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RESEARCH ARTICLE

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Responses to different feeding levels during the first month post-insemination in highly prolific multiparous sows

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Abstract

Aim of study: To evaluate the impact of the feed level during the first month of gestation on body weight evolution, backfat and loin muscle depths and reproductive performances in highly prolific sows.

Area of study: Galicia (Northwestern Spain).

Material and methods: Thirty-six Danbred sows were assigned to three experimental groups (n=12) receiving, from day 1 to 30 of pregnancy, 2.5, 3.0 or 3.5 kg/d of a standard diet (8.83 MJ net energy and 138.5 g crude protein/kg). In each group, the number of sows in the second-, third- and fourth-cycle was the same. All animals received, of the same diet, 2.5 kg/d from day 31 to 90 and 3.0 kg/d from day 91 to 107. Seven days prior the parturition, sows were moved to the farrowing-lactating facilities where spent until weaning receiving a common standard lactation diet. At 24 h post-farrowing, litters were standardized to 13 piglets each by cross-fostering.

Main results: The optimal feeding level during the first 30 days of gestation was 3.0 kg/d because a lower amount penalized their body weight gain and a higher amount did not improve their fatty reserves. It is worth considering that the increase from 2.5 to 3.5 kg/d generated advantages at birth (higher and more homogenous piglet weights) but also handicaps (lower litter size). The effects were similar irrespective of the cycle number.

Research highlights: Different feeding levels during the early pregnancy were tested because it is a critical period. Suppling 3.0 kg/d carried out the best productive and reproductive implications.

Additional keywords: body weight; backfat depth; loin muscle; reproductive performances; feeding level; early gestation; sow nutrition.

Abbreviations used: BFD (backfat depth); BW (body weight); LMD (loin muscle depth).

Authors' contributions: JML and MAL: design, interpretation of data; writing the original draft and general supervision of the work. SS and PG: acquisition of data. LPC, SS and MAL: analysis of data. PDP, AM, LPC and MAL: writing and reviewing the paper. JML: coordination of the research project and obtaining funding.

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Introduction

The modern swine industries rely on the sustainable, efficient and inexpensive process to produce pigs. Therefore, pig-producing structures managing large herds of sows and growing pigs from weaning until slaughter wish to maximize their economic return. Nevertheless, there are many items for lowering a farm's operational costs and improving its bottom line; the main topic over which pig producers have control is the feeding of their pigs.

Since sows and their litters represent no more than 20% of the total feeding, pig producers have focused more on growing pigs (from weaning to slaughter), as they represent the highest feeding costs for the swine industry. Consequently, sows and their litters are still fed under a general criterion without great emphasis on their physiological status apart from clearly differentiating the gestating from the lactating sow plus their litter. Therefore, this may be a forgotten step in swine production in which specific feeding strategies may play a major role to produce pigs at minimum cost (Solà-Oriol & Gasa, 2017).

In sows, various nutritional strategies have been evaluated in an attempt to improve their body condition and the survival rate of the progeny, such as supplying different feeding levels at early- (Sinclair *et al.,* 2001; Almeida *et al.,* 2017), mid- (Cerisuelo *et al.,* 2009, 2010) or late-gestation (Mallmann *et al.,* 2019). Contradictions have arisen especially about the effect of the feeding plan during the first stage of pregnancy on embryonic survival and therefore on litter size and weight. Some authors suggest that high levels have negative effects (den Hartog & van Kempen, 1980) whereas others conclude that they have no effect (Quesnel *et al.,* 2010) or even that the effects are positive (Hoving *et al.,* 2011).

In practice, to establish a proper feed intake gestation curve, sows should be fed based on an objective measure of individual body energy and nutrient reserves; measures used on the farm should include body weight (BW), body condition score and, ideally, measurement of backfat thickness (Young *et al.,* 2004), but these are not easy to perform, interpret and integrate in commercial conditions.

The aim of this study was to evaluate the implications of supplying different levels of feed during the first 30 days of gestation on BW evolution, backfat and loin muscle depths (BFD and LMD, respectively) and reproductive performances in highly prolific second-, third- and fourth parity sows.

Material and methods

Animal husbandry and experimental design

The trial was conducted during a 10-month period (Nov. 2016-Aug. 2017). A total of 36 hyperprolific Danbred second-parity (n=12), third-parity (n=12) and fourth-parity (n=12) sows were used. Experimental animals were housed in stalls and checked for oestrus 2 times per day (09:00 h and 15:30 h) using the back-pressure test in the presence of a mature teaser boar. Twenty-four hours after the first standing heat reflex, sows were inseminated with a commercial dose of semen ($2 \cdot 10^9$ sperm cells of a Pietrain boar line; Nucleus, France). If still in oestrus, sows received a second insemination 16 to 24 h after the first insemination and a third application was used when necessary. After, animals were divided into one of three experimental treatments per parity group which were based in the feeding level given from day 1 to 30 post-insemination: 2.5 kg/d, 3.0 kg/d, or 3.5 kg/d.

