Journal of Agriculture, Food, Environment and Animal Sciences
Tarım, Gıda, Çevre ve Hayvancılık Bilimleri Dergisi
http://www.jafeas.com, ISSN: 2757-5659

J. Agric. Food, Environ. Anim. Sci.
5(1): 89-89, 2024

Reproductive and Growth Physiology of Sows and Piglets on Dietary Selenium (Se) Supplementation

Bright Chigozie AMAEFULE[1], Luke Chukwudi ALI[2*], Nnanna Ephraim IKEH[3], Ifeanyi Emmanuel UZOCHUKWU[4], Nnenna Winifred ANIZOBA[5], Ndubuisi Samuel MACHEBE[6]

[1-6] Department of Animal Science, Faculty of Agricultural Sciences, University of Nigeria, Nsukka, NIGERIA

[1]https://orcid.org/0000-0002-7382-5287, [2]https://orcid.org/0000-0001-6393-2217, [3]https://orcid.org/0000-0003-0975-6923
[4]https://orcid.org/0000-0003-2424-0327, [5]https://orcid.org/0000-0003-4412-7145, [6]https://orcid.org/0000-0001-9603-8107

* Corresponding author: aliluke230@gmail.com

Research Article

Article History:
Received: 25 January 2024
Accepted: 19 April 2024
Published online: 01 June 2024

Keywords:
Sows
Selenium
Reproduction
Pre-weaning performance

ABSTRACT

This study examined how dietary supplements of selenium (Se) affected the preweaning growth performance of the piglets and the reproductive performance of the sows. Twelve gestating sows that were cross-bred (Landrace × Large White) were randomly allocated into four groups (G) based on the amount of dietary selenium supplementation. Group 0 (G_0) sows were fed basal diet without selenium supplementation throughout gestation whereas sows in other groups received 0.30 mgSe/kg in feed at second trimester (G_1) and third trimester (G_2) and then during lactation (G_3). Selenium supplementation had no effect (P>0.05) on sow body weight during gestation and lactation, respectively. Litter size at birth was not different (P>0.05) between groups. Litter size was higher (P<0.05) at weaning when sows diet was supplemented with selenium at third trimester and during lactation. The piglet growth rate and weaning weight were higher (P<0.05) in selenium supplemented groups especially in G_2 and G_3 sows. The supplementation of the breeding sows' diet with 0.30 mgSe/kg at third trimester of gestation and during the lactation phase improved litter size at weaning, piglet growth rate and weaning weight.

To Cite : Amaefule BC, Ali LC, Ikeh NE, Uzochukwu IE, Anizoba NW, Machebe NS., 2024. Reproductive and Growth Physiology of Sows and Piglets on Dietary Selenium (Se) Supplementation. Journal of Agriculture, Food, Environment and Animal Sciences, 5(1): 80-89.

INTRODUCTION

In many regions of the world where eating pork is not frowned upon, pig production has recently increased. It has been suggested that local pigs are a good substitute for expensive, high-quality animal protein that is appropriate for the growing human population. Because of their short gestation length, high feed conversion efficiency, polytocous and multiparous natures, capacity to thrive under less-than-ideal tropical conditions and early maturing nature, pigs offer distinct advantages over other foodproducing animals when it comes to potential solutions to the scarcity of meat supply in these countries (Pierozan et al., 2016). Irrespective of these attributes, the productivity of pigs in many countries is yet to improve significantly due to problems of imbalance or excess nutrient intake, poor health, high cost of feed ingredients and more importantly, the negative impact of irregular climatic conditions (temperature, humidity and rainfall) on animal production and reproduction (Machebe et al., 2009). Many reproductive events are negatively impacted when environmental stressors occur at any time during the course of reproduction in animals (Ali et al., 2022). Delays in puberty, decreased ovulation and rate of conception, increased losses of embryos and foetuses, prolonged postpartum anoestrus, inadequate lactation, elevated prenatal mortality, and subpar neonatal function are some of these occurrences (Martin, 2012).

