</td>
</tr>
<tr>
<td>Body weight, kg</td>
<td>From farrowing</td>
<td>77.2</td>
</tr>
<tr>
<td>Loss during lactation</td>
<td>After farrowing</td>
<td>263</td>
</tr>
<tr>
<td>Rectal temperature, °C</td>
<td>At weaning</td>
<td>246</td>
</tr>
</tbody>
</table>

bC = control diet, HF = high-fiber diet.
cResidual standard error.
dFrom an ANOVA including the effects of season (S), diet composition (D), and effect of group of sows within season (G). The interaction between diet and season was not significant (P > 0.10). †P < 0.10, *P < 0.05, **P < 0.01, ***P < 0.001.
eMeasured between 0700 and 0900 every Monday and Thursday.
Table 4. Effect of season and diet composition on conception rate and the weaning to estrus interval

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Season</th>
<th>Diet</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Warm</td>
<td>Hot</td>
<td>C</td>
</tr>
<tr>
<td>No. of sows</td>
<td>35</td>
<td>23</td>
<td>31</td>
</tr>
<tr>
<td>≤5 d</td>
<td>31</td>
<td>22</td>
<td>29</td>
</tr>
<tr>
<td>&gt;5 d</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Conception rate, %(d)</td>
<td>94.8</td>
<td>82.2</td>
<td>90.6</td>
</tr>
</tbody>
</table>

\(^a\) Data calculated without two sows not displaying estrus before 15 d after weaning (one in HF treatment during warm season and one in HF treatment during hot season).


\(^c\) C = control diet, HF = high-fiber diet.

\(^d\) Calculated as the number of pregnant sows relative to the number of all inseminated sows.

In most experiments dealing with the effect of high temperature on lactating sow performance, ambient temperature was kept constant, whereas in reality, and especially in tropical conditions, it fluctuates during the day. In a recent study, Quiniou et al. (2000) demonstrated that sows could partially compensate for the lower consumption during hot periods by higher feed intake during fresh periods of the day when the mean daily temperature exceeded 25°C, so that daily feed intake was higher under fluctuating ambient temperature than at a constant temperature. This feeding pattern was confirmed in the present experiment by measurements of individual feeding behavior parameters in a subgroup of 27 sows (D. Renaudeau et al., unpublished data). However, despite of the temperature fluctuation in our study, which could attenuate the effect of high temperature, the negative effect of high temperature remains very important.

The number of stillborn piglets was higher \((P < 0.05)\) in the hot season. From a 1-yr survey in an intensive Taiwan swine herd, Yang et al. (1996) reported similar observations. In a study conducted in South Nigeria over a 2-yr period, Steinbach (1971) reported a significant increase in the proportion of stillborn piglets in March and April, which was the hottest period of the year, and noted that ambient temperature at farrowing

Table 5. Effect of season and diet composition on performance of litters over a 28-d lactation (least squares means)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Season</th>
<th>Diet</th>
<th>FSD</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Warm</td>
<td>Hot</td>
<td>C</td>
<td>HF</td>
</tr>
<tr>
<td>No. of sows</td>
<td>36</td>
<td>24</td>
<td>31</td>
<td>29</td>
</tr>
<tr>
<td>Litter size</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total born</td>
<td>12.0</td>
<td>12.1</td>
<td>11.9</td>
<td>12.2</td>
</tr>
<tr>
<td>Stillborn</td>
<td>1.1</td>
<td>2.0</td>
<td>1.8</td>
<td>1.2</td>
</tr>
<tr>
<td>At d 1*</td>
<td>10.8</td>
<td>10.2</td>
<td>10.2</td>
<td>10.6</td>
</tr>
<tr>
<td>At weaning</td>
<td>9.6</td>
<td>9.2</td>
<td>9.3</td>
<td>9.5</td>
</tr>
<tr>
<td>Piglet BW, kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At d 1</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>At d 21</td>
<td>6.3</td>
<td>6.6</td>
<td>5.7</td>
<td>6.2</td>
</tr>
<tr>
<td>At weaning</td>
<td>8.3</td>
<td>7.7</td>
<td>7.7</td>
<td>8.3</td>
</tr>
<tr>
<td>Litter BW gain, kg/d</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wk 1 to 3</td>
<td>2.1</td>
<td>1.8</td>
<td>1.9</td>
<td>2.1</td>
</tr>
<tr>
<td>Wk 4</td>
<td>2.7</td>
<td>2.8</td>
<td>2.7</td>
<td>2.8</td>
</tr>
<tr>
<td>Wk 1 to 4</td>
<td>2.3</td>
<td>2.1</td>
<td>2.1</td>
<td>2.3</td>
</tr>
</tbody>
</table>


\(^b\) C = control diet, HF = high-fiber diet.

