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Effect of dietary L-carnitine supplementation on sows performance

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Summary

The effect of L-carnitine supplementation during gestation and lactation on the performance parameters of sows was studied. The trial comprised a total of 73 sows that were divided into the control and treated groups; each was fed diets with and without supplemental L-carnitine during pregnancy (0 vs. 125 mg L-carnitine daily/sow) and lactation (0 vs. 250 mg L-carnitine daily/sow). L-carnitine supplementation resulted in the numerical increase of sow body weight at weaning (215.2±5.4 vs. 205.0±5.0, LSM±Se, $p \leq 0.05$), with a significantly expressed effect on sows born in 1998 (227.1±8.4 vs. 193.6±9.2, LSM±Se, p=0.01). There was a numerical increase in average number of total born and viable piglets per litter in treated sows (11.0±2.0 vs. 10.7±1.9, LSM±Se, $p \geq 0.05$; 10.8±2.1 vs. 10.4±1.9, LSM±Se, $p \geq 0.05$ respectively), although the tendency towards increasing the same parameters was determined in sows born in 1998 (11.00±0.54 vs. 9.82±0.59, LSM±Se, p=0.14; 10.9±0.6 vs. 9.5±0.6, LSM±Se, p=0.09). The total number of piglets which were smaller than 800g at birth tended to be lower (0.9±1.2 vs. 1.4±1.6, LSM±Se, p=0.08) and significantly different in sows born in 1998 (0.9±0.4 vs. 2.5±0.4, LSM±Se, p=0.01). The number of piglets fit for rearing was influenced by L-carnitine supplementation only in the sows born in 1998 (10.8±0.5 vs. 9.1±0.6, LSM±Se, p=0.03). The litter weight was not influenced by L-carnitine supplementation.

Keywords: L-carnitine, sows, pregnancy

Recently L-carnitine, a vitamin – like substance, was drawn to the interest of animal nutritionists in Lithuania, although, the substance has been used in human nutrition and medicine as well during the past decades. L-carnitine is synthesized in the body; however, the case of not fully developed neonate's biosynthesis of L-carnitine, under conditions of stress and sustained physical activities, as well as in high performance of reproduction and growth, feeding diets low in L-carnitine and rich in fat, may require an additional dietary supply of L-carnitine (2, 3). L-carnitine, transferring the activated long chain fatty acids across the inner mitochondrial membrane to the mitochondrial matrix for β-oxidation, is known like a key substance in cells energy provision (3-5, 8-10) and as a buffer substance for the intermediate storage or transport of activated short chain fatty acids in and out of the cell organelles and cytosol (4, 13-15). In recent years quite a few studies exploring the potential L-carnitine supplementation to enhance the performance of farm livestock have been conducted. A study by Musser et al. (11) showed that sows receiving L-carnitine supplement lay down more adipose tissue during pregnancy. According to Eder et al. (7) it was suggested that the effect of L-carnitine supplementation could depend on the age of sows. In a study by Owen et al. (13-15) dietary L-carnitine enhanced the oxidation of fatty acids from adipose tissue and the accretion of body protein, leading to a higher ratio of body protein to adipose tissue in weaned piglets and growing finishing pigs. Other authors postulate a connection between the maternal L-carnitine supply during pregnancy and the stimulation of endogenous growth hormones such as insulin and insulin growth factor I (IGF-I), which are associated with muscle fiber formation in the fetus and increasing number of ovulated eggs. Therefore, it leads to the heavier piglets to be born and at the same time the reduced proportion of very light and non viable piglets (11, 12). The positive effects of L-carnitine supplementation on performance parameters of sows have been reported in literature, although the observed effects did not allow drawing the definitive conclusions about the mode of L-carnitine action. Based on the considerations that L-carnitine is a new supplement in swine nutrition in Lithuania the study was designed to in-vestigate the effect of L-carnitine supplementation during pregnancy and lactation on performance parameters in different sows' age, under practical feeding and housing conditions in sows' unit.