Trace minerals (micronutrients) like selenium, vitamin E, molybdenum, zinc, copper, and vitamin A have been known to reduce or ameliorate these reproductive challenges in animals. As an essential trace mineral, selenium contributes to the regulation of various physiological functions in animals and humans as well (Surai and Fisinin, 2015). As a crucial component of the glutathione peroxidase enzyme, it plays a major antioxidant role by protecting tissues from damages caused by free radicals. Pigs receive their selenium mostly from two sources: inorganic selenium (selenite) and organic selenium (selenomethionine) (Surai and Fisinin, 2015). The sudden mortality of pigs and other issues have been connected to antioxidant deficiencies, particularly in selenium and vitamin E (Rea and Veum-Trygve, 1993). NRC (2012) recommends 0.15-0.30mg selenium in pig diets. However, due to highly intensive system of keeping pigs with no access to organic feeding, pigs are prone to lower intakes of selenium and other vitamins despite their inclusion as vitamin and mineral pre-mixes in the diet during formulation. Somehow, there are chances that the inclusion of these supplements in the pig diet may be lower than the recommended amount due to an incorrect inclusion rate or error in feed mixing (Mavromichalis, 2014).

Supplementation of basal diet of pigs with selenium could help to maintain optimal selenium status as well as high immuno-competence, animal productivity and reproductive abilities (Surai and Taylor-Pickard, 2008). While selenium may be toxic in excess, there is a narrow range between its essentiality and toxicity (Hu et al., 2011). Hu et al. (2011) found that supplementing sows' diets with selenium during gestation and lactation improved both the litter weight and the weight of individual piglets at weaning. In cattle, supplementing during pregnancy increases the number of calves born and also their viability at a later age. The concentration of this element has been reported to increase during lactation not only in blood but also in the milk suckled by the calves (Zhan et al., 2011). A review by Surai and Finisin (2015) revealed that selenium is one of the many factors that affects pig growth rate, particularly during the active growth period. Unfortunately, pigs cannot synthesize SelMet and thus need to be provided in pig diet in adequate amount to enhance reproduction (Surai et al., 2010).

Therefore, the purpose of this study was to assess how selenium supplementation in the diet throughout gestation and lactation affected the sows' reproductive ability as well as weanling piglets' body development.

MATERIALS and METHODS

Ethical Statement

This experiment was conducted in conformity with the directed guidelines approved by the University of Nigeria, Nsukka, Animal Welfare and Ethics Committee, Department of Animal Science on the use of animals as specimens. The approval code is as follows; No: UNN/C024ARO12.09.08.2023.

Location and Duration of the Study

The research was conducted at the Piggery Unit at the Animal Science Department of Teaching and Research Farm, University of Nigeria, Nsukka (UNN). Nsukka is 456 meters above sea level and is situated in the derived Savannah region. Its coordinates are longitude 7°21'39'' E and latitude 6°51'39'' N (Onyenucheya and Nnamchi, 2018; Ihinegbu et al., 2019). The environment is a humid tropical setting with a relative humidity range of 54.5 to 84.32 percent and a temperature range from 22.9 to 27.0 percent. The peak of rainfall occurs during September (108.55 mm), with January and December being the lowest with no observed rainfall (Phil-Eze, 2012; Onyenucheya and Nnamchi, 2018). During the research, the light cycle recorded was 11 hours and the study lasted for 24 weeks (6 months).

Experimental Diet, Animal, Groups and Management

The study used selenium Dietary Supplement Tablets, 200 mcg, 100 count (Spring Valley), which was supplied by Wall-mart Stores Inc. in Bentonville, AR, United States of America. For this study, twelve (12) Landrace × Large White crossbred sows, weighing an average of 56.10 ± 5.04 kg, were used when they were one to two years old. The test animals were kept in clean, well-ventilated pens with normal handling setups. The sows were inoculated and dewormed for both endoparasites and ectoparasites and allowed to acclimatize with the water, feed, and environment for a week. The study was carried out using a Complete Randomized Design. The 12 sows were divided randomly into four (4) treatment groups (G_0, G_1, G_2 and G_3) of 3 sows each according to the amount of dietary selenium supplementation (Table 1). Each sow was housed individually in a pen measuring 3.2 x 2.75 m and served as a replicate. Each pen had inbuilt concrete water and feed troughs. The experimental treatment groups were:

G_0 = Served as the control group and received no selenium supplementation.

G_1 = 0.30 mg Se / kg feed in the second trimester of gestation (30 - 75 days post-coitum).

G_2 = 0.30 mg Se / kg feed in the third trimester of gestation (75 days post-coitum to term).

G_3 = 0.30 mg Se / kg feed during lactation (0 - 30 days after farrowing).