\(^c\) Residual standard error.

\(^d\) From an ANOVA including the effects of season (S), diet composition (D), and effect of group of sows within season (G). The interaction between diet and season was not significant \((P > 0.10)\). \(\dagger P < 0.10, \ddagger P < 0.05; \ast P < 0.01, \ast\ast P < 0.001.\)

\(^*\) After cross fostering.
and percentage of stillborn piglets were correlated (i.e., $r = 0.57$). In our study, the corresponding correlation was lower ($r = 0.25; P = 0.06$). Neonatal losses are often associated with prolonged farrowing and are predominantly the result of a fetal asphyxia (Herpin et al., 1996). Although increased duration of farrowing has not been measured in studies concerned with the effect of heat stress on neonatal mortality in piglets, it might be a plausible explanation.

During the first 3 wk of lactation, litter growth rate in the warm season was similar to the ADG reported by Quiniou et al. (2000) in multiparous lactating sows kept in a cyclic temperature varying from 21 to 29°C with similar litter size (i.e., 2,432 g/d). In agreement with results of Steinbach (1971), litter growth rate was reduced in the hot season between farrowing and d 21; this is also consistent with the reduced growth of the litter when ambient temperature increases (Quiniou and Noblet, 1999). Because litter growth rate and milk production are closely related (Noblet and Etienne, 1989), the reduction of litter BW gain suggests a decrease of milk production in the hot season, which is a consequence of both a reduction in feed intake and a direct effect of heat stress (Black et al., 1993). Between d 21 and weaning, season did not affect the litter growth rate. According to Renaudeau and Noblet (2001), creep feed, when available during the fourth week of lactation, is more consumed in hot conditions and compensates for the reduction in milk production. In addition, these latter authors demonstrated that creep feed consumption was the major source of variation of litter BW. Even if creep feed consumption was not recorded in the present study, the lack of a seasonal effect on litter BW gain during the fourth week of lactation may be related to a higher creep feed intake in the hot season.

During the warm season, lactation BW loss averaged 594 g/d and increased markedly (i.e., 1,180 g/d) in the hot season in connection with the greater negative effect of season on daily DE intake than on milk production. To a lesser extent, the backfat thickness loss also increased during the hot season. This increased mobilization of body reserves in heat-stressed sows has been observed in most literature studies on this topic (Christon et al., 1999; Johnston et al., 1999; Quiniou and Noblet, 1999; Renaudeau et al., 2001).

This increase of body reserves mobilization during the lactation period did not have negative consequence on the weaning-to-estrus interval in our trial; however, this result was obtained on a very small number of observations. Using data collected from 16 commercial swineherds in Minnesota and Iowa (i.e., approximately 10,000 mixed parity sows), Koketsu and Dial (1997) reported a prolonged weaning-to-estrus interval during the summer period. Similar results were also reported in southern France over a 4-yr period for 63,000 sows (Dagorn et al., 1979). From these observations, it can be suggested that ambient temperature may not play a major role in seasonal infertility; the increase of weaning-to-estrus interval was likely due to a larger depletion of body reserves during lactation in relation with the negative effect of heat stress on feed intake (Peltoniemi et al., 2000).

The conception rate was numerically reduced for sows lactating during the hot season, and the lack of significant effect of season may be due to the reduced number of sows used in our study. In a study of more than 1,400 sows, Kabuga and Annor (1991) also reported a reduced conception rate during the hot and humid season in Ghana. Similarly, and again in a small number of sows, mortality of lactating sows occurred only during the hot season in our study. This is in agreement with results obtained from a survey in Canadian breeding herds (Chagnon et al., 1991; D’Allaire et al., 1996), indicating a significant increase of number of deaths during the months of July, August, September, and October.

**Effect of Dietary Fiber Content on Sow and Litter Performance**

Average daily feed intake was not affected by the dietary fiber content, with subsequently lower DE intake with the HF diet. Similar results were reported at 20°C by Schoenherr et al. (1989) when a high-fiber diet (48.5% wheat bran, WB) was compared to a corn–soybean meal diet. In contrast, when oat husk was added to a basal diet, lactating sows increased their ADFI, but DE intake was reduced (Ziopoulos et al., 1982). These results support the concept that ADFI in lactating sows is not sufficiently increased when a high-quality feed is diluted in order to maintain DE intake. At thermoneutrality, the ADFI of the lactating sow fed with a conventional diet is limited by the capacity of the digestive tract (Dourmad, 1988). Moreover, Kyriazakis and Emmans (1995) and Tsaras et al. (1998) demonstrated that in young, growing pigs, ADFI of bulk diets was more related to their water holding capacity (WHC). The WHC of the feed describes the property of

