Scientific Annals of Polish Society of Animal Production - Vol. 10 (2014), No 4, 77-85

The effect of an L-carnitine supplement on reproductive performance in sows

Paweł Rutkowski, Justyna Więcek, Anna Rekiel, Grażyna Tokarska

Warsaw University of Life Sciences, Department of Animal Breeding and Production,
Pig Breeding Section,
ul. Ciszewskiego 8, 02-786 Warszawa

The aim of the study was to determine the effect of L-carnitine administered to sows in late pregnancy and during lactation on their fertility and rearing of offspring. The study involved 20 PIC sows assigned to control (K) and experimental (D) groups. From the 90th day of pregnancy to the end of lactation (day 28), sows from group D received a dietary supplement of L-carnitine (50 mg/kg feed). At weaning, sows from group D had greater litter size (by 0.9 piglets) and their piglets were 0.3 kg heavier than those of sows from group K. Supplementation of the diet of pregnant sows caused no changes in the chemical composition of their milk. However, milk somatic cell count was lower for D compared to K sows, which shows a positive effect of the supplement on the mammary gland of the sows. Supplementing the sows' diet with L-carnitine reduced feeding costs by 0.52 PLN (14.1%) per kg of litter weight until weaning. The performance and economic results indicate that supplementation of sow diets with L-carnitine is advisable.

KEY WORDS: sows / L-carnitine / reproduction / rearing of piglets

Efficient feeding of breeding animals is difficult. During each stage of the reproductive cycle sows require feeds that differ in their content of energy and nutrients, including biologically important ones. One of these is L-carnitine. It is synthesized in the liver, brain and kidneys from lysine and methionine [5]. It is present in all mammalian cells, reaching its highest concentrations in the myocardium, liver and skeletal muscles. When the supply and uptake of lysine and methionine are optimal, L-carnitine deficiency in the body should not occur, as it is synthesized endogenously. However, deficiencies are observed in rapidly growing animals and those used intensively for breeding. Products of animal origin are the main source of L-carnitine in feed [2], while the content of L-carnitine in plant feed materials is low [12]. A reduction in the use of feed of animal origin in pig diets and a high proportion of plant components results in L-carnitine deficiency. A lack of L-carnitine inhibits fatty acid combustion and increases glycolysis, which reduces glycogen reserves. This results in hypoglycaemia and hypoketonaemia [5]. L-carnitine deficiency can be corrected

using its synthetic form. When administered with food it is absorbed actively in the small intestine in a process mediated by Na^+ ions and passively by diffusion. It is also stored in the walls of the small intestine. Carnitine is not metabolized in the body. It is filtered in the renal glomeruli and then almost completely reabsorbed in the renal tubules [5].

In nutritional studies on breeding pigs, L-carnitine has most commonly been added at a rate of 25-125 mg to 1 kg of feed, but the optimum intake of this compound for sows for has not been established [10]. A level of 50 mg/kg of feed is considered most favourable, although the research results obtained are not conclusive [8, 10, 17, 22, 24]. The use of L-carnitine and chromium in the diet of young gestating and lactating sows (in the first and second reproductive cycles) has been found to increase the number of live-born piglets, reduce the post-weaning waiting period before the onset of oestrus, and increase the number of sows mated within 7 days [25].

As the results of previous experiments on the effect of L-carnitine on reproduction in sows are not conclusive, a study was undertaken to determine the effect of L-carnitine administered to sows in advanced pregnancy and during lactation on their fertility and rearing of offspring.

