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Non Ruminant Nutrition

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Effect of L-carnitine supplementation and sugar beet pulp inclusion in gilt gestation diets on gilt live weight, lactation feed intake, and offspring growth from birth to slaughter[1]

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Abstract

This study evaluated the effects of L-carnitine (**CAR**) and sugar beet pulp (**SBP**) inclusion in gilt gestation diets on gilt live weight, cortisol concentration, lactation feed intake, and lifetime growth of progeny. Eighty-four pregnant gilts (Large White × Landrace) were randomly assigned to a treatment at day 38 of gestation until parturition; Control (0% SBP, 0 g CAR), CAR (0.125 g/d CAR), SBP (40% SBP), and SBP plus CAR (40% SBP, 0.125 g/d CAR). Gilts were weighed and back-fat depth was recorded on day 38, day 90, and day 108 of gestation and at weaning. Gilt saliva samples were collected pre-farrowing and fecal consistency was scored from entry to the farrowing room until day 5 post-partum. The number of piglets born (total, live, and stillborn) and individual birth weight was recorded. Piglet blood glucose concentration was measured 24 h post-partum and pigs were weighed on day 1, day 6, day 14, day 26, day 76, day 110, and day 147 of life. Carcass data were collected at slaughter. There was no interaction between CAR and SBP for any variable measured. The SBP-fed gilts were heavier on day 90 and day 108 of gestation ($P < 0.05$) and lost more weight during lactation ($P < 0.05$) than control gilts. They also had a greater fecal consistency score ($P < 0.01$). Total farrowing duration, piglet birth interval, and lactation feed intakes were similar between treatments ($P > 0.05$). The number of piglets born (total, live, and stillborn) and piglet birth weight was likewise similar between treatments ($P > 0.05$). Piglets from CAR-fed gilts had lower blood glucose concentrations ($P < 0.01$), while piglets from SBP-fed gilts had greater blood glucose concentrations ($P < 0.01$). Piglets from CAR gilts had a lower average daily gain between day 1 and day 6 ($P < 0.05$) and day 14 and day 26 post-partum ($P < 0.05$) compared to piglets from control gilts. However, CAR gilts weaned a greater number of pigs ($P = 0.07$). Live weight and carcass weight at slaughter were heavier for pigs from CAR gilts ($P < 0.05$) and from SBP gilts ($P < 0.05$). Pigs from CAR gilts ($P < 0.01$) and SBP gilts ($P < 0.05$) had increased carcass muscle depth. In conclusion, no benefit was found from the combined feeding of CAR and SBP. Fed separately, CAR increased the live weight, carcass weight, and muscle depth of progeny at slaughter. Feeding a high SBP diet increased fecal consistency in gilts pre-farrowing and increased live weight and carcass muscle depth of progeny.

Key words: cortisol, dietary fiber, gestation feeding, gilt, L-carnitine supplementation

Introduction

Intense genetic selection for increased sow prolificacy has resulted in a current increase in litter size at birth. This is positively correlated with a higher proportion of piglets of low birth weight (Beaulieu et al., 2010) and increased within litter variation (Quiniou et al., 2007) which have reduced survival rates (Herpin et al., 2002; Quesnel et al., 2012). Targeted nutritional strategies to increase piglet birth weight and lifetime growth may help to mitigate the negative consequences of increased litter size. Supplementation of sow diets with L-carnitine (**CAR**) during gestation has been associated with more piglets born alive (Ramanau et al., 2004, 2008) and increased piglet birth weights (Eder et al., 2001; Ramanau et al., 2004, 2005). However, most research on CAR supplementation has focused on the multiparous sow (Waylan et al., 2005; Ramanau et al., 2006; Wei et al., 2018). Gilts give birth to lighter piglets (Hoving et al., 2010), with lower post-weaning growth rates than multiparous sows (Calderón Díaz et al., 2017). Consequentially, CAR could be particularly beneficial to mitigate against low birth weight and lifetime growth rates of gilt litters. Gestation sow diets fortified with highly soluble fiber sources such as sugar beet pulp (**SBP**) are more effective at improving satiety than either diets high in insoluble fiber or diets low in fiber (Jørgensen et al., 2010). Prolonged feelings of satiety are associated with decreased stress. DeDecker et al. (2014) reported reduced plasma cortisol concentrations in late gestation in sows fed a high-fiber diet. Diets high in soluble fiber can increase gastrointestinal tract weight (Kass et al., 1980; Jørgensen et al., 1996) as their high water binding capacity allows swelling to fill the gut of the animal (Jørgensen et al., 2010). Increasing gut capacity during gestation should allow the sow to consume a larger volume of feed during the subsequent lactation. Gilts have a lower gut capacity than multiparous sows (Theil et al., 2012). This limits their lactation feed intake and consequently their milk yield, perhaps contributing to the lower lifetime growth observed in piglets from gilts litters than sows (Craig et al., 2019). The objective of this study was to evaluate the effects of CAR and SBP inclusion in gilt gestation diets on gilt live weight (**LW**), salivary cortisol concentration, lactation feed intake, and offspring growth from birth to slaughter. We hypothesized that gilts supplemented with CAR would have heavier piglets at birth and that these piglets would have improved lifetime growth and that gilts receiving a high-SBP diet would have lower salivary cortisol concentrations due to increased feelings of satiety, and would achieve higher feed intakes during lactation due to an increase in gut capacity. We also hypothesized that the benefit of CAR supplementation and SBP inclusion would be additive as their mechanisms of action are entirely different.

Materials and Methods

Ethical approval for this study was granted by the Teagasc Animal Ethics Committee (approval no. TAEC120/2016) and the project was authorized by the Health Products Regulatory Authority (project authorization no. AE19132/P051). The experiment was conducted in accordance with Irish legislation (SI no. 543/2012) and the EU Directive 2010/63/EU for animal experimentation. The experiment was carried out between May 2016 and March 2017, on the Teagasc 200 sow integrated research unit at Moorepark, Fermoy, Co. Cork, Ireland.