Material and methods

Animals and experimental design. The trial was conducted on 73 sows (Lithuanian white breed) in a commercial sow unit in Kaunas district. The trial started in April, 2001 and lasted until October, 2002. The sows were selected by analogous method and separated into a control and treated group. Afterwards the sows were assigned according to their birth year, in order to contain in each group sows born in 1998 (–L-carnitine n = 11; +L-carnitine n = 13), 1999 (–L-carnitine n = 16; +L-carnitine n = 14) and 2000 (–L-carnitine n = 11; +L-carnitine n = 8). All sows received commercial feed mixture; additionally the treated group received L-carnitine.

During the summer season, which lasted about 100 days, the pregnant sows were kept in groups (15 to 20 sows per pen) in the summer station. Afterwards in autumn-winter period the sows were housed in groups in the piggery. The sows were moved into individual farrowing pens 10 days before farrowing, and they were kept until the day of weaning.

Diets and feeding. Two commercial, nutritionally balanced feed mixtures were provided. Pregnant sows from d 1 insemination and until d 1 farrowing received 3 kg/d commercial feed mixture, consisted of (g/kg): barley (323), wheat (240), rye (110), wheat flour (122), wheat bran (110), soybean meal (30), fish meal (10), rapeseed meal (20), limestone (16), dicalcium phosphate (5), sodium chloride (3), premix including minerals, vitamins and L-lysine (11). Lactating sows from the d 1 farrowing until d 1 weaning 5 kg/d commercial feed mixture, consisted of (g/kg): barley (240), wheat (210), triticale (104), oat (100), wheat flour (50), wheat bran (50), soybean meal (120), fish meal (10), rapeseed meal (50), rapeseed oil (20), limestone (15), dicalcium phosphate (15), sodium chloride (3), premix including minerals, vitamins, L-lysine and DL-methionine (13). The gestation diet contained of (per kg): 12.4 MJ metabolizable energy, 140 g crude protein, 24 g crude fat, 45 g crude fibre, 52 g crude ash, 6.4 g lysine, 4.8 sulphur contain amino acids, 8.7 g calcium, 5.9 g phosphorus. The lactation diet contained (per kg): 13 MJ metabolizable energy, 172 g crude protein, 42 g crude fat, 49 g crude fibre, 62 g crude ash, 9.5 g lysine, 6.6 sulphur contain amino acids, 11 g calcium, 7.3 g phosphorus.

The sows of the treated group received L-carnitine during gestation (d 1 of insemination until d 1 of farrowing) a daily supplement of 125.0 mg per sow and during the lactation period 250.0 mg L-carnitine per sow. L-Carnitine was supplied as tablets containing L-carnitine (125 mg/tablet, supplied by Lohmann Animal Health, Cuxhaven, Germany), dextrose and lactose. During the experiment the L-carnitine was mixed into the commercial feed mixtures just before feeding each day in the evening. Water was available *ad libitum* via nipple drinkers.

Parameters. Data were generated over one reproductive cycle. The following performance parameters were recorded: the sows' body weight (BW); total number of born piglets, born alive, stillborns, non viable, fit for rearing and smaller than 800 g piglets; litter weights and individual weight of piglets at birth. The changes in BW of the sows were monitored at insemination, on d 85 of gestation and at the end of the suckling period. The weights of the neonates were recorded during the first 24 h after birth by means of an electronic balance with a precision of ± 20 g.

Statistical analyses. The analysis of variance was carried out for data evaluation using the GLM Procedure of SAS program (18). Besides the main factor L-carnitine sup-

Tab. 1. Body weight development of the sows during the reproduction cycle (LSM ± Se)