Material and methods

The study was conducted on 20 PIC sows, divided into two groups: control (K) and experimental (D). Each group consisted of 8 multiparous and 2 primiparous sows. The experimental sows received an L-carnitine supplement (50 mg/kg feed) from the 90th day of gestation to the end of lactation (day 28). The sows were fed a standard diet [20], which they received twice daily. Until 90 days of pregnancy this was a compound feed for pregnant sows (LP), and during the remainder of the gestation period and during lactation they received a compound feed for lactating sows (LK). The composition and nutritional value of the LK feed are shown in Table 1. Perinatal feeding was restricted: from days 4-5 after farrowing to the 10th day of lactation the ration per feeding did not exceed 3 kg; then up to the 25th day of lactation it was increased to 4.5-5 kg per feeding. During the three days preceding weaning the feed ration was reduced, and on the day of weaning the sows were not fed. Piglets were additionally given Bonni M feed from Sano from 8 days of age. Sows and piglets had unlimited access to water. From days 28 to 105 of gestation the sows were housed in group pens, and then in single farrowing pens (until rearing of the offspring was completed).

During the experiment we monitored the number of live and dead piglets, piglet weight at 1 and 28 days of age, daily weight gains from birth to weaning, milk composition and its somatic cell count (SCC) on day 21 of lactation, number of cases of mastitis, and the duration of the dry period after weaning.

Milk for analysis, in the amount of 50 ml, was collected into containers with a preservative (Mlekostat CC) on day 21 of lactation following an oxytocin injection (2 ml/sow). Content of protein, fat, lactose and dry matter in the milk samples was measured by infrared spectrophotometry using a Foss Electric MilkoScan FT 120. The somatic cell count

Table 1
Composition (%) and nutritive value of diet

Specification	LK compound feed for sows from groups K and D
Wheat	37
Barley	37
Soybean meal 45%	15
Fish meal 55%	4
Soybean oil	3
Premix LNB 8253 (group K)*	4
Premix LNB 820230 (group D)**	4
Estimated nutritive value:	
metabolizable energy (MJ)	13.1
crude protein (g)	165
crude fibre (g)	4.3
total Ca (g)	10.1
lysine (g)	8.0
methionine (g)	5.7
threonine (g)	6.1

*1 kg Premix LNB 8253 contains: 380,000 IU vit. A, 50,000 IU vit. D_3, 3,500 mg vit. E, 125 mg vit. K_3, 57 mg vit. B_1, 150 mg vit. B_2, 100 mg vit. B_6, 1,200 mcg vit. B_{12}, 2500 mg vit. C, 625 mg vit. B_5; 125 mg folic acid, 1,000 mg nicotinic acid, 7,500 mcg biotin, 12,500 mg choline, 1,330 mg Mn, 3,010 mg Zn, 3,300 mg Fe, 510 mg Cu, 17 mg Co, 50 mg I, 8.7 mg Se
**1 kg Premix LNB 820230 contains: as above + 1,250 mg L-carnitine

(SCC) was determined using a Bentley Somacount 150. A simplified economic analysis of production results was performed.

Statistical analysis of the results was performed using the SPSS Statistics 20 package. The normality of the distribution was tested by the Shapiro-Wilk test. The somatic cell count was log-transformed. Differences between groups were tested by Student's t-test (normal distribution) or the Mann-Whitney U test (other features).