Management and controls

From day 1 to 107 post-insemination, sows were housed in pens of 12. For feeding, animals were locked in the crates for 30 min to give each one the chance to eat its portion of the feed. During the first 30 days of pregnancy, sows received the experimental treatment described above (2.5 vs 3.0 vs 3.5 kg/d). From day 18 of gestation onward, sows were checked for signs of oestrus twice daily using a mature teaser boar. If it was positive, date of return to oestrus after the first insemination was recorded as the first date a standing heat reflex was observed. Around 4 weeks of gestation, ultrasound scan (WED-3000V, Well Medical Electronics Co., Ltd., Shenzhen, Hong Kong) was performed to confirm pregnancy. It was decided that if an animal did not return to oestrus but was diagnosed as not pregnant, the date of the ultrasound scan would be recorded as the date when the sow was no longer pregnant.

From day 31 to 90 of gestation, all sows received 2.5 kg/d and from day 91 to 107, the feeding level was increased to 3.0 kg/d. The diet provided until that moment was standard and common for all of them (ingredients and nutrients are shown in Table 1). That feed was distributed twice per day (07:30 h and 14:30 h) and water was available *ad libitum*. Cylinder plastic dispensers with graduation marks were used. They were previously calibrated to verify the feed supply.

At day 108 of pregnancy (7 days prior to the estimated date for parturition), sows were moved to farrowing crates (2.6 × 1.8 m) which included a stall (2.1 × 0.5 × 0.9 m), where stayed until weaning, receiving a commercial lactation diet (Table 1). With the aim of avoiding feed wastage, the days before farrowing, the feed supplies was gradually reduced to 2 kg on the day of farrowing (or- lower, depending on sow appetite). Feed during lactation

Table 1. Composition of the diet provided during gestation and lactation periods (g/kg as-fed basis unless otherwise indicated).

Ingredients	Gestation	Lactation
Barley	150.0	220.0
Wheat	85.5	231.5
Maize	200.0	157.2
Sugarcane molasses	5.0	-
Blended fat	5.0	15.0
Rape seed meal 00	-	20.0
Sunflower meal (36% crude protein)	42.5	30.0
Palm kernel meal	80.0	64.0
Soybean meal (47% crude protein)	10.0	106.0
Maize dried distiller grains and solubles	100.0	60.0
Wheat bran	211.5	30.7
Beet molasses	70.0	20.0
Soybean hulls	7.7	-
Sodium bicarbonate	-	4.0
Calcium carbonate	13.5	19.6
Monocalcium phosphate	2.5	6.4
Sodium chloride	5.0	2.6
L-Lysine 50%	4.9	6.2
Threonine	0.9	1.3
Vitamin and mineral premix[a]	2.0	2.0
Others (additives)[b]	4.0	3.5
Calculated content[c]		
Net energy (MJ/kg)	8.83	9.37
Dry matter	881	882
Crude protein	138.5	161.1
SID[d] Lysine	6.0	8.5
SID Methionine	2.0	2.6
SID Methionine + Cystine	4.0	4.9
SID Threonine	4.3	5.8
SID Tryptophan	1.1	1.5
Neutral detergent fiber	263	184
Ether extract	38.9	40.9
Starch	320	366
Total ash	53.5	60.0
Total Ca	7.5	10.0
Total P	5.3	5.4
Dig. P	2.65	2.67

[a]Premix for gestion provided (per kg of complete diet): 10,000 IU Vitamin A; 2,000 IU Vitamin D3; 75 mg Vitamin E; 2 mg Vitamin K3; 0.8 mg Vitamin B1; 3 g Vitamin B2; 1.5 mg Vitamin B6; 20 mg Vitamin B12; 20 mg nicotinic acid; 10 mg pantothenic acid; 4 mg folic acid; 0.2 mg Biotine; 60 mg Mn (40 mg sulphate and 20 mg chelate); 1 mg I (iodure); 100 mg Zn (50 mg sulphate and 50 mg quelate); 10 mg Cu (chelate); 100 mg Fe (sulphate); 0.3 mg Se (sodium selenite). Premix for lactation provided (per kg of complete diet): 10,000 IU Vitamin A; 2,000 IU Vitamin D3; 125 mg Vitamin E; 4 mg Vitamin K3; 1.2 mg Vitamin B1; 5 g Vitamin B2; 3 mg Vitamin B6; 30 mg Vitamin B12; 30 mg nicotinic acid; 15 mg pantothenic acid; 7 mg folic acid; 0.4 mg Biotine; 70 mg Mn (50 mg sulphate and 20 mg chelate); 2 mg I (iodure); 100 mg Zn (50 mg sulphate and 50 mg quelate); 10 mg Cu (chelate); 100 mg Fe (sulphate); 0.3 mg Se (sodium selenite). [b]Choline chloride, phytases, essential oils. [c]According to FEDNA (2010). [d]SID: standardized ileal digestibility.

was given as dry feed twice a day (07:30 and 14:30 h) and the sows had free access to water via nipple drinkers placed in the feeder. For all animals, feeding level during lactation was gradually increased, from approximately 2 kg/d on the day of farrowing, to an *ad libitum* level until weaning (the average daily feed intake was 5 kg/sow/d irrespective of the treatment).

