Two different feeding levels during late gestation in gilts and sows under commercial conditions: impact on piglet birth weight and female reproductive performance

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ABSTRACT: The increase in the litter size in past decades has caused reduction in the individual piglet birth weight. Therefore, nutritional strategies employed in the last third of gestation in order to improve the piglet birth weight have been studied. This study aimed to evaluate the effects of 2 different feeding levels (1.8 and 2.2 kg/d) in the last third of gestation on the piglet birth weight and the female reproductive performance. A total of 407 females were fed on a diet based on corn-soybean meal (3.25 Mcal ME per kg and 0.65% standardized ileal digestible lysine) from day 90 of gestation until farrowing. The females were weighed on day 90 and day 112 of gestation, and at weaning. Born alive and stillborn piglets were weighed within 12 h of birth. The lactation feed intake and the litter growth rate were measured in a randomly selected subsample of 53 sows from each treatment. The data were analyzed using the generalized linear mixed models, considering the females as the experimental unit. Parity, treatment, and their interaction were analyzed for all responses. The females fed on 2.2 kg/d of diet from day 90 to day 112 exhibited greater body weight gain compared to the females fed on 1.8 kg/d ($P < 0.001$). No evidence of the effects of feeding levels on the individual piglet birth weight and on the within-litter CV were observed, for both gilts and sows ($P \geq 0.90$). Similarly, when the classes of the total born piglets were considered in the analysis (<15 and ≥15 for gilts; <16 and ≥16 for sows), no positive effects of increasing the feeding level were observed on the individual piglet birth weight and the within-litter CV ($P \geq 0.47$). Also, no differences in the stillborn rate, mummified-fetus rate, and percentage of piglets weighing less than 1,000 g at birth were observed between the treatments ($P \geq 0.28$). The females fed on 1.8 kg/d of diet exhibited greater feed intake during lactation, compared to the females fed on 2.2 kg/d ($P < 0.05$). Weaning weight, weaning-to-estrus interval, subsequent litter size, and culling rate were not affected by the dietary levels ($P \geq 0.23$). In conclusion, increasing the feed intake from day 90 of gestation until farrowing increased the body weight gain in sow, demonstrated no effect on the piglet birth weight, and reduced the lactation feed intake. Furthermore, there was no evidence of the effects of the treatments on the litter growth rate or on the subsequent female reproductive performance.

Key words: birth weight, feeding, gestation, gilts, nutrition, sows

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INTRODUCTION

The current increase in the litter size has contributed to a reduction in the individual piglet birth weight (Milligan et al., 2002). The low birth weight impairs lifetime performance, as it has detrimental effects on the postnatal survival, the weaning weight, the market weight (Quiniou et al., 2002; Fix et al., 2010; Alvarenga et al., 2012), and on the reproductive performance as well (Magnabosco et al., 2016). This weight reduction is associated with the competition for nutrients within the limited intrauterine space (Town et al., 2005; Foxcroft et al., 2006), which is greatly increased after 70 d of gestation (McPherson et al., 2004; Ji et al., 2005). Therefore, during late pregnancy, the nutrients are directed, as a priority, toward the uterus for fulfilling the nutritional requirements of the growing fetuses (Theil et al., 2014).

Increasing the daily feed intake in late gestation, traditionally used as a nutritional strategy to improve the piglet birth weight, has been reported with contradictory results (Campos et al., 2012; Gonçalves et al., 2016a). Especially in sows, it does not allow to reach an accurate conclusion regarding the benefits conferred by this practice (Shelton et al., 2009; Soto et al., 2011; Campos et al., 2012; Gonçalves et al., 2016a). Increasing the feed intake during the late gestation has been demonstrated to improve the birth weight moderately in gilts; however, this was not the case with sows (Shelton et al., 2009; Soto et al., 2011). Recent data from a large-scale study conducted under commercial conditions suggested that this moderate improvement in the piglet birth weight achieved by increasing the feed intake was associated with the increase in the daily energy intake, rather than the increase in the amino acid intake as hypothesized initially (Gonçalves et al., 2016b). Lastly, it is important to highlight that offering more feed at the end of gestation increases feed costs per sow.

Most of the published studies have evaluated only the piglet birth weight, while the effects on the dam responses have not been included. However, it is known that the feed intake during lactation could be influenced negatively by the maternal weight and the body composition at parturition (Eissen et al., 2000). Additionally, low feed intake and great loss in body weight during lactation may result in an increase in the weaning-to-estrus interval (**WEI**), incidence of anestrus, return to estrus post insemination, and a reduced farrowing rate (Koketsu et al., 1996, 2017). It is possible that these negative effects have been attenuated in the modern genetic lines, as these effects have not been as exacerbated in the last decade as they were in the previous decade (Schenkel et al., 2010; Patterson et al., 2011). Therefore, the effects of increased feed allowance during late gestation on sow performance remain unclear for hyperprolific dam lines, particularly in high-performing herds (>14.5 total piglets born per sow).