**Figure 3.** Effect of season on weekly litter body weight gain during lactation. Statistical significance: ***$P < 0.001$, *$P < 0.05$.**
the dietary fiber to trap water, swell, and form gels with high water content, which can act as bulk in the gastrointestinal tract (Moughan et al., 1999). Kyriazakis and Emmans (1995) showed that the effect of bulkiness becomes significant when the inclusion level of WB in the diet exceeds 70%. In the present study, the rate of incorporation of WB in the HF diet was moderate (i.e., 36%); thus, it can be surmised that the bulk effect is not the main factor limiting ADFI in sows fed the HF diet. In fact, in tropical conditions, sows are continuously heat stressed, even during the warm season, which could explain the inability of the sow to over-consume feed to compensate for the lower dietary energy concentration.

Dietary fiber addition increased average piglet BW at weaning by about 570 g. This increase was mainly related to the higher BW gain during the first 3 wk of lactation (i.e., +240 g · d⁻¹ · litter⁻¹). In the study of Ziopoulou et al. (1982), adding barley straw to the diet induced a nonsignificant increase of piglet BW gain and milk fat content. Similarly, addition of wheat bran at thermoneutrality resulted in a higher fat and energy content in milk, but without any significant effect on litter BW gain (Schoenherr et al. 1989). Feeding pigs with high levels of fiber increases the rate of fermentation in the hindgut (Jørgensen et al., 1996). From this fermentation, gases (CO₂, H₂, and CH₄), lactate, and short-chain fatty acids (SCFA; acetic, propionic, and butyric acids) are produced. Moreover, an important bacterial mass is produced from the fermentation process (Varel and Yen, 1997). The SCFA may be used for milk fat synthesis and provide higher energy milk content (Linzell et al., 1969). However, as shown by Williams (1995), the supply of protein is the main limiting factor for piglet growth, and consequently, the increase of milk fat content would have little effect on piglet BW gain. The lack of effect of dietary fiber level on the quantity of milk required per unit of BW gain reported by Schoenherr et al. (1989) confirms this hypothesis. Consequently, the increase of piglet growth for the HF diet would be mainly related to an increase of milk production rather than changes in milk composition. However, the mechanisms involved in the response of milk production to dietary fiber change are unknown.

Sows fed the HF diet lost more BW during lactation in connection with reduced DE intake and also increased milk production. In addition, backfat thickness loss was similar for both diets, which implies that the difference in BW loss between the C and HF diets corresponds mainly to lean tissue. These results suggest that lean tissue mobilization increased for HF sows in connection with the lower AA supply relative to the requirement for milk production. However, feeding lactating sow with high dietary fiber does not have detrimental effects on performance. In other words, in response to energy restriction, milk yield was maintained with an increased body reserve mobilization.

### Interaction Between Dietary Fiber and Season

Low heat-increment diets (e.g., diets with reduced CP and/or fat addition) could attenuate the detrimental effects of heat stress on sow performance during lactation (Schoenherr et al., 1989; Renaudeau et al., 2001). In contrast, diets with a high crude fiber level would be less tolerated in hot conditions in connection with increased heat production. However, in agreement with results of Schoenherr et al. (1989), the HF diet did not have a detrimental effect on sow and litter performance during the hot season.

Some previous studies have shown increased heat production and a subsequent lower retained energy with high dietary fiber level in adult sows (Noblet et al., 1989; Ramonet et al., 2000). In the latter studies, the range of fiber level exceeded 260 g of NDF/kg of DM between the C and the HF diets. The corresponding value in our trial was lower (i.e., 53 g NDF/kg DM), which could explain why the calculated NE to ME ratio was close for both diets. Therefore, the absence of detrimental effect of high dietary fiber level on sow performance during the hot season may be explained by the relatively small difference in dietary fiber level between diets. Moreover, DE or ME consumption was lower for the HF diet than the C diet; this attenuated the heat increment in HF sows and contributed to explain the lack of negative effects of feeding the HF diet in the hot season.

### Implications

The present study demonstrates that high ambient temperature has an important negative effect on feed intake and more generally on performance of lactating sows; this effect is emphasized when the relative humidity becomes quite high. Therefore, large variations in temperature and relative humidity that occur over successive seasons in tropical climates will have major effects on performance of lactating sows usually reared in noninsulated buildings, with the poorest results at high temperatures and humidities. Whatever the season, the use of a diet with a high level of wheat bran in lactation may allow increased litter growth rate, but with enhanced mobilization of body reserves. Because of the large mobilization of reserves with such diets, further studies are required to evaluate the long-term effects of addition of fiber in lactation diet.

### Literature Cited