Results and discussion

The average number of total, live-born and stillborn piglets per litter of the group D sows was 0.5, 0.2 and 0.3 higher than in the control (P> 0.05; Table 2). The feed supplemented with L-carnitine was not administered to the sows until the final period of gestation. Studies in which sows received supplemented feed throughout the gestation period have also found no significant improvement in reproductive performance [7, 23]. Studies by other authors [3, 19] obtained a reduction in the number of stillborn piglets per litter. According to Musser et al. [19], the positive but not always statistically confirmed effect of L-carnitine is due to an increase in the number of ovulating cells or a decrease in embryo mortality. In our study, the group D sows reared more piglets per litter than the control group K (11.0 and 10.1, respectively; P≤0.05). The total growth of the piglets during 28-day rearing was 7.4% higher, daily gains were 6% higher and litter weight at weaning was 9.5 kg higher (13.1%). These results confirm those obtained in other research [7]. In an experiment by Eder et al. [7], measurable effects of L-carnitine supplementation were increased weight of piglets at birth and weaning. Newborn piglets and weaned piglets from primiparous sows in the experimental group were 9% and 12% heavier than the piglets from the control sows, while in the case of multiparous cows the differences were 6% and 4%. The best effects of L-carnitine can be observed during lactation in young females, in their first and second reproductive cycle [13]. This is confirmed by the results of our own research. The daily gains of the offspring of sows from groups D and K during 28 days of rearing were 232 g and 136 g, respectively. The L-carnitine in mother's milk may be important for the development of sucklings, as in the first days after birth piglets have a low capacity to synthesize it endogenously [1]. In a study by Ramanau et al. [21], sows fed low-energy and low-protein feeds during lactation had similar weight loss, but only gestating and lactating sows whose feed was supplemented with L-carnitine produced more milk. This, however, was associated with a greater loss of fat reserves. Research conducted in Poland [10] has not found a positive effect of L-carnitine-supplemented feed given from the 100th day of gestation on the number and weight of live-born piglets, the weight of piglets at weaning, or the L-carnitine level in the milk of the sows, but only a reduction in the number of stillborn piglets. Other experiments [7, 8, 9, 16] have found a positive effect of L-carnitine on litter size and weight and on the growth rate of young pigs. During the rearing period, both with their mothers and after weaning, the growth rate of the offspring of experimental sows was higher. The beneficial effect persisted during fattening, so that the pigs from the group D sows reached slaughter weight faster than the control group K.

According to some researchers, L-carnitine shows positive effects only in the prenatal period [18, 19]. By conditioning the intrauterine development of the foetus, it is conducive to a reduction in the number of stillborn piglets. The use of L-carnitine in the diet of gestating sows may increase the oxidation of fatty acids and glucose, improving foetal metabolism, which increases the birth weight of piglets and litters [23, 28]. Lösel and Rehfeldt [16] emphasize the beneficial effect of L-carnitine-supplemented feed on piglets with low birth weight. In their opinion, the use of L-carnitine in the diet of suckling piglets improves the development and growth of muscle fibres, leading to increased body weight.

Table 2
Production performance

Trait	Group		P
	K	D	
Number of piglets born in total	12.0	12.5	0.103
Number of piglets born alive	11.6	11.8	0.260
Number of stillborn piglets	0.4	0.7	0.761
Number of piglets on day 28	10.1	11.0	0.061
Litter weight at birth (kg)	20.4	19.7	0.487
Litter weight on day 28 (kg)	72.6	82.1	0.150
Body weight of piglet at birth (kg)	1.8	1.7	0.135
Body weight of piglet on day 28 (kg)	7.2	7.5	0.097
Total body weight gain days 1-28 (kg)	5.4	5.8	0.043
Daily weight gain days 1-28 (g)	200	212	0.042

The positive effect of L-carnitine used in feeding pregnant sows has also been observed by other researchers [7, 19, 22], who reported an increase in litter weight and the weight of individual piglets born of sows given supplemented feed. Ramanau et al. [22], in an experiment lasting two reproductive cycles, obtained larger litters ($P \leq 0.05$) and higher total litter weight ($P \leq 0.05$) from sows whose diet was supplemented with L-carnitine. Not all studies have shown substantial differences in the body weight of suckling piglets from sows fed L-carnitine-supplemented feed during gestation [19].

In our own study, while piglet body weight at birth was 5% higher in group K than in group D, at weaning the body weight of the group D piglets was much higher (Table 2). Probably the sows fed L-carnitine-supplemented feed produced more milk and possibly with higher content of this biologically important compound [3, 6, 21]. The level of L-carnitine in mammalian milk is varied. The highest content has been noted in sheep milk and the lowest in cow and horse milk, while in pigs its content is 25-60 mg/kg [29]. L-carnitine taken up by foetuses, and then by postnatal piglets in the post-natal period, improves muscle tissue growth, increasing body weight at weaning [15, 16, 27]. The young body requires a lot of energy from carbohydrates and fats for rapid growth. L-carnitine can increase β-oxidation of fatty acids to about 70%, which increases their use as an energy source. The synthesis of L-carnitine in newborn animals is insufficient [1, 4], so it should be supplied to neonates with their mothers' milk [3]. Piglets fed the milk of sows whose