The objective of the present study was to evaluate the effects of 2 different feeding levels in the last third of gestation on the piglet birth weight. Furthermore, we contemplated the feed intake during lactation and the subsequent reproductive performance in hyperprolific females. The hypothesis was that an increased feed allowance during late gestation would increase the piglet birth weight, with no impact on the female reproductive performance.

MATERIALS AND METHODS

The protocol used in the present study was approved by the Ethics Committee of Animal Utilization (CEUA) of the Federal University of Rio Grande do Sul (UFRGS), under process no. 31653. The study was conducted in a pig farm with an inventory of 5,900 females, located in the northern plateau in the state of Santa Catarina (26°17′15,2″S, 50°11′11,3″W), southern Brazil. The study was conducted in the period between January and April, which corresponds to summer and early fall in the southern hemisphere. The average, minimum, and maximum temperatures in the study region during the period of study were 20.8, 15.5, and 25.7 °C, respectively, and the average relative humidity was 85.3%.

Animals and Diets

A total of 421 females, 303 sows and 118 gilts (Landrace × Large White; PIC Camborough, Hendersonville, TN), were individually housed (2.20 × 0.60 m), with automatic feeders and ad libitum access to water. The gestation diet was based on a corn-soybean meal, with 3.23 Mcal ME per kg, 13% crude protein (**CP**) and 0.65% standardized ileal digestible Lysine (**SID Lys**). The gilts and sows were fed on 2 different levels of diet—1.8 and 2.0 kg/d, from day 0 to day 4 of gestation. According to the methodology proposed by Young et al. (2004), from day 5 to day 35 of gestation, the gilts with the body condition score (**BCS**; 1 to 5 scale) of 2 and 3 were fed on 2.7 and 2.1 kg/d of diet, respectively, and the sows with the BCS of 2 and 3 were fed on 2.7 and 2.3 kg/d of diet, respectively. After this, from day 36 to day 89 of gestation, both the gilts and sows were fed on 1.8 kg/d of diet.

Experimental and Treatment Design

On day 89 of gestation, females were selected according to the following characteristics: general health status; BCS between 2.5 and 3.5 (1 to 5 scale; Young et al., 2004) and parity between 0 and 4. Age above 190 d at first service was considered only for gilts, whereas the total number of born piglets (more than 9) in the previous farrowing was considered only for sows. The selected females were weighed individually and randomly assigned to the 2 feed intake treatments—1.8 kg/d (5.85 Mcal ME per day or 4.51 Mcal NE per day and 11.7 g/d SID Lys) or 2.2 kg/d (7.15 Mcal ME per day or 5.51 Mcal NE per day and 14.3 g/d SID Lys) of the gestation diet, to be fed from day 90 of gestation until farrowing (Tables 1 and 2). The females were fed on the gestation diet once a day, with manual addition of the weighed amount of the feed into the feed boxes. The average treatment period (from day 90 of gestation until farrowing) was 25.3 ± 1.3 d, and the gestation length was 115.2 ± 1.4 d, with no differences between treatments or parities ($P \geq 0.607$).

The females were weighed on day 112 of gestation as well as at weaning, using a scale with a resolution of 200 g. The birth weight of the born alive and stillborn piglets was recorded within 12 h of birth, using a scale with a resolution of 1 g. The mummified fetuses were not weighed; however, the number of these piglets was recorded to be included in the total number of piglets born.

Subsequent Female Reproductive Performance

After weaning, estrus detection was performed once a day, and the WEI was recorded after estrus confirmation by the female standing reflex in the presence of a boar. The number of born alive piglets, stillborn piglets, and the mummified fetuses of the subsequent farrowing were recorded. The females that returned to estrus after the insemination in the subsequent cycle were not included in the analyses of the subsequent total born piglets, born alive piglets, and mummified fetuses.

Lactation Feed Intake and Litter Performance

A total of 106 females (16 gilts and 90 sows), each with a minimum of 14 viable teats, were selected randomly to constitute a subsample that would be used to evaluate the voluntary feed intake during lactation and the litter performance. The lactation diet (3.30 Mcal ME per kg, 19.9% CP, and 1.12% SID Lys) was provided 4 times a day from farrowing up to weaning (Table 1), through the manual filling of the feed box. In all times, the feed amount was recorded. The feed wastage was weighed every 4 d to calculate the average lactation feed intake (day 0 to 3, 4 to 7, 8 to 11, and 12 to 15 of lactation), except for the last interval (day 16 to 21), which comprised 6 d because the lactation length

Table 1. Composition of the experimental diets (as-fed basis)

Ingredient	Gestation[1]	Lactation[2]
Corn	80.22	58.22
Soybean meal	15.50	34.30
Vitamin and mineral premix[3]	1.00	1.00
Dicalcium phosphate	1.14	1.04
Limestone	1.26	1.34
Salt	0.50	0.50
L-Lys	0.185	0.215
DL-Met	0.07	0.06
L-Thr	0.12	0.09
Soybean oil	–	3.25
Phytase	0.01	0.01
Total	100.00	100.00
Calculated analysis		
SID[4] AA, %		
Lys, %	0.71	1.19
Met and Cys:Lys, %	70	54
Thr:Lys, %	76	64
Trp:Lys, %	19	20
Val:Lys, %	78	72
ME, Mcal/kg	3.28	3.44
CP, %	14.46	21.69
Ca, %	0.85	0.91
STTD P[5]%	0.43	0.46
Na, %	0.23	0.24
Cl, %	0.48	0.57

[1]Diet was fed from day 90 of gestation until farrowing.

