Lohmann Information

EFFECT OF DIETARY L-CARNITINE SUPPLEMENTATION ON THE PERFORMANCE OF SOWS

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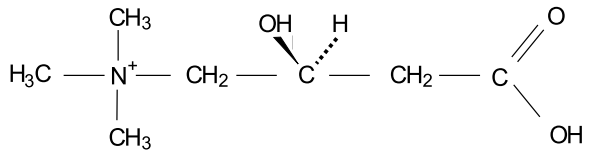
Introduction

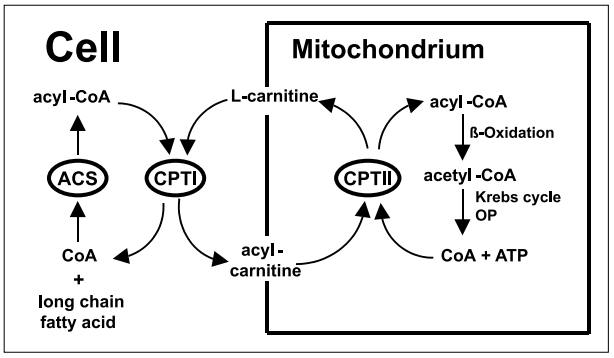
L-carnitine is a chemical compound whose structure resembles that of an amino acid (Figure 1).

Figure 1: Structure of L-carnitine



L-carnitine can be formed in the animal's body. The amino acids lysine and methionine act as precursors. The vitamins B_6, B_{12}, C, folic acid and niacin and the trace element iron are also necessary as catalysts of the endogenous synthesis of L-carnitine. The highest synthesising capacity is found in the liver. The primary biochemical function of L-carnitine is to form esters with long-chain activated fatty acids in the cytosol of cells, catalyzed by carnitine palmitoyl transferase type I. These esters have the capacity to penetrate the mitochondial membrane. Within the mitochondrium the esters are cleaved off again from L-carnitine and fatty acids, catalyzed by type II of carnitine palmitoyl transferase. The activated fatty acids released inside the mitochondrium can be utilised for the production of energy via ß-oxidation. ATP is formed as the energetically utilisable end product (see Figure 2).

Figure 2: The function of L-carnitine in the release of energy from fatty acids in animal cells



ACS=acyl CoA synthetase, CPTI=carnitine palmitoyl transferase type I, CPTII=carnitine palmitoyl transferase type II, CoA=coenzym A, OP=oxidative phosphorylation

Other functions of L-carnitine that have received less attention in the literature include the buffering of acetyl residues (see HARMEYER and SCHLUMBOHM, 1997). As well as being synthesized endogenously, L-carnitine is also supplied to the animal's body through the diet. While animal-derived feedingstuffs are rich in L-carnitine, plant material contains little L-carnitine (see Table 1). Typical rations without animal components generally contain between 5 and 10 mg L-carnitine per kg.

Table 1: L-carnitine concentrations in feedstuffs

Feedstuff	mg/kg	Feedstuff	mg/kg
Barley	10	Milk	20
Maize	5	Skim milk	10-30
Wheat	5	Skim milk powder	100-300
Triticale	5	Whey powder	300-500
Wheat bran	15	Fish meal	60-120
Soybean meal	20	Meat bone meal	50-80

Source: M. Baumgartner, R. Blum (LONZA information)

In recent years there has been a growing number of studies exploring the question whether dietary supplementation with L-carnitine can enhance the performance of farm livestock. Recent trials in sows in particular suggest that adding L-carnitine to the diet can enhance reproductive performance. In a study by HARMEYER (1993) L-carnitine supplementation of sow rations during lactation led to improved weight gains of the piglets during the suckling period. In another study by MUSSER et al. (1999) L-carnitine supplementation during pregnancy improved the reproductive performance of sows, but supplementation during lactation gave no improvement in performance. The effects of adding L-carnitine to sow diets on their reproductive performance have thus not been fully elucidated. In particular, it is not yet clear whether any positive effects of L-carnitine supplementation are maintained over several reproductive cycles. The objective of the present trial was therefore to test the impact of a L-carnitine supplement during pregnancy and lactation on the reproductive performance of sows over several cycles.