Table 1. Percentage composition of experimental ration

Ingredients (%)	G0	G1	G2	G3
Maize	30.00	30.00	30.00	30.00
Groundnut cake	15.00	15.00	15.00	15.00
Palm kernel cake	25.00	25.00	25.00	25.00
Wheat offal	25.00	25.00	25.00	25.00
Limestone	2.00	2.00	2.00	2.00
Bone meal	2.00	2.00	2.00	2.00
Methionine	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25
Vitamin Mineral Premix*	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00
Selenium (mg/kg)	0.00	0.30	0.30	0.30
Calculated				
Crude protein (%)	19.22	19.13	19.28	19.03
Energy (Kcal/kg ME)	2800.00	2800.00	2800.00	2800.00

*Composition of premix: 0.25 kg of premix contains: vitamin A: 1000000 IU; vitamin D3: 250000 IU; vitamin B1: 900 mg; vitamin B2: 1000 mg; Niacin: 15000 mg; vitamin B 12: 7.5 mg; vitamin K3: 1000 mg; vitamin E: 9000 IU; Biotin: 500 mg; Folic acid: 500 mg; Panthothenic acid: 5000 mg; Choline chloride: 250000 mg; Selenium 100 mg; Manganese: 50000 mg; Copper: 5000 mg; Magnesium: 100 mg; Iron: 20000 mg; Zn: 50000 mg; Iodine: 500 mg.

Data Collection

Each animal received 2.20 kg of feed containing 19.33% crude protein and 2800Kcal/kg as ration at 08:00hrs while *ad-libitum* water was supplied. The piglets were weaned five (5) weeks after birth. Data were collected on sow reproductive performance namely: Sow body weight at mating, during gestation, at parturition, and during lactation, piglet birth weight, litter size at birth, litter weight at birth, litter size at weaning, piglet mortality. On the piglet pre-weaning performance data such as piglet birth weight, pre-weaning weight gain and weaning weight gain of piglets.

Statistical Analysis

Analysis of variance (ANOVA) was performed on research data using a completely randomized design. Duncan's New Multiple Range Test (Duncan, 1955) was used to differentiate statistical varied means, and results were deemed significant at the 5%

probability level. The Statistical Package for the Social Sciences (SPSS v20.0) was used for all analyses.

RESULTS and DISCUSSION

Sow Reproductive Performance

The findings on the effect of dietary selenium supplementation on body weight and reproductive performance of sows are presented in Table 2. Results showed that body weight of the sows during gestation, weight loss at farrowing and lactation periods were not significant (P>0.05). These findings were similar to those described by Piatkowski et al. (1979) who reported no effect of selenium (0.1 ppm) and vitamin E (22I U kg^{-1}) fortified diets on weight gain in gilts.

Table 2. Effect of dietary selenium supplementation on sow reproductive performance

Parameters	G0	G1	G2	G3	SEM
Sow body weight at mating (kg)	57.50	58.70	59.00	60.67	2.78
Sow body weight during gestation (kg)	84.17	86.67	87.67	83.00	6.23
Sow body weight at farrowing (kg)	84.00	94.33	84.33	79.33	6.06
Sow gestation weight gain (kg)	26.50	39.00	28.67	22.33	5.23
Sow body weight loss during lactation (kg)	15.33	17.33	11.67	9.67	3.79
Litter size at birth (kg)	5.67	8.33	7.67	6.00	1.13
Litter size at weaning (kg)	3.33^{c}	4.33^{b}	7.00^{a}	5.00^{b}	0.68
Piglet mortality (%)	2.33^{a}	4.00^{a}	0.66^{b}	1.00^{b}	1.05

a,b,c – Means on the same row with different superscripts differs significantly (P<0.05).

On the reproductive performance of sows, Selenium supplementation had no significant effect (P>0.05) on litter size at birth. This is consistent with studies by Svoboda et al. (2008, 2009) and Ma et al. (2014), which found no relationship between gilt reproductive performance from 60 days before weaning and dietary selenium content (0.1 or 0.3 ppm) or source (selenite or selenium-enriched yeast). However, in the present study, supplementing with selenium significantly increased the litter size at weaning (P<0.05). G_2 had the largest litter size at weaning (P<0.05). However statistical similarity (P>0.05) was seen in those in G_3 and G_1 but differed from those in G_0. Hu et al. (2011) found that supplementing with selenium during the lactation and gestation period increased the weight of individual pigs at weaning as well as the litter weight. In mammalian tissues, selenium plays a crucial role in the selenium-protein enzyme glutathione peroxidase. It is commonly acknowledged that consuming enough selenium enhances the body's antioxidant capacity. According to Lyons and Oldfield (1996), piglets often have poor antioxidant status at birth, which rises with age. It is acknowledged that a body with poor antioxidant status was more susceptible to health issues, which have an adverse effect on growth performance (Zhan et al., 2006). Piglets' health may be enhanced by the maternal selenomethionine intake, which may be one of the feeding strategies most successful in raising the antioxidant status of young pigs. Lipase, amylase and protease activities were significantly elevated by the maternal selenomethionine consumption in the pancreatic tissue of the offspring. According to Zhan et al. (2011), maternal use of selenomethionine improved piglets' ability to digest nutrients, which raised their nutritional utilization. The authors noted that the piglets' growth performance had increased from the time of birth to 28th day of weaning.