[2]Diet was fed during lactation.

[3]Provided, per kilogram of gestation diet: 10,800 IU of vitamin A; 2,460 IU of vitamin D_3; 72 IU of vitamin E; 3.08 mg of vitamin K_3; 2.30 mg of vitamin B_1; 5.06 mg of riboflavin (B_2); 2.76 mg of pyridoxine (B_6); 30.82 µg of vitamin B_{12}; 30.82 mg of niacin; 23.80 mg of pantothenic acid; 1.93 mg of folic acid; 0.47 mg of biotin; 1.6 g of choline; 0.40 mg of selenium; 115.95 mg of iron; 25.0 mg of copper; 40.77 mg of manganese; 138.07 mg of zinc; 0.42 mg of iodine. Provided, per kilogram of diet lactation: 11,000 IU of vitamin A; 2,400 IU of vitamin D_3; 80 UI of vitamin E; 2.68 mg of vitamin K_3; 2.00 mg of vitamin B_1; 4.4 mg of riboflavin (B_2); 2.4 mg of pyridoxine (B_6); 26.8 µg of vitamin B_{12}; 26.8 mg of niacin; 12.0 mg of pantothenic acid; 1.68 mg of folic acid; 0.37 mg of biotin; 1.90 g of choline; 0.400 mg of selenium; 113.20 mg of iron; 50.0 mg of copper; 42.37 mg of manganese; 131.67 mg of zinc; 1.26 mg of iodine.

[4]SID = standardized ileal digestible.

[5]STTD = standardized total tract digestible.

Table 2. Chemical analysis of the diets (as-fed basis)[1]

Ingredient	Gestation[1]	Lactation[2]
Proximate analysis, %		
DM	88.10 (88.92)	86.60 (86.36)
CP	12.30 (14.44)	17.30 (21.73)
Crude fiber	2.20 (2.22)	2.23 (2.52)
Fat	2.70 (3.06)	3.31 (5.77)
Ash	5.40 (2.04)	6.33 (2.94)
Ca	0.92 (0.85)	0.80 (0.91)
P	0.53 (0.54)	0.55 (0.60)
Total AA, %		
Lys	0.77 (0.82)	1.18 (1.35)
Ile	0.42 (0.56)	0.76 (0.91)
Leu	1.19 (1.35)	1.56 (1.82)
Met	0.39 (0.31)	0.35 (0.39)
Met and Cys	0.53 (0.58)	0.53 (0.75)
Thr	1.03 (0.57)	0.50 (0.87)
Trp	0.13 (0.15)	0.13 (0.26)
Val	0.48 (0.66)	0.81 (1.00)
His	1.63 (0.40)	0.70 (0.59)
Phe	0.57 (0.69)	1.00 (1.06)

[1]Diet samples were taken once a week, and then CP and total AA analyses were conducted in duplicate on composite samples by Ajinomoto Animal Nutrition Group (São Paulo, SP, Brazil).

[2]Values in parentheses indicate those calculated from diet formulation and are based on values from the NRC (2012).

was 22.1 ± 1.5 d. During lactation, the females were housed in crates (2.20 × 0.70 m), under adiabatic and evaporative cooling temperature control conditions, and with ad libitum access to water.

The cross-fostering of piglets was performed within 24 h of birth, within each treatment, i.e., each piglet was fostered according to the dietary treatment of the respective dam. The piglets weighing less than 900 g were not included in the subsample that was constituted for the evaluation of the lactation performance. The total litter weight at cross-fostering was similar ($P = 0.838$) between treatments (22.07 and 22.27 kg for 1.8 and 2.2 kg/d, respectively). After cross-fostering, there was no further addition of the piglets to the litters, and all the piglets in the subsample were weighed 1 d before weaning.

Statistical Analysis

Among the total of 421 females (212 and 209 females from the 1.8 and 2.2 kg/d treatments, respectively), 2 and 6 gilts were removed from the 1.8 and 2.2 kg/d treatments, respectively, due to the low consumption of the feed offered during the treatment period. Furthermore, in the 1.8 kg/d treatment, a total of 5 sows were removed from the study—2 died, 1 underwent an abortion, and 2 due to sickness during gestation. One sow was removed from the 2.2 kg/d treatment because of uterine prolapse at farrowing. After the removals, 205 (60 gilts and 145 sows) and 202 (50 gilts and 152 sows) females from the 1.8 and 2.2 kg/d treatments, respectively, remained for inclusion in the analyses.