Material and methods

Two trials were carried out in an agricultural cooperative holding a herd of 300 sows (Leicoma). In the first trial 127 sows were selected from this herd and in the second trial, 100. The animals were divided into two groups (control group vs. treated group) by weight and number of previous pregnancies. Both trials were identical in design and conduct but were performed with different animals (Table 2).

Table 2: Experimental design for the investigation of the effects of L-carnitine on reproductive performance of sows

Animals	First trial: 127 sows (Leicoma) Second trial: 100 sows (Leikoma)
Feeding	Restrictiv commercial gestation or lactation diet
Animal housing	Individually, in crates
Parameters of animal performance	Litter sizes and weights at parturation and weaning Piglet development during suckling and rearing
Treatment	Basal diet + 125 mg L-carnitine/day/animal (Pregnancy) + 250 mg L-carnitin/day/animal (lactation)

The sows were kept in single crates and fed individually. From day 1 to day 84 of pregnancy they received a commercial gestation diet, and from day 85 of pregnancy to the end of lactation a commercial lactation diet. The nutrient concentrations of these feed mixtures are shown in Table 3.

Table 3: Nutrients of the experimental basal diets

Nutrient	Gestation diet	Lactation diet
Energy (MJ ME/kg)	12.0[1]	12.9[1]
Crude protein (g/kg)	136[1]	178[1]
Crude fat (g/kg)	39[1]	38[1]
Crude fibre (g/kg)	64[1]	59[1]
Crude ash (g/kg)	55[1]	62[1]
Lysine (g/kg)	7.0[2]	10.0[2]
L-carnitine (mg/kg)	4.7[1]	12.5/<5[1]

[1] analysed value, [2] value declared by the manufacterer

Feeding during pregnancy was restrictive; the feed allowance during lactation was determined by the number of piglets being nursed (Table 4). The animals were fed once daily until day 108 of pregnancy, thereafter three times daily. The native L-carnitine concentration of the gestation diet was below 5 mg per kg, that of the lactation diet 12 mg per kg in the first trial and 5 mg per kg in the second trial. The sows of the treated group received a supplement of 125 mg L-carnitine per head and day during pregnancy and 250 mg during lactation; the supplement was added to the ration in the form of a premix (in wheat bran). Water was available ad libitum to all animals. On day 7 after farrowing the young piglets received a piglet supplement for unrestricted feeding. In both trials performance data were generated over three complete reproductive cycles. The data were evaluated by one-day analysis of variance.

Table 4: Feeding regimes

Stage	Feed mixture/feed amount
Early pregnancy (day 1-85)	Gestation diet, 2.5 kg daily per animal
Late pregnancy (day 86-114)	Lactation diet, 2.5 kg daily per animal
Lactation	Lactation diet
Day 1-4	1.5 to 4.5 kg daily per animal
Day 5-28	5 to 6 kg daily per animal

Results

Data on litter sizes and litter development are summarised in Table 5. The results were very similar in the two trials. While the L-carnitine treatment had no effect on the number of piglets born in both trials, the number of stillborn piglets was marginally lower in the sows treated with L-carnitine than in the control sows of both trials; the number of non-viable piglets was half as high in the L-carnitine treated group as in the control sows in both trials. As a consequence, the number of piglets considered fit for rearing was slightly higher among the sows treated with L-carnitine. As losses during the suckling period were also lower, the number of weaned piglets was higher in the sows treated with L-carnitine than in the control sows, by 0.6 animals in the first trial and by 0.4 animals in the second trial. This positive effect of L-carnitine supplementation was observed across all three studied reproductive cycles. In the first trial the number of weaned piglets in the three reproductive cycles was increased by 0.4, 0.3 and 1.2 piglets per sow as a result of L-carnitine supplementation, and in the second trial by 0.4, 0.3 and 0.5 piglet per sow.