diet was supplemented with L-carnitine have been shown to grow faster than piglets from control litters [19, 22]. Similar results have been reported by other researchers [21], who observed 17% and 19% increases in milk production by experimental sows as compared with controls on the 11th and 18th days of lactation. The weight of piglets from the two groups at birth did not differ significantly, but greater milk production during lactation resulted in a significant difference in litter weight at weaning. In our own study, a 6% difference ($P \leq 0.05$) was noted in the daily weight gains of piglets, in favour of group D (Table 2). The improvement in daily weight gains in the piglets may have been due to the addition of L-carnitine to the sows' feed, as this compound is involved in the metabolism of long-chain fatty acids in the mitochondria, stimulates metabolism of fats, and increases their use as an energy source [26].

On the day of weaning, 0.9 more piglets were obtained in the experimental group than in the control (Table 2). The use of L-carnitine during gestation and lactation may favour lung development in neonates, preventing constriction of the pulmonary alveoli and thus reducing the number of piglet deaths due to cardiorespiratory failure [14]. The higher number of weaned piglets may also be due to better milk production in the group D sows and lower incidence of mastitis. No differences were found in our study in the chemical composition of milk between groups K and D (Table 3). The only significant difference was observed in the log-transformed SCC ($P \leq 0.01$), indicating better health of the mammary gland of group D sows as compared to K. Other authors have demonstrated a positive effect of L-carnitine supplementation on milk production in sows and the frequency of lactation disorders [11]. In our study, three sows from the control were diagnosed with MMA, manifested as elevated body temperature (40°C), appetite loss, hardening of part or all of the mammary gland, and rapid differentiation between piglets in the litter. This resulted in a temporary reduction in feed intake by these sows.

Table 3
Chemical composition and somatic cell count (SCC) of milk

Trait	Group		P
	K	D	
Dry matter (%)	19.76	19.15	0.179
Crude protein (%)	4.49	4.59	0.445
Lactose (%)	5.99	6.13	0.243
Fat (%)	7.49	7.33	0.653
LNSCC*	2.51	1.69	0.001

*LNSCC – natural logarithm of somatic cell count

The content of dry matter, fat, protein and lactose did not differ between groups, but the piglets from group D were heavier at weaning than the group K piglets. The results of our tests of the chemical composition of milk are in agreement with results reported by German authors [23]. The milk of sows from group receiving the L-carnitine supplement, sampled on day 11 of lactation, contained 35% more of the compound than the milk of the control sows. The main source of energy for piglets after birth is milk and the fatty acids contained in it. Piglets do not have brown adipose tissue and have limited ability to stimulate β-oxidation of fatty acids, which can lead to shivering thermogenesis [2]. Enriching the sow diet with bioactive substances affects the prenatal development of the stomach and small intestine in the offspring.

The weaning-to-conception interval in the group K sows lasted for an average of 7 days: nine sows were successfully mated after a 5-day dry period and one after 26 days. In group D, the average weaning-to-conception interval was 9 days: 8 sows were successfully mated 5 days after weaning and two sows after 26 days. The addition of L-carnitine did not reduce the dry period of the sows.

In group D, lactating sows consumed 1,720 kg of feed (on average 172 kg/sow). The group K sows received the same amount of feed every day as the D sows, but without the L-carnitine supplement; however, three of them suffered appetite loss due to the MMA syndrome. Feed consumption in the K group was 1,690 kg (on average 169 kg/sow). The prices of the feeds for the K and D sows were PLN 1.14 and PLN 1.15 per kg, respectively. The increase in litter weight from days 1 to 28 in groups K and D was 52.2 kg and 62.4 kg (Table 2). The cost of 1 kg of litter weight gain during the 4-week rearing period was calculated from the amount of feed consumed by the sows, its unit price,and litter weight gain during lactation (Table 2). In group D, the cost of 1 kg of litter weight gain was 3.17 PLN, which was 0.52 PLN lower than in group K. Thus the addition of L-carnitine to the feed was justified in terms of production and economically.