Experimental groups Number of sows	Control	Treated	Significant factors (p ≤ 0.05)		
			LC*	Year**	LC*Year***
Total:	n = 38	n = 35			
Live weight, d1 insemination, kg	171.7 ± 4.9	186.9 ± 5.2	0.04	<.0001	0.18
Live weight, d85 of gestation, kg	231.1 ± 5.4	234.4 ± 5.8	0.68	0.57	0.64
Live weight gain (d85-d1 insemination), kg	59.4 ± 6.7	47.6 ± 7.1	0.23	<.0001	0.41
Live weight weaning, kg	205.0 ± 5.0	215.2 ± 5.4	0.17	0.66	0.05
Live weight loss (d85-d1 weaning), kg	26.1 ± 7.1	19.2 ± 7.5	0.50	0.44	0.59
Sows born in 1998:	n = 11	n = 13			
Live weight, d1 insemination, kg	183.3 ± 9.0	212.4 ± 8.3	0.02	–	–
Live weight, d85 of gestation, kg	231.3 ± 10.0	244.0 ± 9.1	0.35	–	–
Live weight gain (d85-d1 insemination), kg	48.0 ± 12.2	31.6 ± 11.2	0.33	–	–
Live weight weaning, kg	193.6 ± 9.2	227.1 ± 8.4	0.01	–	–
Live weight loss (d85-d1 weaning), kg	37.7 ± 13.0	16.9 ± 11.9	0.24	–	–
Sows born in 1999:	n = 16	n = 14			
Live weight, d1 insemination, kg	203.0 ± 7.4	201.7 ± 7.9	0.90	–	–
Live weight, d85 of gestation, kg	226.0 ± 11.9	230.1 ± 8.6	0.73	–	–
Live weight gain (d85-d1 insemination), kg	23.0 ± 10.0	28.4 ± 10.7	0.71	–	–
Live weight weaning, kg	208.7 ± 7.5	219.5 ± 8.1	0.33	–	–
Live weight loss (d85-d1 weaning), kg	17.3 ± 10.6	10.5 ± 11.4	0.67	–	–
Sows born in 2000:	n = 11	n = 8			
Live weight, d1 insemination, kg	128.8 ± 9.0	146.4 ± 10.8	0.22	–	–
Live weight, d85 of gestation, kg	236.1 ± 10.0	229.1 ± 11.9	0.66	–	–
Live weight gain (d85-d1 insemination), kg	107.3 ± 12.2	82.7 ± 14.6	0.20	–	–
Live weight weaning, kg	212.8 ± 9.2	199.0 ± 11.0	0.34	–	–
Live weight loss (d85-d1 weaning), kg	23.3 ± 13.0	30.1 ± 15.5	0.74	–	–

Explanations: Significant factors: * L-carnitine supplementation, ** birth year of the sows, *** interactions between L-carnitine and year factors

plementation („LC"), the factor „year" and the interaction in-between („LC*year") were included in the model. The least square means (LSM) and standard error of means (Se) were computed for the interaction („LC*year"). The significance between control and supplemented group at different year was tested using PDIFF option.

Results and discussion

Effect of L-carnitine supplementation on BW development of the sows. The development of sows' BW is summarized in tab. 1. L-carnitine supplementation did not influence the sow's BW at d 85 of pregnancy, BW gain from d 1 insemination to d 85 of pregnancy and BW loss from d 85 of pregnancy to d 1 weaning. In total, due to L-carnitine supplementation the sows BW tended to increase at weaning (215.2 ± 5.4 vs. 205.0 ± 5.0, LSM ± Se, p = 0.17). The effect on the BW at weaning was significantly pronounced in the treated sows born in 1998 compared to those of the control group (227.1 ± 8.4 vs. 193.6 ± 9.2, LSM ± Se, p = 0.01) and had no effect on BW at weaning in sows born in 1999 and 2000. These results are in disagreement with those studies by Musser et al. (11) and Eder et al. (7). Their findings suggest that L-carnitine supplementation increased body weight gain from d 1 to d 85 of pregnancy and gilts in particular respond more strongly to L-carnitine supplementation than sows with high parity. However, the studies by Ramanau at al. (16) did not confirm this suggestion; positive effects emerged throughout all age categories of sows. Biochemical mechanisms underlying the beneficial effects of L-carnitine supplementation in sows are still unknown and difficult to explain biochemically. The study by Musser et al (12) suggests that sows store more adipose tissue under the influence of L-carnitine, although this observation is opposite to findings in growing pigs where L-carnitine supplements reduced fat deposition as a result of increased β-oxidation (13, 14). Further studies are needed to confirm dietary L-carnitine supplementation impact on sows' BW during pregnancy and lactation periods.