Individual BFD and LMD were measured at days 30, 90 and 107 of gestation and at weaning, and also individual sow BW were recorded at the same moments as well as after farrowing (24 h later). The BFD was measured using a Renco device (Renco sonograder 4.2, Renco Corporation, Minneapolis, USA), above the last rib on the left side at 6.0-6.5 cm from the midline. Also, an ultrasound scan (WED-3000V, Well Medical Electronics Co., Ltd., Shenzhen, Hong Kong) was used to record the BFD and LMD measured at the same location. Lipid and protein content of the body were mathematically estimated through the prediction equations developed by Dourmad *et al.* (1997) as following:

$$\text{Lipid (kg)} = -26.4 + (0.221 \cdot \text{Empty BW}) + (1.331 \cdot \text{BFD})$$

$$\text{Protein (kg)} = 2.28 + (0.178 \cdot \text{Empty BW}) - (0.333 \cdot \text{BFD})$$

where Empty BW = BW·0.96.

At farrowing, piglets, including total, alive and stillborn (including mummified, stillborn and died during farrowing), were counted and individually weighed. At 24 h post-farrowing, litter size was adjusted to 13 piglets per litter and cross-fostering was only allowed among sows of the same dietary treatment. The number of pigs and their weights were recorded again after the litter standardization. Lactation lasted 26 ± 2 days as average and no creep feeding was provided to the piglets during that period. Healthy status in sows, piglet mortality and causes of death during lactation were recorded. From day 2 post-weaning, sows were checked every morning and evening in order to detect oestrus and were inseminated again. Weaning-to-mating interval was also recorded. By program design, sows that were not detected in oestrus after 7 days or more from weaning and also those that returned to oestrus after insemination were not maintained in the next cycle. The management during the next cycle was the same as the previous one except for the feeding supply during the first 30 days of gestation, which was 3.0 kg/d for all of them. Again, at farrowing, piglets, including total, alive and stillborn, were counted and individually weighed.

Statistical analyses

Data were analysed as a randomized factorial design (3 × 3), using the GLM procedure of the SAS package (vers. 9.2). The model included the number of parity (second, third or fourth) and the feeding level provided during the first month of pregnancy (2.5, 3.0 or 3.5 kg/day) as main effects, as well as the interaction parity number × feeding level. The CORR procedure of SAS was used to obtain the correlations between BFD or LMD and to

Table 2. Effect of the feeding level during the first 30 days of pregnancy on body weight (BW, kg) in second-, third- and fourth parity sows during the trial.

	Diet			Parity			SEM[a]	p^b	
	2.5 kg/d	3.0 kg/d	3.5 kg/d	2nd	3rd	4th	(n=12)	Diet	Parity
n	4	4	4	4	4	4			
At day 30 of gestation (end of dietary treatment)	223.9	220.8	224.6	224.3	222.9	222.0	1.018	0.06	ns
At day 90 of gestation	237.6xy	234.6y	239.1x	239.0	237.0	235.4	1.046	*	ns
At farrowing (at day 107 of gestation)	244.9y	249.5x	248.7x	249.5	247.6	245.9	1.234	*	ns
After farrowing	216.5y	220.5x	220.4x	220.5	219.7	217.2	0.997	*	ns
At weaning	210.8	213.0	213.0	215.0	212.1	209.7	1.412	ns	ns
Δ BW during farrowing	-28.4	-29.0	-28.3	-29.0	-27.9	-28.8	1.255	ns	ns
Δ BW during lactation	-5.6	-7.5	-7.4	-5.6	-7.6	-7.3	0.755	ns	ns
Δ BW from previous weaning to farrowing	40.0y	44.6x	43.7x	44.6	42.7	41.0	1.234	*	ns
Δ BW between two consecutive weanings	5.8	8.1	8.0	10.1x	7.2xy	4.7y	0.878	ns	**

[a]SEM: standard error of mean. [b]No significant (ns) interaction (diet × parity number) was detected (p>0.10). p significance: *p<0.05; **p<0.01. [x,y] Means with different letters within a row differ (p<0.05).

predict body composition of sows (estimate lipid and protein content calculated from Dourmad *et al.,* 1997). The experimental unit was the sow. A *p*-value < 0.05 was considered as a significant difference and a *p*-value between 0.05 and 0.10 as a trend.

Results

No significant interactions between feed supply and parity number were detected for any of the variables studied and therefore only main effects are reported.