In conclusion, the addition of L-carnitine had a positive effect on rearing of the offspring, as it resulted in 0.9 more piglets per litter at weaning, with 0.3 kg higher body weight. The somatic cell count in the milk of group D sows was lower than for group K, indicating a positive effect of the supplement on the mammary gland. The use of the L-carnitine additive in the sow feed reduced nutritional costs per kg litter weight gain until weaning by 0.52 PLN (14.1%). The production and economic results justify the use of an L-carnitine supplement in feed for sows.

REFERENCES

1. BALTZELL J., BAZER F., MIGUEL S., BORUM P., 1987 – The neonatal piglet as a model for human neonatal carnitine metabolism. ***Journal of Nutrition*** 117, 754-757.
2. BAŁASIŃSKA B., KULASEK G., 2007 – Efektywność karnityny w żywieniu świń. ***Medycyna Weterynaryjna*** 63, 14-17.
3. BIRKENFELD C., DOBERENZ J., KLUGE H., EDER K., 2006 – Effect of L-carnitine supplementation of sows on L-carnitine status, body composition and concentrations of lipids in liver and plasma of their piglets at birth and during the suckling period. ***Animal Feed Science and Technology*** 129, 23-38.

4. BORUM P., BENNETT S., 1986 – Carnitine as an essential nutrient. ***Journal of the American College of Nutrition*** 5, 177-182.
5. CZECZOT H., ŚCIBIOR D., 2005 – Rola L-karnityny w przemianach, żywieniu i terapii. ***Postępy Higieny i Medycyny Doświadczalnej*** (online) 59, 9-19.
6. DOBERENZ J., BIRKENFELD C., KLUGE H., EDER K., 2006 – Effects of L-carnitine supplementation in pregnant sows on plasma concentrations of insulin-like growth factors, various hormones and metabolites and chorion characteristics. ***Journal of Animal Physiology and Animal Nutrition*** 90, 11-12, 487-499.
7. EDER K., RAMANAU A., KLUGE H., 2001 – Effect of L-carnitine supplementation on performance parameters in gilts and sows. ***Journal of Animal Physiology and Animal Nutrition*** 85, 3-4, 73-80.
8. EDER K., RAMANAU A., KLUGE H., 2002 – Effect of dietary L-carnitine supplementation on the performance of sows. ***Lohmann Information*** 26, 1-4.
9. EDER K., 2009 – Influence of L-carnitine on metabolism and performance of sows. ***British Journal of Nutrition*** 102, 5, 645-654.
10. KAWĘCKA M., JACYNO E., KOŁODZIEJ A., KAMYCZEK M., MATYSIAK B., 2007 – The efficiency of L-carnitine in nutrition of sows. ***Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego*** 3, 59-67.
11. KOTOWSKA E., KOTOWSKI K., 2006 – Wpływ L-karnityny na wskaźniki produkcyjne loch. ***Przegląd Hodowlany*** 12, 14-16.
12. KRZEMIŃSKI R., KULASEK G., 2003 – Znaczenie karnityny w żywieniu zwierząt. Część I. ***Magazyn Weterynaryjny*** 12, 76, 31-35.
13. LIPIŃSKI K., 2009 – Znaczenie karnityny w żywieniu świń. ***Trzoda Chlewna*** 7, 31-34.
14. LOHNINGER A., LASCHAN C., AUER B., LINHART L., SALZER H., 1996 – Tierexperimentelle und klinische Untersuchungen über die Bedeutung des Carnitins für den Stoffwechsel der Schwangeren und des Feten während der Prä- und Perinatalperiode. ***Wiener Klinische Wochenschrift*** 108, 2, 33-39.
15. LÖSEL D., KALBE C., REHFELDT C., 2009 – L-carnitine supplementation during suckling intensifies the early postnatal skeletal myofiber formation in piglets of low birth weight. ***Journal of Animal Science*** 87, 7, 2216-2226.
16. LÖSEL D., REHFELDT C., 2013 – L-carnitine supplementation to suckling piglets on carcass and meat quality at market age. ***Animal*** 7, 7, 1191-1198.
17. MUSSER R.E., DRITZ S.S., DAVIS D.K., TOKACH M.D., NELSSEN J.L., GOODBAND R.D., QWEN K.Q., 2007 – Effects of L-carnitine in the Gestating Sow Diet on Fetal Muscle Development and Carcass Characteristics of the Offspring. ***Journal of Applied Animal Research*** 31, 2, 105-111.
18. MUSSER R.E., GOODBAND R.D., OWEN K.Q, DAVIS D.K., TOKACH M.D., DRITZ S.S., NELSSEN J.L., 2001 – Determining the effect of increasing L-carnitine additions on sow performance and muscle fiber development of the offspring. ***Journal of Animal Science*** 79 (Suppl. 2), 157.
19. MUSSER R.E., GOODBAND R.D., TOKACH M.D., OWEN K.Q., NELSSEN J.L., BLUM S., DRITZ S.S., CIVIS C., 1999 – Effects of L-carnitine fed during gestation and lactation on sow and litter performance. ***Journal of Animal Science*** 77, 12, 3289-3295.
20. Normy Żywienia Świń. IFiŻZ PAN. Wyd. Omnitech-Press, 1993.