Animals, Housing, and Treatments

Eighty-four gilts with the same genetic background (Large White × Landrace; Hermitage Genetics, Co. Kilkenny, Ireland) were used in the study. Gilts were artificially inseminated at onset of standing estrus and again 24 h later using pooled semen (Danish Duroc; Hermitage Genetics). Gestating gilts were managed in a dynamic group pen which held 120 animals at any one time. The pen had fully slatted floors, insulated concrete lying bays, and 2 electronic sow feeders [**ESF**s; Schauer Feeding System (Competent 6), Prambachkirchen, Austria]. Water was available ad libitum from single-bite drinkers in the ESFs and from 5 drinker bowls located around the group pen. Experimental gilts were selected from 4 farrowing batches. Batches were inseminated at 3-wk intervals, with approximately 21 gilts per batch. At day 38 of gestation, gilts were blocked within their farrowing batch into 21 blocks of 4 gilts on the basis of LW (mean ± SD; 179.4 ± 9.87 kg) and back-fat depth (**BF**) (16.9 ± 3.42 mm). Within each block, gilts were randomly allocated to one of 4 dietary treatments until parturition: 1) Control (0% SBP, 0 g/d CAR), 2) CAR (0.125 g/d CAR), 3) SBP (40% SBP), and 4) SBP plus CAR (40% SBP, 0.125 g/d CAR). At day 90 of gestation, gilts were moved within their farrowing group to a smaller pen, with the same layout and facilities as the larger group pen. Approximately 6 d before gilts were due to farrow they were moved into standard farrowing rooms, accommodating 7 or 14 animals per room. Farrowing room temperature was maintained at ~24 °C at farrowing and gradually reduced to 21 °C by day 26 of lactation. Artificial lighting was provided daily from 0800 h to 1630 h. Where possible, litter size was standardized during the first 48 h after parturition, within treatment, so that there was an average litter size of 13.4 ± 0.40 piglets per gilt. Rearing capacity of each gilt and the availability of foster sows to take surplus piglets impacted the final number of piglets remaining on each litter at 48 h post-partum. Piglets had their tails docked and teeth clipped within the first week post-partum and all males remained fully intact. Pigs were weaned on day 26 ± 0.1 of lactation.

To study the prolonged effect of CAR supplementation and SBP inclusion to gilt gestation diets on progeny growth and feed efficiency to slaughter, a subsample of 780 pigs were selected at weaning (representing 71% of the total pigs weaned), grouped by gilt treatment and blocked on the basis of sex and weaning weight (average weight of those selected = 7.8 ± 0.93 kg). Then within each block, same sex pens of 12 to 14 pigs per pen were created and moved to weaner accommodation (n = 14 pens created per treatment). On day 76 of age, intact pig groups were moved to finisher accommodation and pig growth and feed intake were monitored to slaughter. Pigs in each group were slaughtered over 2 wk when they reached the target slaughter weight of ~110 kg (average days to slaughter = 146.9 ± 0.45 d). The heaviest pigs in each group were slaughtered in the first week and the remaining pigs were sent to slaughter 7 d later, with an equal number of treatments represented on the different slaughter dates. Pigs were transported 95 km to the abattoir where they were killed by exsanguination after CO_2 stunning.

Experimental Diets and Feeding

Diets were formulated to meet or exceed NRC (2012) recommendations. Gilts were provided with 2 standard gestation diets; the first diet was fed from day 0 to day 90 of gestation and the second diet was fed from day 90 of gestation to parturition. The ingredient composition and nutrient content of the diets are shown in Table 1. The ESF (Schauer Feeding System) recognized individual animals by their transponder, which was programmed with the gilts' dietary treatment and daily feed allowance (2.19 kg/d from day 0 to day 90, increasing to 2.65 kg/d from day 90 to parturition). Gilts on the CAR treatments had their diets top dressed with a 30 g supplement once a day, that contained 0.25 g of Carniking (purity 50%; Lonza Ltd, Basel,

Table 1. Composition of experimental diets (on an air dry basis)

Dietary SBP[1] inclusion	0%		40%		
Days of gestation[2]	Day 0 to day 90	Day 90 to F	Day 0 to day 90	Day 90 to F	Lactation diet
Ingredients, %					
Wheat	0.00	0.00	0.00	0.00	44.33
Barley	89.78	87.54	49.28	47.36	30.00
Soya bean meal	7.97	9.12	8.06	9.00	16.00
Unmollassed beet pulp	0.00	0.00	40.00	40.00	0.00
Soya oil	0.00	0.20	1.15	1.26	6.43
Lysine HCL (78.8)[3]	0.10	0.24	0.11	0.25	0.44
DL-Methionine[3]	0.00	0.04	0.04	0.12	0.06
L-Threonine (98)[3]	0.00	0.05	0.08	0.15	0.14
L-Tryptophan[3]	0.00	0.00	0.00	0.02	0.02
Di-calcium phosphate	0.17	0.52	0.40	0.75	0.84
Limestone flour	1.30	1.48	0.30	0.50	1.15
Salt	0.40	0.40	0.40	0.40	0.40
Minerals and vitamins[4]	0.15	0.15	0.15	0.15	0.15
Phytase 5,000 iu/g[5]	0.01	0.01	0.01	0.01	0.01
Sepiolite[6]	0.10	0.22	0.00	0.00	0.00
Nutritive value, %[7]					
Dry matter	86.93	87.07	88.35	88.48	87.69
Crude protein	13.50	14.00	13.50	14.00	15.75
Ash	4.42	5.07	4.78	5.32	4.83
Fat	2.11	2.28	2.70	2.78	7.97
Crude fiber	4.51	4.45	9.81	9.75	3.33
NDF	17.05	16.80	24.25	24.03	12.27
ADF	6.19	6.13	10.93	10.87	4.35
SID lysine[8]	0.53	0.66	0.53	0.66	0.95
DE, MJ/kg	13.20	13.20	13.20	13.20	15.10

[1]SBP = sugar beet pulp.
[2]Day 0 to day 90: day 0 to day 90 of gestation; day 90 to F: day 90 of gestation to farrowing.
[3]Synthetic amino acids.
[4]Gestation and lactation diet provided (mg/kg completed diet): Cu, 30 mg; Fe, 70 mg; Mn, 62 mg; Zn, 80 mg; I, 0.6 mg; Se, 0.2 mg; vitamin A as retinyl acetate, 3 mg; vitamin D3 as cholecalciferol, 25 µg; vitamin E as DL-α-tocopheryl acetate, 100 mg; vitamin K, 2 mg; vitamin B12, 15 µg; riboflavin, 5 mg; nicotinic acid, 12 mg; pantothenic acid, 10 mg; biotin, 200 µg; folic acid, 5 mg; thiamin, 2 mg; pyridoxine, 3 mg.
[5]Sow diets contained 500 phytase units (FTU) per kg finished feed from Natuphos 5000 (RONOZYME HiPhos, DSM, Belfast, UK).
[6]Sow gestation diets with an inclusion level of 0% SBP contained inorganic carrier Sepiolite to achieve isoenergetic diets.
[7]Values given are tabulated values.
[8]Values for standardized ileal digestible (SID) lysine.

Switzerland) and 29.75 g of inorganic carrier sepiolite (EXAL- H, TOLSA, Madrid, Spain), to provide gilts with 0.125 g/d CAR. In the farrowing room prior to parturition, the CAR supplement was added to the diet by top dressing the morning feed once a day, and all diets were fed using a computerized feed delivery system (DryExact Pro, Big Dutchman, Vechta, Germany). Once farrowed, gilts received a standard lactation diet (Table 1). Gilts were fed twice daily from day 0 to day 6 of lactation and 3 times daily thereafter. The gilt lactation feeding curve started at 33 MJ DE/d at day 0 of lactation and gradually increased to 82, 106, 120, and 125 MJ DE/d at days 7, 14, 21, and 26 of lactation, respectively. Feed troughs were checked once a day in the morning and feed allowance was increased further in cases where gilts were leaving their troughs completely empty. Water was provided to gilts from a single-bite drinker in the feed trough and to suckling piglets from a bowl in the farrowing pen.