Evolution of sow body weight

The Table 2 shows the BW evolution of sows during the trial. The increase of feeding planning from 2.5 to 3.0 kg/d, but not above it, during the first 30 days of gestation, increased the sow BW at day 107 of pregnancy ($p<0.05$) and after farrowing ($p=0.02$) but the effect disappeared at weaning ($p>0.05$). The mentioned effect was also detected on the BW gain from the previous weaning to the farrowing (40.0, 44.6 and 43.7 kg, for 2.5, 3.0 and 3.5 kg/d, respectively; $p<0.05$) although it was diluted when the evaluated period was longer (full cycle, between two consecutive weaning) ($p>0.05$).

In the present trial, there was no difference due to the parity number in the initial BW of sows (the first data were taken at day 30 of gestation), which was also observed at days 90 and 107 of pregnancy, after farrowing and at weaning ($p>0.05$). However, the BW gain considering the full cycle was affected, being higher in the second- than in the fourth-parity sows, with those in the third one in an intermediate position (10.1, 7.2 y 4.7 kg, respectively; $p=0.005$).

Development of backfat and loin muscle

From the results obtained by scan, we can observe that the BFD and LMD increased through the gestation being, in both cases, 1.6 mm as average (calculated between the day 30 of pregnancy and the farrowing) (Table 3). Also, both parameters decreased through the lactation by 3.6 and 0.4 mm, respectively. The Figure 1 shows an overview of

Table 3. Effect of the feeding level during the first 30 days of pregnancy on backfat depth (BFD) and loin muscle depth (LMD) measures in second-, third- and fourth parity sows during the trial.

	Diet			Parity			SEM[a]	p[b]	
	2.5 kg/d	3.0 kg/d	3.5 kg/d	2nd	3rd	4th	(n=12)	Diet	Parity
n	4	4	4	4	4	4			
BFD by Renco (mm)									
at day 30 of gestation (end of dietary treatment)	10.8	11.7	10.9	10.7	11.6	11.1	0.328	ns	ns
at day 90 of gestation	10.4	11.4	13.1	12.1	11.4	11.4	0.715	0.06	ns
at farrowing (at day 107 of gestation)	11.1y	13.3x	13.3x	11.8	12.5	13.5	0.561	*	ns
at weaning	9.4	9.5	9.6	8.8	9.8	9.9	0.452	ns	ns
BFD by scan (mm)									
at day 30 of gestation (end of dietary treatment)	11.3	11.7	11.5	11.0	11.7	11.7	0.292	ns	ns
at day 90 of gestation	12.5	11.6	13.1	12.1	12.3	12.8	0.469	ns	ns
at farrowing (at day 107 of gestation)	12.0	13.5	13.8	12.2y	12.8xy	14.4x	0.532	0.08	*
at weaning	9.3	9.5	9.8	9.1	9.3	10.2	0.474	ns	ns
Δ BFD during lactation	-2.6	-2.1	-4.0	-3.0	-3.5	-4.3	0.551	ns	ns
Δ BFD from the previous weaning to farrowing	1.2	3.4	3.6	1.9y	2.6xy	4.2x	0.532	0.08	*
LMD by scan (mm)									
at day 30 of gestation (end of dietary treatment)	43.6	43.5	42.9	42.7	43.3	43.9	0.366	ns	ns
at day 90 of gestation	43.9	44.8	43.6	43.6	43.9	44.7	0.407	ns	ns
at farrowing (at day 107 of gestation)	43.9y	43.7y	47.2x	44.6	45.4	44.9	0.535	***	ns
at weaning	43.4y	42.5y	47.8x	44.4	45.9	44.2	0.542	***	ns
Δ LMD during lactation	-0.55x	-1.23x	+0.60y	-0.16	-0.36	-0.65	0.337	*	ns
Δ LMD from the previous weaning to farrowing	0.77y	0.55y	4.06x	1.45	2.20	1.73	0.535	***	ns

[a]SEM: standard error of mean. [b]No significant (ns) interaction (diet × parity number) was detected ($p>0.10$). p significance: *$p<0.05$; ***$p<0.001$. [x,y] Means with different letters within a row differ ($p<0.05$).

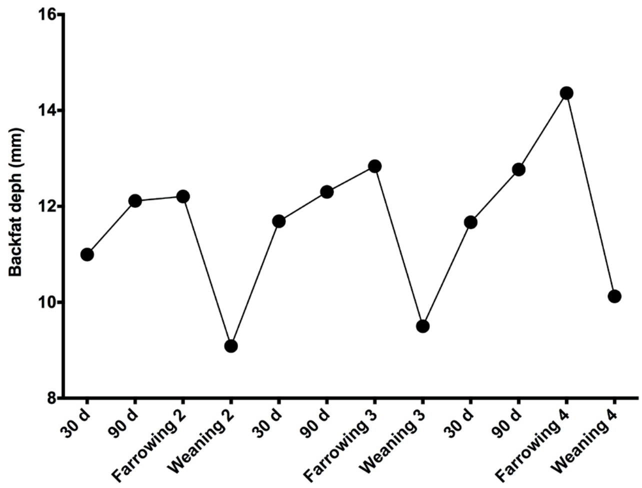

Figure 1. Evolution of backfat depth (measured by scan), during the experimental period, in second-, third- and fourth-parity highly prolific sows, irrespective of diet.