21. RAMANAU A., KLUGE H., EDER K., 2005 – Effects of L-carnitine supplementation on milk production, litter gains and back-fat thickness in sows with a low energy and protein intake during lactation. ***British Journal of Nutrition*** 93, 5, 717-721.
22. RAMANAU A., KLUGE H., SPILKE J., EDER K., 2002 – Reproductive performance of sows supplemented with dietary L-carnitine over three reproductive cycles. ***Archives of Animal Nutrition*** 56, 287-296.
23. RAMANAU A., KLUGE H., SPILKE J., EDER K., 2004 – Supplementation of sows with L-carnitine during pregnancy and lactation improves growth of the piglets during the suckling period through increased milk production. ***Journal of Nutrition*** 134, 1, 86-92.
24. RAMANAU A., KLUGE H., SPILKE J., EDER K., 2007 – Effect of dietary supplementation of L-carnitine on the reproductive performance of sows in production stocks. ***Livestock Science*** 113, 34-42.
25. REAL D.E., NELSSEN J.L., TOKACH M.D., GOODBAND R.D., DRITZ S.S., WOODWORTH J.C., OWEN K.Q., 2008 – Additive effects of L-carnitine and chromium picolinate on sow reproductive performance. ***Livestock Science*** 116, 63-69.
26. ROSENBAUM S., RINGSEIS R., MOST E., HILLEN S., BECKER S., ERHARDT G., REINER G., EDER K., 2013 – Genes involved in carnitine synthesis and carnitine uptake are up-regulated in the liver of sows during lactation. ***Acta Veterinaria Scandinavica*** 55, 24. doi:10.1186/1751-0147-55-24.
27. WIGMORE P., STRICKLAND N., 1983 – DNA, RNA and protein in skeletal muscle of large and small pig fetuses. ***Growth*** 47, 67-76.
28. XI L., BROWN K., WOODWORTH J., SHIM K., JOHNSON B., ODLE J., 2008 – Maternal dietary L-carnitine supplementation influences fetal carnitine status and stimulates carnitine palmitoyltransferase and pyruvate dehydrogenase complex activities in swine. ***Journal of Nutrition*** 138, 12, 2356-2362.
29. ZEYNER A., HARMEYER J., 1999 – Metabolic functions of L-carnitine and its effects as-feed additive in horses. A review. ***Archives of Animal Nutrition*** 52, 115-138.