Suckling piglets received creep feed (1.6% lysine, 16.2 MJ DE/kg) twice a day from approximately 13 d of age. Post-weaning, pigs were fed the following sequence of dry pelleted diets (3 mm in diameter): Starter diet (1.6% lysine, 16.2 MJ DE/kg) from day 26 to day 33, link diet (1.5% lysine, 15.0 MJ DE/kg) from day 33 to day 47, weaner diet (1.3% lysine, 14.4 MJ DE/kg) from day 47 to day 76, and a finisher diet (1.1% lysine, 13.8 MJ DE/kg) from day 76 to slaughter (day 147). Water was available ad libitum in both weaner and finisher accommodation from a bowl in each pen (DRIK-O-MAT, Egebjerg International A/.S, Egebjerg, Denmark), as well as a water drinker located in the feeder.

Live Weight and Back-Fat Depth

Gilt LW and BF were recorded at day 38, day 90, and day 108 of gestation, and again at weaning. Gilt LW was recorded using an electronic sow scales (EziWeigh 7i, O'Donovan Engineering, Co. Cork, Ireland). Gilt BF was measured using a digital back-fat indicator (Renco LEAN-MEATER, Renco Corporation, Golden Valley, Minneapolis) by placing the probe of the digital indicator on the back of the gilt at the level of the second last rib, 6.5 cm from the side of the backbone. A reading was taken from the right and left side of the gilts back and the average reading was recorded.

Salivary Cortisol

Saliva samples were collected from gilts once every week between day 90 and day 104 of gestation so that 3 samples were taken per gilt. On the day of sampling, saliva samples were collected by allowing gilts to chew on a large cotton swab for 30 to 40 s until it was saturated (Salivette, Sarstedt, Co. Wexford, Ireland). Samples were collected between 0900 h

and 1000 h each morning, approximately 9 h after the gilts' last meal. Immediately after collection, the swabs were placed into plastic eppendorf tubes and centrifuged for 10 min at 400 × *g* at room temperature. Samples were stored at −20 °C until analysis. Salivary cortisol concentration was assessed using an enzyme-linked immunosorbent assay (Salivary Cortisol kit, Salimetrics Europe Ltd., Suffolk, UK) and samples were assayed in duplicate. The minimum detectable concentration of cortisol that could be distinguished from 0 was < 0.003 µg/dL. The intra- and inter-assay CVs were 4.5% and 4.2%, respectively. Cortisol concentration was quantified by interpolating absorbance readings from a standard curve generated in the same assay.

Fecal Consistency Score

Gilt fecal consistency was evaluated from 7 d before to 5 d after farrowing by making a daily qualitative evaluation of the feces. The feces of each gilt was scored by visual and tactile qualitative evaluation, using a scoring system described by Oliviero et al. (2009) which ranged from 0 (absence of feces) to 5 (very wet, unformed, and liquid feces). Fecal scores were averaged to get an average pre- and post-farrowing fecal consistency score per gilt.

Number of Visits to the ESF and Lactation Feed Intake

To determine whether feeding a high level of SBP influenced the frequency of feeder visits due to the decreased bulk density of the diet, the number of daily gilt visits to the ESF was recorded during gestation. Lactation feed intakes were recorded daily on an individual basis, from which the total lactation and average daily feed intake (ADFI) for each gilt were calculated.

Farrowing Duration and Pre-Weaning Piglet Growth Performance

Video cameras were installed above a subset of gilts (n = 8 gilts per treatment) before farrowing so that farrowing duration and the birth interval between each piglet born could be recorded. The time of farrowing and the number of piglets born were extracted from the recordings. Supervision at farrowing allowed for the number of stillborn and mummified piglets to be accurately identified. The weight and sex of each piglet were recorded at birth, and each piglet was tagged for identification purposes. Thereafter, piglets were individually weighed on day 1, day 6, day 14, and day 26 after farrowing and these data were used to determine piglet pre-weaning average daily gain (ADG). Litter size (total and live), litter weight, and piglet mortality between birth and weaning were also recorded.

Blood Glucose Measurement

At 24 h post-partum, a blood sample was taken from the ear vein of piglets by needle prick (30 G/0.3 mm) and glucose concentration was determined from a droplet of blood using a hand held blood glucose monitor (IDIA Blood Glucose monitor, Arctic Medical, Folkestone, UK) and a glucose test strip.

Post-Weaning Pig Growth Performance and Carcass Quality

Pigs were individually weighed on day 26, day 76, day 110, and day 147 (slaughter) and the average body weight (BW) and ADG for each individual pig in a pen was calculated. Animals were not fasted before weighing. Feed intakes were recorded on a pen basis and these data were used to determine the ADFI and feed conversion ratio (**FCR**) for each pen of pigs. At the abattoir, carcass cold weight was obtained by deduction of 2% from the hot carcass weight recorded within 45 min of the pig being exsanguinated. Back-fat thickness and muscle depth, measured from the edge of the split back at the level of the third and fourth last rib, were determined using a Hennessy Grading Probe (Hennessy and Chong, Auckland, New Zealand). Lean meat content was estimated according to the following formula: Estimated lean meat content (%) = 60.3 − 0.847x + 0.147y, where x = fat depth (mm); y = muscle depth (mm) (Department of Agriculture Food and Rural Development, 2001).

Statistical Analysis

Statistical analysis was carried out using the mixed model procedure (Proc Mixed) in SAS (v 9.4, SAS Institute Inc., 1989) for a 2 × 2 factorial arrangement. The gilt/litter was the experimental unit for analysis pre-weaning and pen was the experimental unit for analysis of post-weaning pig growth performance. All data were tested for normality prior to analysis by examination of histograms and normal distribution plots using the univariate procedure. Residuals were inspected in all models to confirm normality. Model fit was determined by choosing models with the minimum finite-sample corrected Akaike Information Criteria (**AIC**). Differences in least square means were investigated using the t-test after Tukey adjustment for multiple comparisons. Degrees of freedom were estimated using Satterthwaite adjustment. The statistical model included the main effects of gilt treatment (CAR or SBP), their interaction, and the fixed effect of gilt batch. Block was included as a random effect for analysis of gilt and litter data and weaner/finisher room were included as a random effect for analysis of post-weaning pig data. To investigate whether CAR supplementation to gestating gilts could be particularly beneficial to light weight piglets of gilt litters, separate statistical analysis was carried out on all piglets that weighed ≤ 1.2 kg at birth (n = 493 piglets in total). Variables of interest measured were piglet birth weight, individual piglet weight and ADG from birth to weaning, pig ADG from birth to slaughter, pig BW and carcass weight at slaughter, and carcass lean meat yield and muscle depth at slaughter. For measures repeated over time, the time of recording was included in the model in the repeated statement. Covariates used in the model included initial gilt LW and BF for analysis of subsequent gilt LW and BF, plate number for analysis of cortisol concentration, lactation length and number of pigs weaned for analysis of gilt weight change during lactation, total number of piglets born for analysis of farrowing duration, litter size at birth for analysis of litter weight at birth, piglet birth weight and glucose concentration, pig wean weight for analysis of post-weaning pig growth, and pig age at slaughter for analysis of BW and carcass weight at slaughter. There was no significant interaction between dietary treatments for any variable of interest measured, and as such only the main effects were considered. The results are presented in the text and tables as the least square means together with the pooled standard error. Differences were considered significant at $P < 0.05$ and as tendencies at $P > 0.05$ but less than $P < 0.10$.