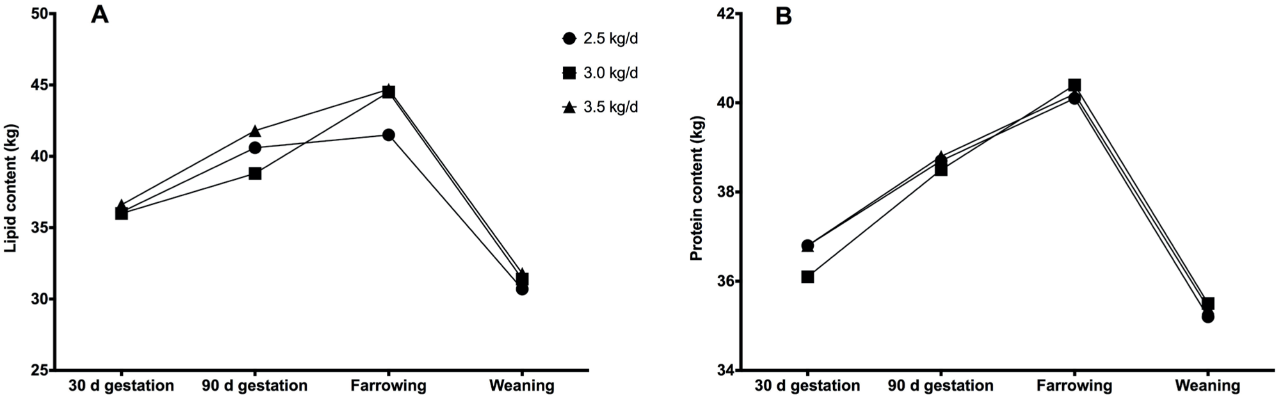

Figure 2. Effect of the feeding level during the first 30 days of pregnancy on the lipid content (A) and protein content (B) change through gestation and lactation in highly prolific sows. Data estimated using the prediction equations of Dourmad *et al.* (1997).

the development of BFD over parities (obtained by linking the mean data from the three parity groups studied). Each cycle can be clearly identified, with the peaks corresponding with the farrowing and the valleys with the weaning. Also, the influence of the different feeding levels provided during the first 30 days of pregnancy on the change of the lipid content (Fig. 2A) and protein content (Figure 2B) in the sows shows a clear increase of both parameters through gestation and a drastic decrease in both parameters through lactation. It was estimated according to Dourmad *et al.* (1997).

The Table 3 also shows that sows receiving 3.0 or 3.5 kg/d, during the first month of pregnancy, had thicker BFD than those given 2.5 kg/d. It was detected at 90 days of gestation (measured by Renco, p=0.06) and also at farrowing (measured by Renco, p=0.03 and by scan, p=0.08) but these differences were not maintained through lactation. On the other hand, sows fed 3.5 kg/d had higher LMD than the remaining groups as much at farrowing as at weaning (p<0.001) and that group was the only one in which LMD increased through the lactation (p=0.02). When the period studied is longer (from the previous weaning to the farrowing), it was found that BFD and LMD gains were higher as feeding level increased (p=0.08 y p<0.001, respectively).

With respect to the number of cycle, thicker BFD was observed in fourth- than in second-parity sows, which was detected by scan especially at farrowing (p=0.03). In

Table 4. Effect of the feeding level during the first 30 days of pregnancy on reproductive performances in second-, third- and fourth parity sows during the trial.

	Diet			Parity			SEM[a] (n=12)	p^b	
	2.5 kg/d	3.0 kg/d	3.5 kg/d	2[nd]	3[rd]	4[th]		Diet	Parity
n	4	4	4	4	4	4			
At farrowing									
Total number of piglets born	19.8	17.7	16.2	17.5	17.8	18.5	0.930	0.06	ns
Total number of piglets born alive	16.9	15.1	14.0	14.7	15.2	16.0	0.770	0.07	ns
Mortality (%)[c]	14.5	14.7	13.6	16.0	14.4	13.5	2.792	ns	ns
Litter weight (kg)[d]	20.3	20.4	20.0	19.9	20.2	20.6	1.298	ns	ns
Litter weight variability (CV)[e]	23.7	19.8	19.5	17.6y	23.8x	21.6x	1.135	0.08	*
Piglet weight (kg)[d]	1.20y	1.35xy	1.43x	1.36	1.33	1.29	0.048	*	ns
After standardization of litters[f]									
Litter weight (kg)	17.6y	19.3xy	20.2x	18.8	19.2	19.1	0.591	*	ns
Piglet weight (kg)	1.35y	1.48xy	1.55x	1.44	1.47	1.47	0.045	*	ns
At weaning									
Total number of piglets weaning	12.4	12.2	12.2	11.7	12.5	12.5	0.260	ns	ns
Litter weight (kg)	66.1x	51.3y	70.6x	56.7y	64.9x	66.5x	2.221	***	*
Piglet weight (kg)	5.34x	4.21y	5.77x	4.83	5.18	5.31	0.151	***	ns
Mortality during lactation (%)	5.2	7.2	7.9	12.1	4.0	4.1	2.450	ns	0.08
At the next parity									
Total number of piglets born	17.4	15.8	16.9	16.2	17.0	16.9	0.804	ns	ns
Total number of piglets born alive	16.1	13.9	14.9	14.5	15.0	15.3	0.762	ns	ns
Mortality (%)[c]	7.4	10.1	12.1	8.3	11.8	9.6	1.412	ns	ns