A considerable decrease in mortality (P<0.05) was seen in the selenium supplemented groups during the third trimester of gestation and lactation phase compared to those during the second trimester of gestation and control Groups. Piglets' growth and development during and after lactation depend greatly on colostrum in the milk (Hurley, 2015). It has been discovered that supplemental selenium during gestation and lactation raises the concentration of selenium in milk and colostrum. According to Quensel et al. (2008), there is a 33% and 89% increase in selenium contents in colostrum and milk, respectively. This improvement in the nutrient and antioxidative status of the sows alleviated oxidative stress on the sows which led to improvement in the sow's ability to produce enough milk without much stress. This in turn increased the vitality of the piglets due to better transport of selenium and other nutrients from mother to offspring through the milk and this improved the immunity of piglets and effectively enhanced the piglets' resistance to adverse environments thereby reducing piglet mortality. These outcomes corroborate the results of Stanley (2001), Chen et al. (2016) when they reported that, larger litter size at weaning, higher survival rate and better growth of piglets were obtained when diet was supplemented with selenium.

Pre-Weaning Growth Performance of Piglets

Piglet birth weight and weight gain during the first 2 weeks of growth were comparable (P>0.05) among the groups (Table 3). This observation agrees with the reports of Mahan (2000), Yoon and Mcmillian (2006) who reported no differences in litter size at birth and piglet birth weight when dietary selenium was supplemented during gestation. Although the findings of this study did not report improved piglet birth weight and litter size when sows diet during gestation and lactation were supplemented with selenium, Mahan (1991), Mavromatis et al. (1999), Migdal and Kackzmarczyk (1993) reported improvements in piglet birth weight and litter size when sows diet during gestation and lactation was supplemented with Vitamin E and 0.30 mg selenium via injection compared to control animals. The variations in outcomes could be ascribed to the selenium's source (injection) as well as the synergistic effects of selenium and vitamin E to improve reproductive function. There was a substantial variance (P<0.05) in body weight growth across the treatment groups in weeks 3 and 4. This increase in weight gain from the 3rd week coincides with the period of improved milk production in sows which usually peaks around day 21

(Aherne, 2007). During this period of peak milk production, selenium was effectively transported from the dam to the piglets. This led to improved weight gain in the selenium treated group during this phase of life.

Table 3. Effects of dietary selenium supplementation on pre-weaning growth performance of piglets

Parameters	G_0	G_1	G_2	G_3	SEM
Piglet birth weight (kg/piglet)	1.00	1.08	0.97	1.12	0.30
Weight gain week 1 (kg)	0.72	1.26	1.09	0.72	0.24
Weight gain week 2 (kg)	1.19	0.90	1.12	1.21	0.10
Weight gain week 3 (kg)	0.90^{b}	0.86^{b}	1.22^{ab}	1.37^{a}	0.23
Weight gain week 4 (kg)	1.25^{c}	1.68^{a}	1.25^{c}	1.38^{b}	0.23
Pre-weaning weight gain of piglets (kg)	4.07^{c}	4.80^{a}	4.69^{b}	4.77^{ab}	0.58
Weaning weight (kg/piglet)	5.08^{b}	5.79^{a}	5.83^{a}	5.79^{a}	0.16

^{a,b,c} – Means on the same row with different superscripts differs significantly (P<0.05).