In the subsample selected for the analysis of lactation performance, 2 females were excluded from the 1.8 kg/d treatment—1 gilt because of death and 1 sow because of illness in the farrowing barn. As a result, a total of 51 (7 gilts and 44 sows) and 53 (8 gilts and 45 sows) females from the 1.8 and 2.2 kg/d treatments, respectively, were included in the analysis.

Statistical Analysis System version 9.3 (SAS Inst. Inc., Cary, NC) was used to perform the statistical analysis. All the models included the dietary treatment, parity category (gilts or sows), and the interaction between treatment and parity category, as the fixed effects. The week of onset of the feed treatment was included as a random effect, except in the nonparametric models of analysis.

The GLIMMIX procedure was used to analyze maternal body weight on day 90 and day 112 of gestation, maternal body weight at weaning, body weight gain from day 90 to day 112 of gestation, body weight loss from day 112 of gestation to weaning, total born piglets, total born alive piglets, the sum of born alive and stillborns piglets, individual piglet birth weight, total litter weight, litter size subsequent to cross-fostering, individual and total piglet weight at cross-fostering, litter size at weaning, individual and total piglet weight at weaning, daily weight gain of the piglets, lactation length, and the subsequent WEI.

The appropriate distribution for each of the response variables was selected according to Gonçalves et al. (2016b). The percentage of the weaned piglets was evaluated using the GLIMMIX procedure, and fitted with the assumption that the data exhibited a binomial distribution. The CV of the weight of the piglets at birth, after cross-fostering, and at weaning was analyzed using the GLIMMIX procedure, considering that the data exhibited a beta distribution. The percentages of stillborn piglets, mummified fetuses, and the piglets weighing less than 1,000 g at birth were analyzed using a nonparametric approach (the NPAR1WAY procedure), and the treatments were compared using the Wilcoxon test. The percentage of females bred until day 7 after weaning, farrowing rate, culling rate, and retention rate until second parity were analyzed, as binary distributions, using the GLIMMIX procedure. A model with repeated measures was fitted for the analysis of the feed intake during lactation.

Two litter-size classes based on the median of the total born piglets were created—<15 and ≥15 piglets for gilts, and <16 and ≥16 piglets for sows—to investigate whether the effect of the dietary levels on the birth weight could be affected by the litter-size class. The total born, the sum of the born alive and stillborn piglets, the individual piglet birth weight, and the total litter weight in the 2 litter-size classes (for gilts as well as for sows) were analyzed using the GLIMMIX procedure. Treatment, litter-size class, and the interaction between treatment and litter-size class were considered as the fixed effects in this analysis.

The results were considered significant at $P \leq 0.05$, and tendency at $0.05 < P \leq 0.10$. Each female was considered an experimental unit in all the analyses.

RESULTS

Validating the randomization process, no differences between the 1.8 and 2.2 kg/d treatments were observed ($P \geq 0.15$) in the parameters: initial body weight on day 90 of gestation within each parity class (Table 3); total born piglets at previous farrowing (14.9 ± 2.6 and 14.5 ± 2.7), for sows; age at first service (208.6 ± 11.4 and 210.6 ± 11.4 d), for gilts; and the average value of BCS for both the parity classes (3.2 ± 0.3).

The interaction between treatment and parity was assessed for all the response variables; however, no effect was observed for any of the variables ($P > 0.10$).

Although the body weight at day 112 was not different between the 2 treatments ($P = 0.20$; Table 3), females of the 2.2 kg/d treatment had a greater ($P < 0.01$) body weight gain (19.48 vs. 16.39 kg), between day 90 and day 112 of gestation, compared to females of the 1.8 kg/d treatment. The sows were heavier ($P < 0.001$) than the gilts at day 90 (217.04 vs. 179.94 kg) and day 112 (234.75 vs. 197.72 kg) of gestation as well as at weaning (217.83 vs. 169.63 kg), whereas the body weight loss between day 112 of gestation and weaning was greater ($P < 0.001$) in gilts than in sows (28.28 vs. 17.20 kg, respectively).

No effects of the treatments were observed, in both gilts and sows, on the number of total born piglets, number of born alive piglets, percentage of stillborn piglets, number of mummified fetuses, and the sum of live-born and stillborn piglets ($P \geq 0.13$; Table 3). However, the sows had a greater number of total born piglets, born alive piglets, and the sum of born alive and stillborn piglets, compared to the gilts ($P < 0.05$; Table 3). The individual piglet birth weight, the total litter weight, within-litter CV for piglet birth weight, and the percentage of piglets weighing less than 1,000 g at birth were not significantly different between the 2 treatments ($P \geq 0.11$; Table 3). The piglets born from the sows were 97.27 g heavier and, consequently, the litter was 2,583.77 g heavier in sows than in the gilts ($P < 0.01$).