Table 5: The effect of supplementing basal sow diets with L-carnitine on litter sizes and development of litters in two trials (piglets per sow, means of three reproductive cycles)

Parameter	Control (-L-carnitine)	Treatment (+L-carnitine)	Difference (%)	p
First trial	*n=109*	*n=103*		
Total number of piglets born	12.1	11.8	-3	0.444
Number of piglets born alive	10.5	10.6	+1	0.983
Number of stillborn piglets	1.6	1.2	-25	0.250
Number of non-viable piglets	0.6	0.3	-50	0.002
Number of piglets fit for rearing	9.9	10.3	+4	0.381
Number of weaned piglets	8.3	8.9	+7	0.056
Mortality	1.6	1.4	-13	0.211
Second trial	*n=86*	*n=87*		
Total number of piglets born	12.0	12.0	0	0.953
Number of piglets born alive	11.3	11.5	+2	0.399
Number of stillborn piglets	0.7	0.5	-29	0.075
Number of non-viable piglets	0.4	0.2	-50	0.083
Number of piglets fit for rearing	10.9	11.3	+4	0.180
Number of weaned piglets	9.0	9.4	+4	0.056
Mortality	1.9	1.9	0	0.490

L-carnitine supplementation of sows during pregnancy significantly increased the birth weight of the piglets (Table 6). This effect was evident in both trials and was similar in magnitude (+5 % in the first trial, +6 % in the second trial). The litter mass of the sows whose diet had been supplemented with L-carnitine was also higher than in the control sows, by 5 % and 9 % respectively.

Table 6: The effect of supplementing basal sow diets with L-carnitine on liveweights of piglets and litters at parturition in two trials (kg, means of three reproductive cycles)

	Control (-L-carnitine)	Treatment (+L-carnitine)	Difference (%)	p
First trial	*n=109*	*n=103*		
Piglets	1.44	1.51	+5	0.033
Litters	15.0	15.8	+5	0.122
Second trial	*n=86*	*n=87*		
Piglets	1.45	1.53	+6	0.027
Litters	16.0	17.5	+9	0.007

It was further noted that the piglets of L-carnitine treated sows gained significantly more weight during the suckling period than the piglets of the control sows (Table 7). This difference amounted to 2 % per individual piglet in the first trial and 6 % in the second trial. The differences in the development of the litter mass during the suckling period were even greater. As fewer losses occurred in the litters of the L-carnitine treated sows the differences in litter mass increases during the suckling period were as high as 10 % (first trial) and 11 % (second trial). As a consequence, the litters of the L-carnitine supplemented sows were significantly heaver after an identical 28-day suckling period than the litters of the control sows (9 % vs. 11 %).

Table 7: The effect of supplementing basal sow diets with L-carnitine on liveweight gains of piglets during the suckling period and liveweights of piglets at weaning in two trials (kg, means of three reproductive cycles)

	Control (-L-carnitine)	Treatment (+L-carnitine)	Difference (%)	p
First trial	*n=109*	*n=103*		
Weight gain of piglets	6.67	6.79	+2	0.256
Weight gains of litters	54.4	60.0	+10	0.026
Weight of piglets at weaning	8.11	8.30	+2	0.484
Weights of litters at weaning	69.4	75.8	+9	0.029
Second trial	*n=109*	*n=103*		
Weight gain of piglets	6.10	6.45	+6	0.018
Weight gains of litters	51.8	57.4	+11	0.019
Weight of piglets at weaning	7.55	7.98	+6	0.007
Weights of litters at weaning	67.8	74.9	+11	0.001

The effects of L-carnitine on birth weight and liveweight gains were evident across all three reproductive cycles, although the responses were not of equal strength in the three cycles (Table 8). In the second reproductive cycle of the first trial the benefits of L-carnitine supplementation were only slightly in evidence, but they were much more pronounced in the third cycle. It is conceivable that compensatory mechanisms come into play here. In the second trial the positive effects of L-carnitine supplementation were uniform in all three reproductive cycles.

At weaning some piglets were removed from both groups of sows and their subsequent development during the rearing period was monitored (Table 9). An identical standard grower ration was fed to both groups. The weaned piglets from the L-carnitine treated sows were only slightly heavier at housing but grew considerably faster and reached the target weight of 25 kg about five days earlier than the piglets of the control sows. These findings suggest that the piglets of the L-carnitine supplemented sows develop faster during the postnatal period as well.