Collectively, in the pre-weaning weight gain of piglets, a highly significant effect (P<0.05) was observed in the selenium supplemented groups compared to those in the control groups. Generally, piglets of sows fed selenium during gestation and lactation had better results in comparison to G_0. Compared to the control groups, the weaning weight of the selenium-supplemented groups was considerably higher (P<0.05). This outcome is consistent with that of Pinda et al. (2004), who found that supplementing the feed of sows with selenium yeast throughout gestation and lactation improved the weight of the piglets at weaning. Piglets' weaning weight was successfully raised by supplementing with selenium, particularly for those weaned after 21 days. Increasing the weaning age guarantees that there is enough selenium available to improve the piglets' early growth phase adaptability to intestinal infections and unfavourable conditions (Li et al., 2019; Zhou et al., 2021). This in turn increased the vitality and weight gain of the piglets.

CONCLUSION

Dietary Selenium supplementation improved the reproductive prowess of sows and the growth indices of piglets. The findings indicate that supplementing with 0.30 mg/kg of selenium throughout the third trimester of pregnancy and during lactation enhanced the reproductive and pre-weaning abilities of sows and piglets.

ACKNOWLEDGMENTS

We wish to acknowledge the entire staff of the Animal Science Department, Faculty of Agricultural Sciences, University of Nigeria, Nsukka (UNN) for their immeasurable support throughout this work.

Conflict of Interest

There are no conflicts of interest, according to the authors.

Authors Contribution

Each author made an equal contribution to the paper.

REFERENCES

Aherne FX., 2007. Feeding the Lactating Sow. Retrieved from www.gov.mb.ca/agriculture/livestock/pork/swine/bab10s04.html

Ali LC, Ikeh NE, Amaefule BC, Obinna AL, Machebe NS., 2022. The effects of discarded cocoa (*Theobroma cacao*) seed meal based diets on semen traits, testicular morphometry and histomorphology of rabbit bucks. Advances in Animal and Veterinary Sciences, 10(6): 1245-1254.

Chen J, Han JH, Guan WT, Chen F, Wang CX, Zhang YZ, Lv YT, Lin G., 2016. Selenium and vitamin E in sow diets: I. Effect on antioxidant status and reproductive performance in multiparous sows. Animal Feed Science and Technology, 221: 111-123.

Duncan DB., 1955. New Multiple Range Test. Biometrics, 11:1-42.

Hu C, Li H, Xiong YL, Zhang HM, Song J, Xia MS., 2012. Comparative effects of nano elemental selenium and sodium selenite on selenium retention in broiler chickens Animal Feed Science and Technology, 177: 204.

Hurley WL., 2015. Composition of sow colostrum and milk. In: Farmer, C. (Ed.), The Gestating and Lactating Sow. Wageningen Academic Publishers, Wageningen, The Netherlands, pp. 193-229.

Ihinegbu C, Nnadi GS, Madu IA., 2019. Analysis of economic benefits of flooding in Alor Uno Community, Nsukka, Enugu State. International Journal of Geography and Environmental Management, 5(2): 76-90.

Li N, Sun Z, Ansari AR, Cui L, Hu Y, Li Z, Briens M, Kai L, Sun L, Karrow NA, Liu H., 2019. Impact of Maternal Selenium Supplementation from Late Gestation and Lactation on Piglet Immune Function. Biological Trace Element Research, 194: 159-167.

Lyons TP, Oldfield JE., 1996. The case for organic selenium. In: Grimbergen B (ed) Bull Selenium–Tellurium Development Association. June issue: pp 1-3.

Ma YL, Lindemann MD, Pierce JL, Unrine JM, Cromwell GL., 2014. Effect of inorganic or organic selenium supplementation on reproductive performance and tissue trace mineral concentrations in gravid-first-parity gilts, fetuses, and nursing piglets. Journal of Animal Science, 92: 5540–5550.

Machebe NS, Onyekuru NA, Ekweogu N., 2009. Socio-economic factors affecting Pig Production in Enugu State. Journal of Forestry and the Social Science, 7(1): 2.

Mahan DC., 1991. Assessment of the influence of dietary vitamin E on sows and offspring in three parities: reproductive performance, tissue tocopherol, and effects on progeny. Journal of Animal Science, 69: 2904-2917.

Mahan DC., 2000. Effect of organic and inorganic selenium sources and levels on sow colostrum and milk selenium content. Journal of Animal Science, 78: 100–105.

Martin RW., 2012. Effects of heat stress on thermoregulation, reproduction and performance of different parity sows. A Thesis presented to the Faculty of the Graduate School University of Missouri.

Mavromatis J, Koptopoulos G, Kyriakis SC, Papasteriadis A, Saoulidis K., 1999. Effects of a-tocopherol and selenium on pregnant sows and their piglets' immunity and performance. Journal of Veterinary Medicine, 46: 543-553.