When the 2 litter-size classes were considered (Table 4), the piglet birth weight and within-litter CV were not affected by the treatment or the interaction between litter-size class and treatment ($P \geq 0.40$). Unfortunately, despite the randomization process, the sows from the 2.2 kg/d treatment had on average 0.5 more piglets ($P < 0.02$), which was not sufficient to impact the individual piglet birth weight negatively.

Among the 407 females analyzed after the first farrowing posttreatment, 395 females were weaned, and 370 were bred in the subsequent cycle (186 and 184 females from the 1.8 and 2.2 kg/d treatments, respectively). No interaction ($P > 0.10$) was observed between the treatment and parity for WEI, percentage of the females bred until day 7 after weaning, farrowing rate, culling rate, total born piglets, born alive piglets, and the percentage of stillborn piglets (Table 3). There were differences between gilts and sows ($P < 0.05$) in WEI (5.75 and 4.57 d, respectively), percentage of the females bred until day 7 after weaning (89.4% and

Table 3. Least square means estimates and probability values of the effects of feed treatment in the last third of gestation and parity on maternal body weight, farrowing performance, and characteristics related to the offspring of gilts and sows under commercial conditions[1]

	Gilts			Sows			*P*-value		
	Treatments[2]			Treatments[2]					
	1.8	2.2	SEM	1.8	2.2	SEM			
Item	*n* = 60	*n* = 50		*n* = 145	*n* = 152		Treatment	Parity	Treatment× parity
BW on day 90, kg	180.2	179.7	2.75	217.2	216.9	1.67	0.869	<0.001	0.948
BW on day 112, kg	196.6	198.8	2.72	233.1	236.4	1.60	0.204	<0.001	0.794
BW gain day 90–112, kg	16.6	19.2	0.85	16.2	19.7	0.59	<0.001	0.952	0.450
BW at weaning, kg	170.2	169.0	3.02	217.1	218.6	1.93	0.959	<0.001	0.564
BW variation day 112–weaning, kg	−26.3	−30.2	1.82	−16.2	−18.3	1.19	0.031	<0.001	0.519
BW variation day 112–weaning, %	−13.4	−15.1	0.80	−6.9	−7.7	0.53	0.038	<0.001	0.478
Total piglets born, *n*	14.6	14.5	0.45	15.1	15.8	0.27	0.356	0.013	0.315
Born alive, *n*	13.5	13.8	0.42	14.2	14.9	0.24	0.132	0.014	0.561
Born alive + stillborn, *n*	14.2	14.3	0.44	14.8	15.5	0.26	0.206	0.101	0.325
Stillborn[3], %	4.2	2.9	0.70	3.8	4.1	0.43	0.951	0.579	0.611
Mummified fetuses[3], %	2.4	1.6	0.71	2.4	1.7	0.42	0.282	0.376	0.499
Litter weight[4], kg	17.3	17.5	0.52	19.4	20.5	0.31	0.113	<0.001	0.253
Average piglet birth weight[4], g	1258	1264	27.8	1360	1356	16.3	0.969	<0.001	0.814
Within-litter birth weight CV, %	19.2	18.6	0.81	20.4	21.0	0.49	0.902	0.007	0.383
Piglets weighing <1,000 g, %	20.0	17.2	2.42	16.8	16.1	1.32	0.426	0.345	0.576
Subsequent performance									
Weaning-to-estrus interval, d	5.8	5.7	0.48	4.5	4.7	0.31	0.846	0.003	0.821
Bred up to 7 d after weaning, %	89.5	89.4	4.50	97.7	96.4	2.55	0.627	0.005	0.644
Farrowing rate, %	93.1	86.2	3.39	81.2	86.1	5.81	0.121	0.584	0.121
Adjusted farrowing rate[5], %	93.0	88.9	3.41	81.0	88.1	5.82	0.104	0.943	0.158
Total piglets born, *n*	12.7	13.5	0.63	13.9	14.2	0.41	0.238	0.042	0.615
Born alive, *n*	12.0	12.9	0.55	13.3	13.4	0.38	0.270	0.04	0.400
Stillborn[3], %	3.8	2.6	0.99	3.0	4.5	1.05	0.898	0.615	0.894
Mummified fetuses[3], %	1.7	1.7	0.99	1.2	1.9	0.36	0.068	0.411	0.285
Retention rate, %	93.4	88.1	4.60	80.6	81.5	3.34	0.426	0.020	0.339
Subsample performance[6]									
Litter size after cross-fostering, *n*	14.3	14.5	0.18	14.3	14.3	0.10	0.596	0.500	0.275
Piglets weight after cross-fostering, kg	1.7	1.7	0.08	1.3	1.4	0.04	0.859	0.001	0.792
Cross-fostering weight CV, %	7.5	8.1	1.10	7.2	7.4	0.40	0.603	0.577	0.834
Weaned piglets, %	88.0	86.2	3.25	91.1	89.3	1.22	0.411	0.171	0.908
Individual weaning weight, kg	5.9	6.2	0.30	6.2	6.3	0.12	0.451	0.474	0.624
Weaned litter weight, kg	75.0	76.8	4.60	80.9	79.8	1.90	0.913	0.190	0.653
Piglet average daily gain, g	200.1	228.8	11.7	239.4	239.3	4.66	0.101	0.005	0.101
Within-litter weaning weight CV, %	12.0	9.8	1.25	14.8	13.4	0.65	0.110	0.005	0.589

[1]A total of 407 females (PIC Camborough, Hendersonville, TN) were used, with 205 females for the treatment 1.8 kg/d and 202 females for the treatment 2.2 kg/d.