Results

Gilt Live Weight and Back-Fat Depth

There was no effect of CAR supplementation on gilt LW on day 90 and day 108 of gestation, or at weaning (Table 2). Gilt LW during gestation was increased by feeding a diet high in SBP ($P < 0.01$; Table 2). Gilts that were fed the 40% SBP diet were 6.9 ± 0.96 kg heavier on day 90 of gestation ($P < 0.01$) and 4.7 ±

Table 2. Effect of L-carnitine supplementation and sugar beet pulp inclusion in gilt gestation diets on gilt live weight, back-fat depth, and body condition loss during lactation[1]

	CAR[2], g/d				SBP[2], %			
Measure	0	0.125	SEM	P-value	0	40	SEM	P-value[1]
LW[2], kg								
Day 90	209.3	208.4	0.96	0.46	205.4	212.3	0.96	< 0.01
Day 108	226.2	225.4	1.18	0.61	223.4	228.2	1.18	0.04
Empty farrowing weight[3]	192.0	192.7	2.08	0.71	189.5	195.2	2.08	< 0.01
Weaning	187.1	186.4	1.72	0.77	186.6	186.8	1.72	0.95
BF[2], mm								
Day 90	16.7	17.1	0.47	0.62	17.1	16.7	0.47	0.64
Day 108	16.9	17.1	0.36	0.70	17.1	17.0	0.36	0.85
Weaning	11.8	12.2	0.27	0.33	12.2	11.8	0.27	0.38
Lactation LW loss, kg								
Day 108 to weaning[4]	–41.3	–37.8	1.78	0.14	–37.1	–41.9	1.76	0.04
Farrowing to weaning[5]	–5.9	–5.4	1.81	0.85	–3.0	–8.4	1.81	0.03
Lactation BF loss, mm[6]								
Day 108 to weaning	–5.3	–5.1	0.45	0.82	–5.1	–5.3	0.45	0.82

[1]There was no significant interaction between dietary treatments and therefore only the main effects are presented in Table 2. Probability values at $P < 0.05$ are considered significant and as tendencies at $P > 0.05$ but less than $P < 0.10$.
[2]CAR = L-carnitine; SBP = sugar beet pulp; LW = live weight; BF = back-fat depth.
[3]Estimated value: empty farrowing weight = [gilt weight at day 108 – (total born × 2.25)]. The value of 2.25 kg is an estimate of the increased weight in the gravid uterus and in mammary tissue attributed to each pig in a litter (NRC, 1998).
[4]Lactation body weight loss = (gilt live weight at weaning – gilt live weight at day 108 of gestation).
[5]Lactation body weight loss = (gilt live weight at weaning – estimated gilt empty farrowing weight).
[6]Lactation back-fat loss = (gilt back-fat depth at weaning – gilt back-fat depth at day 108 of gestation).

1.18 kg heavier on day 108 of gestation ($P < 0.05$) compared to gilts fed the 0% SBP diet. The estimated empty farrowing weight of gilts was also increased by SBP ($P < 0.01$; Table 2). There was no effect of SBP on gilt LW at weaning. Gilt BF on day 90 and day 108 of gestation and at weaning was unaffected by dietary treatment. Gilts' in all treatment groups lost weight during lactation. Gilt LW losses during lactation were not influenced by CAR supplementation; however, LW losses from day 108 of gestation to weaning and from farrowing (estimated empty weight) to weaning were 4.8 ± 1.76 kg ($P < 0.05$) and 5.4 ± 1.81 kg ($P < 0.05$) greater, respectively, for gilts fed 40% SBP compared to gilts fed 0% SBP. Gilt BF losses from day 108 to weaning were not affected by treatment.

Salivary Cortisol Measurement

Salivary cortisol concentration between day 90 and day 104 of gestation was similar for all treatment groups ($P > 0.05$; Table 3). Cortisol concentration ranged from 0.47 to 0.53 ± 0.043 nmol/L.

Fecal Consistency Score

Gilt fecal consistency score from 7 d before to 5 d after farrowing was unaffected by CAR supplementation. During the 7 d before farrowing, gilts fed the 40% SBP diet had a higher average fecal consistency score, indicating that the feces had a wetter consistency, than gilts fed the 0% SBP diet ($P < 0.01$; Table 3). This effect was not seen in the post-farrowing period.

Number of Visits to the ESF and Lactation Feed Intake

The number of daily visits to the ESF was unaffected by treatment (Table 3). Gilts visited the ESF 4.2 ± 0.26 times/d on average, with feed being consumed during the first feeder visit only. Feed intake during lactation did not differ between treatment groups. The average total feed intake during lactation was 142.6 ± 1.34 kg, equating to 5.5 ± 0.05 kg/d (26-d lactation period; Table 3) or 83.1 MJ DE/d.

Farrowing Duration and Performance

Overall farrowing duration ($P > 0.05$) and the birth interval between each piglet born ($P > 0.05$) were not affected by gilt dietary treatment. The average farrowing duration and average piglet birth interval across all 4 gilt treatments were 3 h and 53 min and 16 min and 50 s, respectively. The total number of piglets born (14.7 ± 0.37), number born alive (14.3 ± 0.88), and number stillborn (0.5 ± 0.11) did not differ between treatment groups (Table 4). Litter weight at birth (total and live) and individual piglet birth weight (total and live) also did not differ between dietary treatments (Table 4). At birth, the average total litter weight and the litter weight of piglets born alive was 18.8 ± 0.30 kg and 18.2 ± 0.27 kg, respectively. The average birth weight of total piglets born and of piglets born alive was both 1.31 ± 0.018 kg (Table 4).

Blood Glucose Measurement

Piglets from gilts which were not supplemented with CAR during gestation had a greater blood glucose concentration at 24 h post-partum than piglets from gilts supplemented with CAR (5.06 vs. 4.79 ± 0.139 mmol/L; $P < 0.01$). Piglets from gilts fed 40% SBP had a greater blood glucose concentration than piglets from gilts fed 0% SBP (5.10 vs. 4.74 ± 0.139 mmol/L; $P < 0.01$).