Effect of L-carnitine supplementation on litter size and weight. Data of litter size and litter development have been summarized in tab. 2. The average number of total born and viable piglets in the sows litter treated with L-carnitine was slightly numerically increased. However, there was a tendency towards higher number of born and viable piglets (11.0 ± 0.5 vs. 9.8 ± 0.6, LSM ± Se, p = 0.14; 10.9 ± 0.6 vs. 9.5 ± 0.6, LSM ± Se, p = 0.09) in the sows born in 1998. The total and viable number of piglets in litters of sows born in 1999 and 2000 was not affected by L-carnitine supplementation. The effect of L-carnitine on the number of stillborn, non-viable, smaller than 800 g and fit for rearing piglets differed within the sows of different parities of supplemented group. The number of piglets smaller than 800 g tended to be lower (0.9 ± 1.2 vs. 1.4 ± 1.6, LSM ± Se, p = 0.08), while there was a significant effect due to L-carnitine supplementation (0.9 ± 0.4 vs. 2.5 ± 0.4, LSM ± Se, p = 0.01) in sows born in 1998. The number of piglets fit for rearing was not influenced by L-carnitine supplementation with exception of the sows born in 1998. Their number of piglets fit for rearing was significantly increased (10.8 ± 0.5 vs. 9.1 ± 0.6, LSM ± Se, p = 0.03). A similar observation was made by Musser et al. (12). In those studies additive of L-carnitine in

Tab. 2. Litter sizes at parturition (LSM ± Se)

Experimental groups Number of sows	Control	Treated	Significant factors (p ≤ 0.05)		
			LC*	Year**	LC*Year***
Total:	n = 38	n = 35			
Total number of piglets born,	10.7 ± 1.9	11.0 ± 2.0	0.50	0.28	0.39
Number of viable piglets,	10.4 ± 1.9	10.8 ± 2.1	0.35	0.16	0.40
Number of stillborn piglets,	0.3 ± 0.8	0.1 ± 0.4	0.41	0.13	0.87
Number of non-viable piglets,	1.2 ± 0.6	0.1 ± 0.4	0.38	0.07	0.49
Number of piglets fit for rearing,	10.2 ± 1.8	10.8 ± 2.0	0.20	0.08	0.22
Number of piglets < 800 g	1.4 ± 1.6	0.9 ± 1.2	0.08	0.14	0.06
Sows born in 1998:	n = 11	n = 13			
Total number of piglets born,	9.8 ± 0.6	11.0 ± 0.5	0.14	–	–
Number of viable piglets,	9.5 ± 0.6	10.9 ± 0.6	0.09	–	–
Number of stillborn piglets,	0.3 ± 0.2	0.1 ± 0.2	0.44	–	–
Number of non-viable piglets,	0.5 ± 0.1	0.2 ± 0.1	0.12	–	–
Number of piglets fit for rearing,	9.1 ± 0.6	10.8 ± 0.5	0.03	–	–
Number of piglets < 800 g	2.5 ± 0.4	0.9 ± 0.4	0.01	–	–
Sows born in 1999:	n = 16	n = 14			
Total number of piglets born,	10.9 ± 0.5	10.6 ± 0.5	0.67	–	–
Number of viable piglets,	10.4 ± 0.5	10.4 ± 0.5	0.91	–	–
Number of stillborn piglets,	0.4 ± 0.2	0.3 ± 0.2	0.50	–	–
Number of non-viable piglets,	0.0 ± 0.0	0.0 ± 0.0	1.00	–	–
Number of piglets fit for rearing,	10.4 ± 0.5	10.4 ± 0.5	0.91	–	–
Number of piglets < 800 g	1.3 ± 0.3	0.8 ± 0.4	0.35	–	–
Sows born in 2000:	n = 11	n = 8			
Total number of piglets born,	11.2 ± 0.6	11.6 ± 0.7	0.63	–	–
Number of viable piglets,	11.2 ± 0.6	11.5 ± 0.7	0.73	–	–
Number of stillborn piglets,	0.0 ± 0.0	0.0 ± 0.0	1.00	–	–
Number of non-viable piglets,	0.2 ± 0.1	0.1 ± 0.2	0.80	–	–
Number of piglets fit for rearing,	11.0 ± 0.6	11.5 ± 0.7	0.56	–	–
Number of piglets < 800 g	0.7 ± 0.4	1.3 ± 0.5	0.53	–	–