[a]SEM: error of mean. [b]No significant (ns) interaction (diet × parity number) was detected ($p>0.10$). p significance: *$p<0.05$; ***$p<0.001$. [c]Including mummified, stillborn and died during farrowing. [d]Only piglets alive born were considered. [e]It was calculated as standard deviation of the individual body weight of piglets × 100/litter weight. Only pigs born alive were considered. [f]The litter size was standardized to 13 piglets per litter. [x,y]Means with different letters within a row differ ($p<0.05$).

addition, the oldest sows (fourth cycle) had higher BFD gain than those youngest (second cycle) ($p=0.03$), measured from the previous weaning to the farrowing, but they also had higher fat losses (BFD) during lactation although it was not significant ($p>0.05$).

Reproductive performances

The farrowing rate during the experimental period was 100%. However, in the next cycle, three sows were negative to pregnancy diagnosis; one sow fed previously 3.5 kg/d (third parity) and two sows fed 3.0 kg/d (1 of the third and 1 of the fourth parity). The increase of the feeding level from 2.5 to 3.5 kg/d during the first 30 days of gestation impaired some parameters related to the sow reproductive performance (Table 4); it tended to reduce the total number of piglets born ($p=0.06$) and also the number of piglets born alive ($p=0.07$). On the other hand, the increase of feed intake also had some positive consequences on sow reproductive variables such as the increase in the average piglet weight at birth (from 1.20 to 1.43 kg; $p=0.02$) and a trend was detected to reduce the variability in the litter birth weight ($p=0.08$).

Regarding to the impact of cycle, it was observed that the litter size (total or alive piglets) and weight at birth increased and the average piglet weight decreased from the second to the fourth parity but the differences were only numerical ($p>0.05$). However, a higher variability in the litter birth weight was found in third- and fourth- than in the second-parity sows ($p=0.02$).

After the standardization of litters (to 13 piglets per litter), heavier litters ($p=0.03$) and also heavier piglets. ($p=0.03$) were found in the group of sows given the highest feeding plan than in those fed the lowest plan. However, the litter weight and the average piglet weight were similar irrespectively of the parity number after the adjustment of litters ($p>0.05$). At weaning, no differences in the litter size due to feeding plan during gestation or to the number of parity were detected ($p>0.05$). However, sows fed the intermediate feeding treatment (3.0 kg/d) had lighter litters ($p<0.001$) because of a lower average piglet weight ($p<0.001$). On the other hand, the second-parity sows tended to have the highest mortality during lactation ($p=0.08$) and it carried out that their litters were less heavy at weaning ($p=0.03$). At the next parity, no effect of dietary treatment received during the previous cycle was observed on the reproductive performances ($p>0.05$).

Discussion

Evolution of sow BW

The increase of feeding supply from 2.5 to 3.0 kg/d during the first 30 days of gestation increased the sow BW at farrowing (~ 4 kg) but differences disappeared at weaning. It can be also observed that a feeding level higher than 3.0 kg/d did not have any influence on BW. Unfortunately, the BW at the day of insemination was not recorded, and therefore BW gain during the full gestation could not be calculated. However, the mentioned effect was also observed on the BW gain from the previous weaning to the farrowing although it was diluted when the evaluated period was longer (full cycle, from weaning to weaning). Hoving *et al.* (2011) tested 2.5 vs 3.25 kg/d provided to gilts from day 3 to 32 post-insemination finding differences in sow BW up to 10 kg. Virolainen *et al.* (2004) also detected improvements in gilt weight with high feeding level suggesting that the duration of that supply had to go beyond day 17 of gestation in order to derive the beneficial effect on pregnancy rate. Hoving *et al.* (2012) concluded that increased feed intake improved sow development and might thereby increase sow longevity.

In the current trial, there was no difference in the BW among sows due to the cycle number through the pregnancy and lactation periods, which was surprising because heavier sows were expected as the number of parity increased. Probably the reason for the discrepancies could be the random when choosing the sows and also to the limited number of replicates. However, taking into account a full cycle, the BW gain was higher in the second- than in the fourth-parity sows which would indicate firstly that these sows are growing and secondly that the BW was achieving the *plateau* of the adult BW. Close & Cole (2000) suggested as optimum 5 kg in the sow BW gain between two consecutive parities although it could change with the number of cycle and also depend on the crossbred.