Pre-Weaning Piglet Growth Performance

During the first 24 h after farrowing, piglets born to gilts fed 40% SBP during gestation tended to have a greater ADG than piglets from gilts fed 0% SBP ($P = 0.06$; Table 5). This effect was not seen thereafter. Piglets born to gilts supplemented with 0.125 g/d CAR during gestation had a lower ADG between day 1 and day 6 after farrowing (–16 ± 5.0 g/d; $P < 0.05$) and between day 14 after farrowing and weaning (–17 ± 5.8 g/d; $P < 0.05$), compared to

Table 3. Effect of L-carnitine supplementation and sugar beet pulp inclusion in gilt gestation diets on gilt salivary cortisol concentration, fecal consistency, number of daily visits to the electronic sow feeder (ESF) during gestation, and lactation feed intake[1]

	CAR[2], g/d				SBP[2], %			
Measure	0	0.125	SEM	*P*-value	0	40	SEM	*P*-value[1]
Cortisol, nmol/L[3]	0.49	0.52	0.04	0.55	0.48	0.54	0.04	0.18
Fecal consistency score[4]								
Pre-farrowing	3.31	3.42	0.082	0.77	2.94	3.78	0.082	<0.0001
Post-farrowing	2.99	2.99	0.084	1.00	2.95	3.03	0.084	0.92
No. ESF visits/d[5]	4.31	4.21	0.265	0.76	4.20	4.32	0.264	0.71
Lactation feed intake								
Total, kg	142.04	143.17	1.341	0.52	143.14	142.07	1.345	0.55
Average, kg/d[6]	5.46	5.51	0.050	0.54	5.51	5.46	0.050	0.56

[1]There was no significant interaction between dietary treatments and therefore only the main effects are presented in Table 3. Probability values at $P < 0.05$ are considered significant and as tendencies at $P > 0.05$ but less than $P < 0.10$.
[2]CAR = L-carnitine; SBP = sugar beet pulp.
[3]Salivary cortisol concentration was measured between day 90 and day 104 of gestation and is a mean of 3 samples taken during this period.
[4]Gilt fecal consistency was evaluated from 7 d before to 5 d after farrowing using a scoring system that ranged from 0 (absence of feces) to 5 (very wet, unformed and liquid feces). The values presented are the average fecal consistency scores pre- and post-farrowing.
[5]Feed was consumed during the first daily visit to the feeder only.
[6]Average feed intake/d over a 26-d lactation period.

Table 4. Effect of L-carnitine supplementation and sugar beet pulp inclusion in gilt gestation diets on the number of piglets born, litter weight at birth, and individual piglet birth weight[1]

	CAR[2], g/d				SBP[2], %			
Measure	0	0.125	SEM	*P*-value	0	40	SEM	*P*-value[1]
Litter size, number								
Total born[3]	14.8	14.8	0.37	0.99	15.0	14.6	0.37	0.38
Live born	14.4	14.4	0.88	0.99	14.8	13.9	0.88	0.14
Stillborn	0.5	0.5	0.11	0.73	0.4	0.6	0.11	0.42
Litter weight, kg								
Total born[4]	18.9	18.9	0.30	0.85	19.2	18.6	0.30	0.13
Live born	18.2	18.3	0.27	0.90	18.4	18.0	0.27	0.23
Piglet birth weight, kg								
Total born[4]	1.33	1.31	0.018	0.41	1.32	1.31	0.018	0.68
Live born	1.33	1.30	0.018	0.39	1.32	1.31	0.018	0.66

[1]There was no significant interaction between dietary treatments and therefore only the main effects are presented in Table 4. Probability values at $P < 0.05$ are considered significant and as tendencies at $P > 0.05$ but less than $P < 0.10$.
[2]CAR = L-carnitine; SBP = sugar beet pulp.
[3]Total number born = number of piglets born alive, stillborn, and mummified.
[4]Total litter weight and individual piglet birth weight = weight of piglets born alive and stillborn. Mummified piglets were not weighed.

piglets born to gilts that received no CAR. There was no effect of gilt dietary treatment on individual piglet BW at day 1, day 6, and day 14 after farrowing. However, as a consequence of the reduction in ADG, piglets born to gilts supplemented with CAR during gestation tended to be lighter at weaning than piglets born to gilts that received no CAR ($P = 0.08$; Table 5). Total litter weight at all weighing's recorded between day 1 post-partum and weaning was similar for all gilt treatment groups (data not shown). There was no effect of SBP on litter size at weaning. L-Carnitine supplemented gilts tended to wean a greater number of suckling piglets compared to gilts that were not supplemented with CAR ($P = 0.08$; Table 5).

Post-Weaning Pig Growth Performance

There was no effect of dietary treatment on pen weights from day 26 to slaughter or on the BW of individual pigs from day 26 to day 110. At slaughter, pigs from CAR gilts ($P < 0.05$) and pigs from SBP-fed gilts ($P < 0.05$) had a heavier BW than pigs from gilts that were not supplemented with CAR or fed SBP. The number of days for pigs to reach slaughter was unaffected by treatment (Table 6). During the entire post-weaning period, ADG was greater for pigs from CAR-supplemented gilts than pigs from gilts that were not supplemented with CAR ($P < 0.05$). Pig ADFI and FCR were similar across all treatments.

Carcass Quality at Slaughter

In line with the heavier BW at slaughter, pigs from CAR-supplemented gilts ($P < 0.05$), and pigs from SBP-fed gilts ($P < 0.05$) had heavier carcass weights than pigs from gilts that were not supplemented with CAR or fed SBP (Table 7). Furthermore, the carcass muscle depth was increased in progeny from gilts supplemented with CAR ($P < 0.01$) and in progeny from gilts fed SBP ($P < 0.05$). There was no effect of treatment on carcass fat depth, lean meat yield, and kill out yield (Table 7). Although carcass ADG from day 76 to slaughter was unaffected by gilt treatment, carcass FCR was improved in pigs from CAR-supplemented gilts ($P < 0.05$). There was not effect of SBP on carcass FCR. Pig lean ADG, calculated from birth to slaughter, was similar across all treatments (Table 7).