[2]Treatments: 1.8 or 2.2 kg/d from day 90 until farrowing.

[3]Submitted to a nonparametric analysis.

[4]Calculated considering the number of born alive + stillborn.

[5]Dead females and those removed due to nonreproductive reasons were not included in the analysis of the adjusted farrowing rate.

[6]The subsample consisted of 51 (7 gilts and 44 sows) and 53 (8 gilts and 45 sows) females for treatments 1.8 and 2.2 kg/d, respectively.

97.0%), total born piglets (13.1 and 14.1), born alive piglets (12.5 and 13.4), retention rate until the next farrowing (90.7% and 81.1%), and culling rate (9.1% and 18.8%). The percentage of mummified fetuses in the subsequent farrowing tended to be greater ($P = 0.068$) in the 2.2 kg/d treatment (Table 3).

In the subsample selected for the evaluation of the weaning performance, the percentage of weaned piglets, piglet weaning weight, total litter weight at weaning, piglet daily weight gain, and the CV of weaning weight were not different between the 2 treatments ($P \geq 0.10$; Table 3). However, the piglets nursed by sows had greater daily weight gain

Table 4. Least square means estimates (SEM) and probability values of the effects of feed treatment during late gestation and class of litter size on the birth weight of piglets

	Gilts						
	Class of litter size[1]						
	<15		≥15				
	Treatments[2]				*P*-value		
	1.8	2.2	1.8	2.2			
Item	*n* = 28	*n* = 22	*n* = 32	*n* = 28	Treatment	Litter-size class	Treatment × litter-size class
Total piglets born, *n*	12.1 (0.4)	11.9 (0.4)	16.7 (0.3)	16.6 (0.4)	0.666	<0.001	0.910
Born alive + stillborn, *n*	11.9 (0.4)	11.7 (0.4)	16.2 (0.4)	16.3 (0.4)	0.930	<0.001	0.729
Piglet birth weight, g	1379.7 (29.2)	1376.8 (33.7)	1151.2 (27.3)	1179.2 (29.2)	0.676	<0.001	0.606
Within-litter birth weight CV, %	16.2 (1.0)	16.1 (1.1)	22.1 (1.0)	20.6 (1.1)	0.470	<0.001	0.534
	Sows						
	Class of litter size[1]						
	<16		≥16				
	Treatments[2]				*P*-value		
	1.8	2.2	1.8	2.2			
Item	*n* = 74	*n* = 71	*n* = 71	*n* = 81	Treatment	Litter-size class	Treatment × litter-size class
Total piglets born, *n*	12.6 (0.2)	13.2 (0.2)	17.7 (0.2)	18.1 (0.2)	0.050	<0.001	0.682
Born alive + stillborn, *n*	12.5 (0.2)	13.1 (0.2)	17.2 (0.2)	17.7 (0.2)	0.017	<0.001	0.834
Piglet birth weight, g	1454.4 (20.7)	1439.8 (21.0)	1262.1 (21.2)	1281.5 (19.8)	0.907	<0.001	0.413
Within-litter birth weight CV, %	18.3 (0.6)	19.2 (0.6)	22.6 (0.7)	22.5 (0.6)	0.566	<0.001	0.428

[1]Class of litter size: considering the median of the total born in gilts and in sows.

[2]Treatments: 1.8 or 2.2 kg/d from day 90 until farrowing.

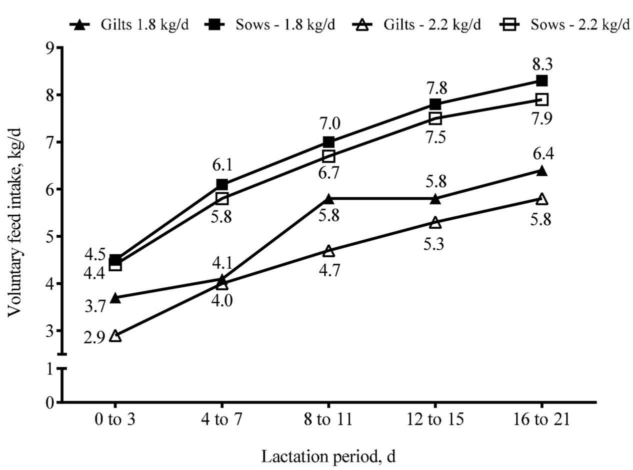

Figure 1. Voluntary feed intake during the lactation of females from the randomly selected subsample, according to feed intake level (1.8 or 2.2 kg/d) from day 90 of gestation until farrowing. Treatment effect: $P = 0.028$; parity effect: $P < 0.001$; treatment × parity interaction: $P = 0.354$; period effect: $P < 0.001$; SEM = 0.17.

and CV of weaning weight, compared to the piglets that were nursed by gilts ($P < 0.05$).