Table 8: The effect of supplementing basal sow diets with L-carnitine on performance parameters in individual reproductive cycles

Parameter	First trial			Second trial		
Liveweights of piglets at parturition (Improvement by L-carnitine, %)	6	1	8	2	10	6
Litter weights at parturition (Improvement by L-carnitine, %)	7	1	8	6	10	12
Litter weights at weaning (Improvement by L-carnitine, %)	14	1	24	8	11	14
No of weaned piglets (Improvement by L-carnitine, no of animals)	0.4	0.3	1.2	0.4	0.3	0.5

Table 9: The effect of supplementing basal sow diets with L-carnitine on growth performance of rearing piglets

Parameter	Control (-L-carnitine) *(n=297)*	Treatment (+L-carnitine) *(n=335)*	Difference (%)
Initial liveweight (kg)	7.35	7.61	+ 4
Final liveweight (kg)	25.9	25.0	- 3
No of days	47.2	42.0*	- 10
Daily liveweight gain (g)	394	415*	+ 5

* Statistically significant difference (P<0.05) between control and treatment group

Discussion

This study shows conclusively that dietary L-carnitine supplementation of sows significantly improves reproductive performance. Our results confirm a study by MUSSER et al. (1999) where L-carnitine supplementation during pregnancy also led to higher birth weights of the piglets. The biochemical mechanisms responsible for the higher piglet weights at farrowing are still uncertain. It would appear unlikely that the effect of L-carnitine is based on its classic function as a carrier of fatty acids into the mitochondrium. The study by MUSSER et al. (1999) showed that sows receiving a carnitine supplement lay down more adipose tissue during pregnancy. In our own study (EDER et al., 2001) L-carnitine supplementation of sows also led to higher liveweight gains during pregnancy. In fattening pigs on the other hand L-carnitine supplementation reduced the proportion of body fat, an effect that is attributed to increased ß-oxidation (OWEN et al., 1997).

The observation that treatment of sows with L-carnitine caused heavier piglets to be born while at the same time reducing the proportion of very light, non-viable piglets, suggests an improved intrauterine nutrient supply. MUSSER et al. (1999) showed that sows whose diet was supplemented with L-carnitine had higher concentrations of insulin and IGF-1 in the blood. These results suggest that L-carnitine supplements influence the glucose metabolism. Glucose is the most important energy source for the fetus; raised blood glucose levels, which might be due to an increased secretion of IGF-1, would provide a hypothetical explanation for the improved intrauterine fetal development. Treatment of pregnant sows with porcine growth hormone also results in higher piglet weights at birth. This effect is due to an increased release of IGF-1 (REHFELDT et al., 1993). The higher birth weights of piglets

from L-carnitine supplemented sows can thus be plausibly explained by higher concentrations of IGF-1 in the blood. An increased release of IGF-1 during pregnancy as induced by exogenous administration of porcine growth hormone also stimulates muscle cell formation in the fetus (REHFELDT et al., 1993). It is interesting that in the present study the postnatal development of the piglets was also better with L-carnitine. This observation might well be due to a greater number of muscle fibres. Further studies are needed to ascertain whether these assumptions are correct.

Summary

Two trials were conducted to study the effect of dietary L-carnitine supplementation on the reproductive performance of sows. Supplements of 125 mg L-carnitine per head and day during pregnancy and 250 mg L-carnitine per head and day during lactation did not affect the number of piglets born, but the number of stillborn and non-viable piglets was lower than among the untreated control sows. The number of piglets weaned was therefore higher by half a piglet on average among the L-carnitine treated sows. The piglets of the treated group were not only significantly heavier at birth than those of the control sows, they also grew faster during the suckling period and the subsequent rearing period than the piglets of the control sows. The effects of L-carnitine supplementation were identical in both trials and persisted over several reproductive cycles. In all, the study shows that adding L-carnitine to sow diets has highly beneficial effects on the reproductive performance of sows. The biochemical mechanisms on which the performance improvements are based will have to be elucidated in future studies.

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