Table 5. Effect of L-carnitine supplementation and sugar beet pulp inclusion in gilt gestation diets on individual piglet body weight and average daily gain from day 1 post-partum to weaning, number of piglets weaned, and litter weight weaned[1]

	CAR[2], g/d				SPB[2], %			
Measure	0	0.125	SEM	*P*-value	0	40	SEM	*P*-value[1]
BW[2], kg								
Day 1[3]	1.41	1.40	0.031	0.86	1.39	1.42	0.031	0.43
Day 6	2.4	2.3	0.05	0.29	2.3	2.3	0.05	0.46
Day 14	4.2	4.0	0.08	0.19	4.0	4.2	0.08	0.28
Day 26[4]	7.1	6.8	0.14	0.08	6.9	7.1	0.14	0.32
Number weaned	12.2	12.9	0.31	0.07	12.8	12.2	0.31	0.11
Litter weaned, kg	88.1	88.0	1.70	0.65	89.3	87.8	1.70	0.54
ADG[2], g/d[5]								
Birth to day 1	82	87	6.3	0.61	77	93	6.3	0.06
Day 1 to day 6	199	183	5.0	0.02	188	194	5.0	0.36
Day 6 to day 14	255	242	6.1	0.14	248	250	6.1	0.82
Day 14 to day 26	247	230	5.8	0.03	237	240	5.8	0.67
Overall	196	185	3.8	0.05	187	194	3.8	0.18

[1]There was no significant interaction between dietary treatments and therefore only the main effects are presented in Table 5. Probability values at $P < 0.05$ are considered significant and as tendencies at $P > 0.05$ but less than $P < 0.10$.
[2]CAR = L-carnitine; SBP = sugar beet pulp; BW = body weight; ADG = average daily gain.
[3]On average, piglets were weighed 24 h, 23 min, and 41 s after the time that they were weighed at birth (time ranged from 17 to 32 h and 53 min).
[4]Day 26 = age at weaning.
[5]ADG is calculated on the basis of the difference in individual piglet body weight at specific time points during the suckling period/number of days between each time point.

Table 6. Effect of L-carnitine supplementation and sugar beet pulp inclusion in gilt gestation diets on individual pig body weight, average daily gain, average daily feed intake, and feed conversion ratio from weaning (26 d old) to slaughter (147 d old)[1]

	CAR[2], g/d				SBP[2], %			
Measure	0	0.125	SEM	*P*-value	0	40	SEM	*P*-value[1]
BW[2], kg								
Day 26	7.8	7.8	0.94	1.00	7.5	8.1	0.93	0.98
Day 76	37.7	37.9	0.86	0.99	37.5	38.1	0.86	0.98
Day 110	72.0	72.5	0.87	0.99	71.5	73.1	0.88	0.46
Day 147[3]	111.3	113.1	0.64	0.05	111.2	113.1	0.63	0.03
ADG[2], g/d								
Day 26 to day 76	550	563	14.4	0.81	563	551.	14.4	0.83
Day 76 to day 110	988	1,021	16.2	0.27	990	1,019	16.1	0.47
Day 110 to day 147	1,091	1,110	38.0	0.98	1,100	1,101	38.0	1.00
Overall[4]	877	898	11.0	0.04	885	890	10.9	0.60
ADFI[2], g/d								
Day 26 to day 76	807	813	16.6	0.99	816	805	16.5	0.99
Day 76 to day 110	2,135	2,147	51.4	0.99	2,115	2,167	51.4	0.86
Day 110 to day 147	2,668	2,623	34.5	0.99	2,631	2,660	34.5	0.99
Overall[4]	1,870	1,861	24.0	0.77	1,854	1,877	23.9	0.47
FCR[2], g/g								
Day 26 to day 76	1.45	1.44	0.040	0.99	1.44	1.46	0.040	0.97
Day 76 to day 110	2.17	2.11	0.072	0.65	2.15	2.13	0.072	0.99
Day 110 to day 147	2.45	2.38	0.090	0.88	2.41	2.42	0.090	1.00
Overall[4]	2.02	1.98	0.039	0.07	2.00	2.00	0.039	0.82

[1]There was no significant interaction between dietary treatments and therefore only the main effects are presented in Table 6. Probability values at $P < 0.05$ are considered significant and as tendencies at $P > 0.05$ but less than $P < 0.10$.
[2]CAR = L-carnitine; SBP = sugar beet pulp; BW = body weight; ADG = average daily gain; ADFI = average daily feed intake; FCR = feed conversion ratio.
[3]Day 147 = average age at slaughter.
[4]Overall = day 26 to day 147 of age.

Lifetime Growth Performance of Piglets Weighing ≤ 1.2 kg at Birth

Results for the growth performance of piglets born ≤ 1.2 kg at birth are presented in Table 8. The birth weight, pre-weaning BW, and pre-weaning ADG of piglets were unaffected by gilt treatment. Pigs from CAR-supplemented gilts ($P = 0.10$) and pigs from SBP-fed gilts ($P < 0.05$) had a greater ADG from birth to slaughter than pigs from gilts that were not supplemented with CAR or fed SBP. Furthermore, the BW ($P = 0.08$) and carcass weight ($P < 0.05$) of pigs from CAR-supplemented gilts, as well as the BW ($P < 0.05$) and

Table 7. Effect of L-carnitine supplementation and sugar beet pulp inclusion in gilt gestation diets on the number of days to slaughter and carcass quality at slaughter (147 d old)[1]

	CAR[2], g/d				SBP[2], %			
Measure	0	0.125	SEM	P-value	0	40	SEM	P-value[1]
Days to slaughter	146.6	147.3	0.46	0.22	146.9	147.0	0.45	0.95
Carcass								
Weight, kg	85.1	86.6	0.46	0.02	85.2	86.5	0.46	0.04
Fat depth, mm	12.4	12.4	0.15	0.74	12.4	12.4	0.15	0.89
Muscle depth, mm	50.5	51.3	0.20	0.01	50.6	51.2	0.20	0.04
Lean meat, %	57.2	57.2	0.13	0.82	57.1	57.2	0.13	0.67
Kill out, %	76.5	76.6	0.15	0.63	76.6	76.4	0.15	0.44
Carcass ADG[2], g/d[3]	865	870	6.9	0.63	861	874	7.2	0.18
Carcass FCR[2], g/g[4]	2.80	2.72	0.029	0.04	2.75	2.78	0.028	0.49
Lean ADG[2], g/d[5]	333	336	2.8	0.45	332	337	2.8	0.18

[1]There was no significant interaction between dietary treatments and therefore only the main effects are presented in Table 7. Probability values at $P < 0.05$ are considered significant and as tendencies at $P > 0.05$ but les s than $P < 0.10$.
[2]CAR = L-carnitine; SBP = sugar beet pulp; ADG = average daily gain; FCR = feed conversion ratio.
[3]Carcass ADG (from day 76 to slaughter) = [(carcass weight in kg – day 76 weight in kg × 0.65) × 1,000]/number of days from day 76 to slaughter (Lawlor and Lynch, 2005).
[4]Carcass FCR (from day 76 to slaughter) was calculated as follows: carcass FCR = daily feed intake (g)/carcass ADG (g).
[5]Lean ADG (from birth to slaughter) = (carcass weight × carcass lean meat percentage × 10)/number of days to slaughter (Lawlor and Lynch, 2005).