The feed intake during lactation (Fig. 1) was affected by treatment during late gestation ($P = 0.028$), parity ($P < 0.001$), as well as by the lactation period ($P < 0.001$), with no interaction effect. Females fed on 1.8 kg/d of diet during the late gestation period exhibited greater ($P < 0.001$) lactation feed intake compared to the females fed on 2.2 kg/d of diet (5.94 ± 0.19 and 5.50 ± 0.18 kg/d, respectively). Sows exhibited greater feed intake during lactation compared to gilts (6.59 ± 0.15 and 4.85 ± 0.22 kg/d, respectively).

DISCUSSION

The selection for the hyperprolific genotypes without selecting for piglet birth weight, during the last few decades, has caused a reduction in the individual piglet birth weight, and therefore, has created a necessity to reassess the nutritional requirements of the gestating sows. Several studies have been conducted with the aim of increasing the piglet birth weight through the enhancement of feed allowance during late gestation. However, most of these studies have not evaluated the effects of increasing the feed intake during late gestation on the lactation performance, such as litter weight at weaning, sow feed intake, and the subsequent reproductive performance after weaning. Therefore, the present study aimed to verify the effects of increasing the feed amount during the last third of gestation on the piglet birth weight, as well as on the litter during lactation and on the female reproductive performance.

Piglet Birth Weight

It is known that there is a greater demand for nutrients for the fetal growth in the last third of gestation (McPherson et al., 2004; NRC, 2012). We assumed that increasing the feed amount (400 g; 1.3 Mcal ME per day or 1.0 Mcal NE per day) during this period would increase the piglet birth weight. In a summary of the literature on this subject, an average increase of 28 g in the piglet birth weight has been reported (Gonçalves et al., 2016a), and the benefits were observed mainly in gilts and not in sows (Shelton et al., 2009; Soto et al., 2011). A recent study conducted with 741 gilts in a 2 × 2 factorial arrangement, with 2 lysine levels (10.7 or 20.0 g/d SID Lys) and 2 energy levels (5.9 or 8.85 Mcal ME per day), during a period from day 90 of gestation until farrowing, reported an increase of 30 g in the piglet birth weight (1,250 g increased to 1,280 g), with 14.5 piglets per litter, in gilts that were submitted to the high-energy diet (Gonçalves et al., 2016b). Although the increase of 1.3 Mcal ME per day is lower than 2.9 Mcal ME per day reported by Gonçalves et al. (2016b), an increase in birth weight was still expected in females receiving 2.2 kg/d because the 1.8 kg/d treatment is not characteristic of overfeeding. However, the fact that birth weight was not affected in the present study or even when the increase in feed amount from day 100 of gestation onwards (2.3 to 3.9 kg/d) was greater (Miller et al., 2000), reinforces the controversial aspect of this issue.

Piglet Birth Weight Within the Litter-Size Classes

It is not well understood whether the females with large litter sizes respond differently to changes in the feed levels compared to the females with smaller litters. However, in the present study, where 2 different litter-size classes were constituted for each parity class (gilts and sows), no interactions were observed between treatments and litter-size classes for piglet birth weight, despite a difference of approximately 5 piglets between the classes created.

Body Weight Gain

Gonçalves et al. (2016a) summarized the scientific literature regarding this subject and concluded that the female BW gain increased by 7 kg for every 3.3 Mcal ME (approximately 1 kg of a diet based on a corn-soybean meal) increase in the daily energy intake beyond 5.9 Mcal ME. In the present study, the increase of daily energy intake by 1.3 Mcal ME resulted in 3.1 kg more of body weight gain in the 2.2 kg/d treatment, which was very close to the value of 3.0 kg as reported in the previous studies cited by Gonçalves et al. (2016a).

The similar body weight gain between gilts and sows contradicts the assumption that a greater weight gain is expected for gilts (NRC, 2012), as these females are growing even during their last third of gestation, hence exhibiting a relatively greater growth rate than older females. The model suggested by NRC is an estimation based on litters with 12.5 piglets and 2.53 kg daily feed intake (7.93 Mcal ME per day), which is in contrast with the 14.5 total born piglets and the 2.2 kg/d daily feed intake (7.1 Mcal ME per day) in the present study. Therefore, the nutritional levels were lower in the present study, compared to those in the study by Gonçalves et al. (2016b), in which the gilts with 14.5 total born piglets and fed on a diet of 8.9 Mcal ME per day and 20 g SID Lys demonstrated a body weight accretion of 24.5 kg in the same gestation period.