As it is logical, under a physiological point of view, independently of the dietary treatment and the number of parity, the sow BW increased through the gestation (24.6 kg as average, considering only the difference between the days 30 and 107 of gestation) and it decreased with the farrowing (by 28.5 kg) and later during lactation (~ 7 kg). Close & Cole (2000) recommended that the BW loss during lactation was not higher than 10 kg, although Hoving *et al.* (2011) found losses of 20 and 23.4 kg in first- and second-parity sows, respectively.

Development of backfat and loin muscle

Literature focuses mainly on the P2 method when measuring backfat thickness of the sows, which makes difficult to compare recommendations or findings. In the current trial, and as it was expected, BFD and LMD increased through the gestation (1.6 mm in both cases) and decreased through the lactation (by 3.6 and 0.4 mm, respectively). It indicates that gains and losses were in fat and also in lean tissue. Close & Cole (2000) reported, in P2, 3 mm of increase during pregnancy and 2 mm of decrease during lactation. Also, Cerisuelo *et al.* (2010) showed during lactation decreases in BFD by 2.8 mm and in LMD higher than 3 mm in PIC Landrace × Large White sows from first to third parity. Probably, the differences in data among authors could be due to the different crossbreed used, as not all breeds have the same genetic tendency to gain backfat reserves (Jansen-Venneboer, 2011). In addition, Rigon *et al.* (2008) carried out a meta-analysis from 14 studies finding significant correlations between BFD at gestation and feed intake at this phase (-0.09) and also a significant trend between BFD at gestation and feed intake at lactation (-0.08).

Gestation is an anabolic period in the sow's life representing the period of highest weight and body reserves gains of all the reproductive cycle. However, it has to be noted that sows fed 3.0 or 3.5 kg/d during the first 30 days post-insemination resulted fattier though the gestation than those fed 2.5 kg/d although these differences disappeared at weaning. It agrees with Cerisuelo *et al.* (2008) who allowed an extra feed during mid-gestation but other authors found differences also in lactation (Mullan & Williams, 1989; Sinclair *et al.,* 2001). Our results agree with those of Ren *et al.* (2017) who reported that increasing feeding levels during three short periods of pregnancy (27-34 d, 55-62 d and 83-90 d) increased BW and BFD gains during gestation and caused less BW gain and more BFD loss during lactation. However, those authors detected a reduction of lactation feed intake in response to increasing gestation feeding levels and we did not.

The fact of that BFD at farrowing resulted positively correlated with BFD at weaning ($r=0.65$; $p<0.01$) might indicate that the implementation of a feeding strategy that increases backfat level during pregnancy might also assure higher values at weaning. In general, BFD results reported in the present experiment at farrowing and at weaning (13 and 9.5 mm as average, respectively) were far from those obtained by some authors (17 and 13.5 mm; Cerisuelo *et al.,* 2008) or those suggested by others (24 and 22 mm, respectively; Mullan & Williams, 1989). This would indicate that the recommended BFD and gain values must be adapted to each genetic line and commercial conditions. On the other hand, sows fed 3.5 kg/d had thicker LMD than the other groups at farrowing and at weaning and that group was the only one in which LMD increased through the lactation; in fact, it even was reduced (thinner LMD at weaning than at farrowing) in the other groups. When the period studied was longer (from the previous weaning to the farrowing), it was found that BFD and LMD gains were higher as feeding level increased. Thaker & Bilkei (2005) concluded that the sow's reproductive performance can be improved by reducing their weight losses during lactation but higher parity sows can recycle and conceive with higher lactation weight losses compared to parity one animals.

The most common equations used to predict body compositions of sows estimate body lipid and also protein content using BFD and BW values (Dourmad *et al.,* 1997). Figures 2A and 2B show the evolution of the tissues through the gestation (increasing) and lactation (decreasing). However, it should be taken into account that the relation between BFD and body protein content in the sows probably has changed compared to some years ago, due to the strong genetic selection for lean tissue that the modern lines have gone through. In fact, the correlation obtained between the estimated body protein and LMD measured in this study was moderate ($r=0.38$; $p<0.05$). Therefore, the use of a more direct measurement of the muscle such as ultrasonic LMD could be better suited in order to estimate body protein content in these modern genotype instead of, or additionally, to BFD values. The present results also suggest, according to other studies (Whittemore & Morgan, 1990; Pettigrew & Yang, 1997), that BW gain in pregnant sows was more in the form of protein than in the form of fat.

The number of cycle also affected the sow fatness; thicker BFD was observed in fourth- than in second-parity sows at farrowing. It was detected also from the previous weaning to the farrowing, but those sows (fourth parity) also had higher fat losses (BFD) during lactation although it was not significant. It agrees with the paper of Close & Cole (2000) who reported an increase of 1 mm per cycle in P2 as the number of parity increased from the second to the fourth one.