Table 8. Effect of L-carnitine supplementation and sugar beet pulp inclusion in gilt gestation diets on the lifetime growth performance of piglets that weighed ≤ 1.2 kg at birth[1]

	CAR[2], g/d				SBP[2], %			
Measure	0	0.125	SEM	P-value	0	40	SEM	P-value[1]
Pig weight, kg								
Day 0[3]	0.99	1.01	0.019	0.99	0.99	1.00	0.01	1.00
Day 1	1.1	1.1	0.02	0.99	1.1	1.1	0.02	0.99
Day 6	1.8	1.8	0.04	1.00	1.8	1.8	0.04	0.99
Day 14	3.4	3.3	0.08	0.99	3.4	3.4	0.08	1.00
Day 26[3]	6.1	5.8	0.14	0.77	5.8	6.1	0.15	0.93
Day 147[3]	106.6	108.5	1.32	0.08	106.2	108.9	1.32	0.01
Piglet ADG[2], g/d[4]								
Day 0 to day 26	164	169	4.9	0.50	158	166	4.9	0.21
Day 0 to day 147	710	723	6.2	0.10	706	726	6.2	0.01
Carcass weight, kg	82.4	84.1	1.02	0.05	82.2	84.3	1.02	0.01
Muscle depth, mm	50.0	51.6	0.40	<0.01	50.6	51.0	0.40	0.39
Lean meat, %	57.2	57.5	0.32	0.22	57.6	57.1	0.32	0.10

[1]There was no significant interaction between dietary treatments and therefore only the main effects are presented in Table 8. Probability values at $P < 0.05$ are considered significant and as tendencies at $P > 0.05$ but less than $P < 0.10$.
[2]CAR = L-carnitine; SBP = sugar beet pulp; ADG = average daily gain.
[3]Day 0 = birth; day 26 = age at weaning; day 147 = age at slaughter.
[4]ADG is calculated on the basis of the difference in individual pig body weight at specific time points/number of days between each time point.

carcass weight ($P < 0.05$) of pigs from SBP-fed gilts, were heavier than pigs from gilts that were not supplemented with CAR or fed SBP. Carcass muscle depth was also increased in progeny from gilts supplemented with CAR ($P < 0.01$), and lean meat yield tended to be decreased in carcasses of progeny from SBP-fed gilts ($P = 0.10$).

Discussion

This study investigated the effects of CAR supplementation and SBP inclusion in gilt gestation diets on gilt LW, cortisol concentration, lactation feed intake, and offspring growth from birth to slaughter. Gilt LW was increased and fecal consistency improved pre-farrowing in response to feeding SBP during gestation. Contrary to expectations, piglet birth weight was similar for all treatments. Furthermore, piglets from CAR-supplemented gilts had a lower pre-weaning ADG and consequentially these piglets were lighter at weaning. However, this is most likely explained by CAR-supplemented gilts tending to wean a greater number of piglets per litter. Body weight, carcass weight, and muscle depth of progeny at slaughter were increased by both the CAR and SBP gilt treatments.

The greater weight during gestation of gilts fed the high-fiber diet is in agreement with previous work done on sows (Ramonet et al., 1999; Danielsen and Vestergaard, 2001). It is likely due to an increase in gut fill and/or gastrointestinal tract growth, linked to the high soluble fiber content in the diet (Kass et al., 1980; Jørgensen et al., 1996). Jørgensen et al. (1996) observed almost a 3-fold increase in the gut fill of pigs fed a high-fiber diet containing pea fiber and pectin, compared to pigs fed a low-fiber diet. Jørgensen et al. (2010) confirmed that feeding sows diets

rich in soluble dietary fiber increased intestinal tract capacity, resulting from increased swelling in the stomach. Another likely explanation for the increased weight gain in gilts is that the net energy value for the SBP used in our study was underestimated when formulating the diet and therefore, the energy content of the SBP diet was greater than expected. Body weight loss in lactation was greater for gilts fed the SBP diet compared to those who received no SBP, which is also in agreement with other sow and gilt studies that compared low-fiber diets to diets with high contents of soluble and insoluble fiber (Danielsen and Vestergaard, 2001; Guillemet et al., 2006). The observed increase in lactation BW losses in the SBP-fed gilts in our study could simply be because these gilts were significantly heavier pre-farrowing and therefore had proportionately more weight to lose.

It is critical to promote high voluntary lactation feed intake in gilts to minimize severe weight loss. A high energy and nutrient intake during lactation are necessary to maximize milk production and consequently, the growth of suckling piglets. Our hypothesis that feeding a diet high in soluble fiber in gestation (40% SBP) would result in increased gut capacity, thus allowing gilts to consume a larger volume of feed during lactation, was not observed.

It is difficult to compare this result directly with those from previous studies, due to variations in sow parity, fiber inclusion level and source of dietary fiber. Indeed, the lactation feed intake of young gilts is lower than that of mature sows and this is simply due to gastrointestinal limitations in the gilt (King and Dunkin, 2010; Theil et al., 2012). The gastrointestinal tract of gilts is both smaller than and not as well developed as that in sows; consequently, reducing the physical intake capacity of gilts (Lindberg, 2014). Zhao et al. (2015) also observed no increase in voluntary lactation feed intake when gilts were fed diets supplemented with 0%, 10%, and 20% SBP in late gestation. Earlier studies, however, report lactation feed intake increases of 0.94 kg/d for gilts fed a high-fiber diet containing varying fibrous ingredients, with a crude fiber content of 11% (Quesnel et al., 2009) and feed intake increases of 0.32 kg/d during lactation when sows were fed a 50% SBP-rich diet in gestation (Danielsen and Vestergaard, 2001).

High-fiber diets play a positive role in avoiding constipation issues around the time of parturition (Solà-Oriol and Gasa, 2017). The inclusion of SBP to the diet during gestation resulted in a small reduction in the hardness of the feces, which is linked to a reduced risk of constipation around farrowing. Our data confirm results from other recent gilt and sow studies that found similar results when differing amounts of SBP, fermentable carbohydrates, and inert carbohydrates were included in the diet (Zhao et al., 2015; Guillou et al., 2016).

However, it must be noted that the effects of SBP on fecal hardness did not speed up the farrowing process for gilts nor did it impact the number of stillborn piglets per litter.

Salivary cortisol is often used to estimate the level of physiological stress the animal is experiencing. We did not find that SBP-fed gilts had lower salivary cortisol concentrations during gestation, associated with prolonged feelings of satiety, as we had expected. Data from experiments, where sows and gilts are fed various amounts of dietary fiber from different sources, are still limiting, and have shown somewhat conflicting results. In contrast to our observations, DeDecker et al. (2014) found that high fiber-fed sows (control diet supplemented with 30% soya bean hulls and 15% wheat middlings) had lower plasma cortisol levels on day 90 of gestation than sows fed a control diet. However, factors such as the level of dietary fiber inclusion, space allowance, and the sow feeding regime used could have influenced this measure.