Lactation Feed Intake and Performance

The reduced feed intake during lactation in the females of the 2.2 kg/d treatment was probably the result of their greater body weights at farrowing due to greater BW gain during late gestation. It is well known that the females with great feed intake during gestation are heavier at farrowing, and exhibit lower feed intake during lactation (Weldon et al., 1994; Revell et al., 1998); this is because the voluntary feed intake is controlled by the metabolic condition and driven by central nervous system (Eissen et al., 2000). Two studies with similar findings have reported negative effects on the feed intake during lactation as a result of increasing the feeding levels during the last third of gestation (Cromwell et al., 1989; Shelton et al., 2009). Although the females from the 1.8 kg/d treatment exhibited greater feed intake during lactation, the additional feed intake did not appear to be converted into milk production, as no effects on the litter performance were observed. It is possible that, even with our reasonable sample size, the magnitude of change in the feed intake was not sufficiently great to affect the weaning weight of the piglets. The small difference in the feed intake between the 2 treatments (approximately 5%) contrasts with approximately 25% lower feed intake reported by Sulabo et al. (2010), which was shown to reduce the piglet performance. Indeed, severe reductions in the feed intake (King and Dunkin, 1986; Sulabo et al., 2010) and daily lysine intake (Kusina et al., 1999) affect the milk production, especially during the last week of lactation, when the demand for nutrients is raised up by the piglets. However, the body reserves are also important in this regard, as the restricted feed intake is compensated by the mobilization of the body reserves (Theil et al., 2012). Summarizing, it is likely that piglet performance was not affected by the feed amount offered in late gestation because the increased feed intake during lactation in the 1.8 kg/d treatment was offset by a greater body weight loss in the 2.2 kg/d treatment.

Subsequent Reproductive Performance

Although the females of the 2.2 kg/d treatment lost more body weight from day 112 of gestation until weaning, the WEI was not affected. Schenkel et al. (2010) weighed sows after farrowing as well as at weaning and observed that the body weight losses during the lactation period (≤8% or >8%) caused no negative effects on the WEI. Similarly, Gonçalves et al. (2016b) did not find evidence of an impact on the reproductive variables in the subsequent cycle with the increasing feed level in the last third of gestation. It is clear that the excessive losses during lactation are responsible for the negative effects on the subsequent reproductive cycle (Koketsu et al., 1996; Koketsu et al., 2017). However, it is also important to note that the contemporary females are less sensitive and more resilient to metabolic changes during lactation (Patterson et al., 2011). Finally, even with the logistical challenges involved, the studies demonstrating the long-term effects of the gestation feeding programs over several cycles on sow longevity and the subsequent reproductive performance may prove to be beneficial.

Comments on the Current Factorial Requirement Models

The findings of the present study and the other recent studies regarding this subject prompted the authors to presume that the current factorial models, such as NRC (2012), appear to fail in being related to productive parameters, such as birth weight and maximum lactation feed intake, probably because such models are mostly based on nitrogen balance. Additionally, the hierarchical priorities of gestating gilts and sows change when they progress from early to late gestation (Theil et al., 2014), which is apparently not accounted for in the current models. In late gestation, even though conceptuses are the priority, the birth weight is not easily modified by maternal nutrition. The events that occur earlier in gestation can also affect the fetal development. Foxcroft (2012) suggests that exaggerated ovulation rates drive the crowding of embryos in utero and thus set up the programming of a low birth weight phenotype. Furthermore, the estimation of nutritional requirements for pregnant sows can be influenced by mechanisms set up at the end of gestation, which can affect the fetal growth. A scenario of insulin resistance is established, allowing for an improved placental transfer of glucose to fulfill the increasing demand by the growing conceptuses (Père and Etienne, 2007). In a recent study, the glucose uptake per fetus and the insulinemia were lower in sows with more fetuses (Père and Etienne, 2018), suggesting that hyperprolific females can develop a limited insulin resistance, which can impair the transfer of nutrients to the fetuses, regardless of the amount of energy intake.

The greater amino acid and energy requirements estimated by the current models on the basis of nitrogen balance appear to predict the weight gain of the female adequately; however, they do not appear to account for the negative effects on the feed intake during lactation, as observed in the present and other studies, nor do these models account for the increased stillborn rate (Gonçalves et al., 2016b) in the litters of heavier females. Lastly, as the litter size increased over the years, there has been a sustained genetic selection for growth and feed efficiency in both sire and maternal lines, which could be partially contributing to the lack of response to greater nutrient levels during gestation. With the recent addition of individual piglet birth weight to the genetic selection index by a few genetic companies, avoiding over-conditioned herds will become paramount.

CONCLUSION

Increasing the feed intake in the last third of gestation from 1.8 to 2.2 kg/d in the females with adequate body conditions increased the female body weight gain; however, it failed to improve the piglet birth weight. This increase in the feed intake caused negative effects on the feed intake during lactation and did not lead to any improvement in the litter growth or in the subsequent female reproductive performance.

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