Reproductive performance

The increase of the feeding level from 2.5 to 3.5 kg/d during the first 30 days of gestation had positive and negative consequences. By one hand, it tended to reduce the total number of born and alive born piglets. It has been accepted the association of high feed allowances at early pregnancy with higher embryonic mortality (den Hartog & van Kempen *et al.,* 1980) being the reason the negative influence on plasma progesterone concentration because of increased progesterone clearance in the liver (Prime & Symonds, 1993). A sufficiently increased progesterone level is necessary for synchronous uterine and embryonic development during early pregnancy (Ashworth, 1992). Although it seems to be more evident in gilts than in multiparous sows (Varley & Prime, 1993; Jindal *et al.,* 1997), some authors have concluded that low levels (2 kg/d) were optimal, in eighth-parity sows, because neither a higher (4 kg/d) nor a modified program (2 kg/d for 11 days, 4 kg/d for the next 10 days and 2 kg/d for the next 15 days) gave any benefit (Virolainen *et al.,* 2005). The discrepancies among researchers might be due to differences on the amount of energy and nutrients, the length of time and the period of gestation in which the feed supplementation was provided.

On other hand, in the current trial, the increase of feed intake from 2.5 to 3.5 kg/d increased the piglet weight at birth (by 230 g/piglet) and tended to reduce the variability in the litter birth weight. Cerisuelo *et al.* (2008, 2010) also found that effect on the piglet birth weight, when sow nutrition increased during mid-gestation, but the differences disappeared at day 18 of lactation. It might be related to the muscle fibres formation in utero; the smallest piglets show lower number of them at birth and it also seems to affect the pork tenderness at slaughter (Gondret *et al.,* 2006). Some researchers suggest that there might be key periods during pregnancy, other than late gestation, in which sow feeding allowance can affect fetal growth and development (Dwyer *et al.,* 1994; Gatford *et al.,* 2003).

Literature states an increase in litter size during the first three parities, after which it remain relatively constant, and also a declined average birth weight of piglets as litter size increases (Tummaruk *et al.,* 2000; Kemp *et al.,* 2009). In the present trial, although not significantly, the litter size at birth (total or alive piglets) increased and the average piglet weight decreased with the number of parity. It is important to keep high the average birth weight of the piglets, as this increases their survivability. However, a higher variability in birth weight was found in the piglets from third- and fourth-parity sows than in those from second-parity (Hoving *et al.,* 2011). Quesnel *et al.* (2010) concluded that the high embryonic survival, especially detected in hyperprolific sows, leads to intrauterine crowding with possible subsequent negative impact on placenta and fetus at later stages of development. Literature is indicating that within-litter variation and low birth weight will increase pre-weaning mortality (Damgaard *et al.,* 2003).

The standardization of litters to a regular number of piglets (12-14) is a usual practice in commercial farms with hyper prolific sows to achieve optimal survival rates during lactation and more homogeneity in the piglet weights at weaning. In the present trial, cross-fostering was carried out to achieve it and the adjustment was to 13 piglets per litter. After the standardization, the litters and piglets from sows given the highest feeding plan during the first 30 days of gestation resulted heavier than those fed the remaining plans. It is logical because the litter weight was similar among treatments but more piglets had to be moved from the sows fed 2.5 kg/d, due to their greater litter size than from those fed 3.0 or 3.5 kg/d (3.9, 2.1 and 1.0 piglets were moved, respectively). The litters were similar among sows from different parities after the adjustment, which was expected because few piglets had to be moved in this sense.

At weaning, no impact due to feeding plan during gestation or to the number of parity was detected in the litter size. However, sows fed the intermediate feeding plan (3.0 kg/d) had lighter litters because of a lower average piglet weight. Authors do not have any explanation for that because the lactation length was similar for all treatments and the mortality data were normal for that group showing no healthy problem. Ren *et al.* (2017) found that increasing feeding levels just from 27 to 34 d of gestation increased piglet birth weight, but did not affect piglet weaning weight. On the other hand, the second-parity sows tended to have the highest mortality in piglets during lactation and it carried out that their litters were the lightest at weaning. Morrow *et al.* (1992) reported that sows in the second-parity often show worse reproductive performances. It is difficult to draw conclusions from these findings, as the variation in weight gain or even survivability of piglets may be addressed to cross-fostering.

Finally, at the next parity, no effect of dietary treatment during the previous cycle was observed, according to the results of Ren *et al.* (2017), suggesting that the influences found were diluted through the time.

Under our experimental conditions, it can be concluded that the optimal feeding supply, in highly prolific multiparous sows, during the first 30 days of gestation was 3.0 kg/d because a lower amount penalized their normal body growth and a higher amount did not improve their fat reserves. Other consideration that was taken into account was that the increase from 2.5 to 3.5 kg/d had advantages (more homogenous litters and an increase in the average piglet weight) but also handicaps (lower litter size). The effects were similar irrespective of the parity number.

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