Explanations: as in tab. 1

either gestation, lactation, or both, increased the number of pigs born alive and reduced the number of stillborns piglets in the subsequent litter. The beneficial effects of L-carnitine added to the sows diet may result in an increase of the number of eggs ovulated and/or improve embryo survival. Some authors discuss the effects of L-carnitine on the number of piglets born alive as related to increased insulin and insulin growth factor I (IGF I) concentration in the plasma of supplemented sows. Musser et al. (11) observed increasing concentrations of insulin and IGF I on d 30 and d 50 during the sows' gestation. It has been associated not only with changes in fetal muscle fiber development, resulting in leaner, faster growing offspring, but also with increasing numbers of ovulated eggs. Cox et al. (6) observed that administration of exogenous insulin (0.1 IU/d) increased luteinizing hormone (LH) secretion resulting in increased ovulation rate too. If additional dietary L-carnitine increases insulin and IGF-I, then indirectly effects on LH secretion, the improvement in ovulation rates could be evident.

Litter weights and mean birth weights of piglets are shown in tab. 3. The weight of litter and piglet at birth was not influenced by L-carnitine supplementation. The treated sows born in 1998 tended to produce heavier litter weights (15.5 ± 1.0 vs. 13.6 ± 1.0, LSM ± Se, p = 0.05) compared to those of the control group, although these differences are not statistically significant. Our own observation is contrary to other authors' studies, which showed heavier piglets and/or litter weights at birth in sows, receiving L-carnitine supplement during gestation period (7, 11, 16, 17). It is suggested that this effect might be due to higher milk yield and increased transfer of energy and nutrients from the sow to piglets with milk. Newborn pigs can synthesize L-carnitine only to a small extent (1); an increased concentration of carnitine in the milk of sows treated with L-carnitine could therefore induce more efficient energy utilization in suckling piglets (17).

Recent trials in sows in particular suggest that addition of L-Carnitine to the diet can enhance weaning weights and survivability of litter (7, 9, 12, 16). Unfortunately in our study, the respond of weaning piglets to L-Carnitine was not determined because of the impossibility to follow up with every piglet from the farrowing to the end of the suckling period (data are not shown).

In conclusion, this study shows that dietary L-carnitine supplementation improves reproductive performance of multiparious sows, although the experiment was conducted only one reproduction cycle. Further studies on dietary supplementation of L-Carnitine are required to prove whether L-Carnitine supplementation would have a positive effect over several reproductive cycles, to confirm the effect on ovarian function, ovulation rates and on fetal development with various dietary L-Carnitine supplement inclusion rates, to establish the impact on subsequent litter size, milk production and some blood parameters.

Tab. 3. Litter and piglet weights at parturition (LSM ± Se)

Experimental groups Number of sows	Control	Treated	Significant factors ($p \leq 0.05$)		
			LC[1]	Year[2]	LC*Year[3]
Total:	n = 38	n = 35			
Litter weight, kg	15.7 ± 3.7	15.7 ± 3.6	0.94	0.02	0.20
Piglet weight, kg	1.5 ± 0.4	1.5 ± 0.3	0.61	0.64	0.34
Sows born in 1998:	n = 11	n = 13			
Litter weight, kg	13.6 ± 1.0	15.5 ± 1.0	0.17	–	–
Piglet weight, kg	1.5 ± 0.1	1.4 ± 0.1	0.69	–	–
Sows born in 1999:	n = 16	n = 14			
Litter weight, kg	15.3 ± 0.9	15.5 ± 0.9	0.84	–	–
Piglet weight, kg	1.4 ± 0.1	1.5 ± 0.1	0.49	–	–
Sows born in 2000:	n = 11	n = 8			
Litter weight, kg	18.4 ± 1.0	16.4 ± 1.2	0.23	–	–
Piglet weight, kg	1.6 ± 0.1	1.4 ± 0.1	0.19	–	–

Explanations: as in tab. 1

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