Mavromichalis I., 2014. Formulating pig diets: Selenium toxicity, deficiency. An online article accessed on 10th September, 2022 from https://www.wattagnet.com/articles/19843-formulating-pig-diets-selenium-toxicity-deficiency

Migdal W, Kaczmarczyk J., 1993. Effect to injection of selenium and vitamin E on reproductive performance of sows and Se concentration in sow milk. World Review of Animal Production, 28: 68-71.

National Research Council: NRC., 2012. Nutrient Requirement of Swine, 11th Revised Edition, National Academies Press, Washington, DC, USA.

Onyenucheya CO, Nnamchi HC., 2018. Diurnal and annual mean weather cycles over Nsukka, Nigeria during 2010/2011. Nigerian Journal of Technology, 37(2): 519-524.

Phil-Eze PO., 2012. The influence of elevation and aspect on plant species diversity in a tropical landscape of Nsukka plateau in Nigeria. Tropical Built Environment Journal, 1(3): 255-266.

Piatkowski TL, Mahan DC, Cantor AH, Moxon AL, Cline JH, Grifo AP Jr., 1979. Selenium and vitamin E in semi-purified diets for gravid and non-gravid gilts. Journal of Animal Science, 48(6): 1357-1365.

Pierozan CR, Agostini PDS, Gasa J, Novais AK, Dias CP, Santos RSK, Pereira JR, Nagi JG, Alves JB, Silva CA., 2016. Factors affecting the daily feed intake and feed conversion ratio of pigs in grow-finishing units: the case of a company. Porcine Health Management, 2(1): 7.

Pinda A, Borbolla AG, González G, Mahan DC., 2004. Intake of organic selenium (Sel-Plex) by primiparous sows for a long period of time: evaluation on reproductive performance. Poster presentation at Alltech's 20th Annual Symposium on Nutritional Biotechnology in the Feed and Food Industries, Lexington, KY, USA.

Quensel H, Renaudin A, Le Floch N, Jondreville C, Pere MC, Taylor-Pickard JA, Le Dividich J., 2008. Effect of organic and inorganic selenium sources in sow diets on colostrum production and piglet response to a poor sanitary environment after weaning. Animal, 2: 859-866.

Rea JC, Veum TL., 1993. Vitamin E and selenium in swine rations. University of Missouri-Columbia, Extension.

Stanley J., 2001. A selenium supplement for Sows. Pig International, 31(10): 19 - 20.

Surai PF, Fisinin VI., 2015. Selenium in sow nutrition. Animal Feed Science and Technology, 211(2016): 18-30.

Surai PF, Pappas AC, Karadas F, Papazyan TT, Fisinin VI., 2010. Selenium Enigma: Health Implications of an Inadequate Supply. In: De Meester, F, Zibadi S, Watson DR (Eds.), Modern Dietary Fat Intakes in Disease Promotion, Humana Press pp. 379-403.

Surai PF, Taylor-Pickard JA., 2008. Current Advances in Selenium Research and Applications. Wageningen Academic Pub; Wageningen, Netherlands: Vol. 1.

Svoboda M, Ficek R, Drabek J., 2008. Efficacy of organic selenium from se-enriched yeast on selenium transfer from sows to piglets. Acta Veterinaria Brunensis, 77: 515-521.

Svoboda M, Kotrbacek V, Ficek R, Drabek J., 2009. Effect of organic selenium from se-enriched alga (chlorella spp.) on selenium transfer from sows to their progeny. Acta Veterinaria Brunensis, 78: 373-377.

Yoon I, McMillan E., 2006. Comparative effects of organic and inorganic selenium on selenium transfer from sows to nursing pigs. Journal of Animal Science, 84(7): 1729-1733.

Zhan XA, Qie YZ, Wang M, Li X, Zhao RQ., 2011. Selenomethionine: An effective Selenium Source for Sow to Improve Se distribution, antioxidant status, and growth performance of pig offspring. Biological Trace Element Research, 142(3): 481-491.

Zhan XA, Wang M, Xu ZR, Li WF, Li JX., 2006. Effects of fluoride on hepatic antioxidant system and transcription of Cu/Zn sod gene in young pigs. Journal of Trace Elements in Medicine and Biology, 6: 83-87.

Zhou SY, Wu BX, Liu Z, Zhang TJ., 2021. Effects of different selenium sources on sow reproductive performance and piglet development: a meta-analysis. Journal of Animal and Feed Sciences, 30: 260-270.