We found no difference in total or born alive litter size at birth. This however was expected, as the CAR supplementation to gilts began on day 38 of gestation; at which point the number of fertilized oocytes could not be influenced by maternal feeding (Eder et al., 2001). L-Carnitine supplementation during gestation did not significantly increase total or alive litter weight or individual piglet weight at birth. This is in contrast with recent sow studies. Reid et al. (2016) reported that CAR inclusion from day 28 of gestation to parturition increased the birth weight of piglets born alive by 60 g. Similarly, Musser et al. (1999) found that feeding sows 100 mg/d of supplementary CAR from day 5 until day 112 of gestation increased total litter weight (15.5 vs. 14.6 kg) and individual piglet weight at birth (1.53 vs. 1.49 kg) compared to control sows. Several other studies reported similar findings (Ramanau et al., 2002, 2004, 2008; Wei et al., 2018). According to Bee (2017), CAR positively influences the IGF-1 axis in sows, consequently improving intrauterine nutrition and promoting glucose oxidation in the developing fetuses. However, evidence exists that CAR may affect gilts (Ramanau et al., 2005; Birkenfeld et al., 2006a,b) and sows differently (Ramanau et al., 2002, 2008; Wei et al., 2018). It is possible that CAR promotes greater nutrient uptake in the mature uterus of older animals which results in improved nutritional status of the fetus, and greater fetal growth, and development and consequently, heavier piglets at birth (Brown et al., 2008). However in gilts, additional nutrients are partitioned away from the uterus and more towards their own maintenance and growth requirements, which are significantly greater than that of gestating sows (Foxcroft et al., 1997).

In the present study, piglets from gilts fed CAR had lower concentrations of blood glucose at 24 h post-partum, whereas the opposite effect was observed in piglets from gilts fed SBP. Blood glucose concentration at this time is very much linked to the amount of colostrum that the piglet has suckled since birth and the time since the piglet last suckled. Supplemental dietary fat to sows during late gestation and lactation increases both milk production and the fat content of colostrum and milk (Pettigrew, 1981). In the present study, the 40% SBP diet was formulated to have a marginally higher level of fat than the 0% SBP diet and this was done to ensure that the energy density of both diets was uniform. We therefore cannot disregard that the higher blood glucose concentration and indeed the greater ADG observed in the first 24 h post-partum in piglets from gilts fed SBP were in fact attributable to the greater dietary fat content in the SBP-fed group. As a decrease in piglet ADG from birth to weaning was observed in response to CAR supplementation, it is likely that the lower glucose concentration observed in these piglets at day 1 of lactation was a result of reduced feed intake and that this continued to weaning. The fact that litter size was numerically higher for CAR-supplemented gilts (+0.43 piglets at 24 h post-partum) almost certainly explains this decreased intake of milk by piglets from CAR-supplemented gilts. This result is somewhat in line with previous work by our group (Reid et al., 2016), where an increase in piglet birth weight as a result of feeding CAR to sows during gestation was lost by the time of weaning. As a consequence of the reduction in piglet ADG, individual weight at weaning was lower in piglets from CAR-fed gilts compared to piglets from control gilts. However, as stated earlier, gilts in the CAR-fed group tended to wean a greater number of piglets (+0.69 piglets) compared to control gilts which explains the lower average piglet weaning weight observed.

The number of studies investigating the effects of maternal CAR supplementation on lifetime growth performance of offspring is limited, as most studies focus solely on the pre-weaning period. What is interesting is that in the present study, the most pronounced effect of the supplement was found in pigs at market age (147 d). Gestating gilts supplemented with CAR produced pigs with both a heavier BW and a heavier carcass weight at slaughter. Additionally, carcass muscle depth was increased and carcass FCR was improved in pigs born to CAR-supplemented gilts. Of importance is that the observed benefit of CAR supplementation on pig weight, carcass weight, and carcass muscle depth at slaughter was also evident in the pigs that were categorized as being "light weight" at birth (i.e., those with a birth weight of ≤ 1.2 kg). The magnitude of the response to CAR in these light weight piglets was similar however to the response rate seen when piglets of all birth weights were included in the analysis. Nevertheless, piglets of gilt litters responded well to maternal CAR supplementation, demonstrating that CAR has the potential to be a valuable supplementation strategy to lessen the impact of poorer post-weaning growth rates seen in gilt offspring compared to offspring of multiparous sows (Hoving et al., 2010; Calderón Díaz et al., 2017).

Maternal supplementation with CAR during gestation has previously been shown to stimulate prenatal muscle hyperplasia, with piglets born to CAR supplemented sows having a greater number of muscle fibers at birth than piglets from control sows (Musser et al., 2001, 2007). It was formerly believed that total muscle fiber number was fixed at birth (Bérard et al., 2010), however, a more recent study showed that muscle hyperplasia in piglets can occur during the first few weeks after birth (Lösel and Rehfeldt, 2013). It can be reasoned that the pigs born to CAR-supplemented gilts had an increased muscle fiber number and that increased myofiber hyperplasia is likely to have occurred either in utero or in the early pre-weaning period. Consequently, pigs from CAR-fed gilts had an increased potential to gain muscle later in life, and this likely contributed to the increased weight and carcass quality seen at slaughter in the current study. Unfortunately, myofiber data were not collected during this study and therefore further work needs to be conducted to support this hypothesis.

In the present study, pigs born to SBP-fed gilts had increased BW, carcass weight, and muscle depth at slaughter. One might speculate that the microbiome of sows was beneficially modulated by feeding SBP which as a consequence, resulted in an altered microbiome in progeny. There is growing evidence to show that the diet, particularly those high in fiber, plays an important role in the control of intestinal health and associated microbial populations (de Lange et al., 2010; Bach Knudsen et al., 2012). Interestingly, recent work demonstrated that BW variability in pigs can be explained by differences in intestinal microbiota composition (McCormack et al., 2018). However, as metagenomic analysis was not conducted in the present study, further research on the association between feeding high-fiber diets to gilts during gestation and a change in the intestinal microbiome of progeny is warranted.

Conclusion

This study showed that there was no benefit from the combined feeding of CAR and SBP to gilts during gestation. Fed separately, CAR supplementation tended to increase the number of piglets weaned and increased the BW, carcass weight, and muscle depth of progeny at slaughter, even though it decreased piglet pre-weaning ADG and weaning weight. Although dietary SBP inclusion did improve fecal consistency in gilts prior to farrowing, the beneficial effect of SBP on fecal hardness did not speed up the farrowing process for gilts nor did it impact the number of stillborn piglets per litter. Feeding gilts a 40% SBP diet during gestation did not increase subsequent lactation feed intake. Unexpectedly, feeding 40% SBP in the gestation diet of gilts increased the BW and carcass weight of pigs at slaughter, and increased carcass muscle depth at this time also. The latter may have been mediated through beneficial changes in the intestinal microbiome of gilts and progeny, but this needs further examination.

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