www.directivepublications.org

Journal of
Nutrition and Food Science Research

ISSN 2770-4475

Research Article

Impact Of Bio-Active Clay On Sow Productivity And Piglet Survival.

Vangroenweghe Frédéric1,2,*

[1]Elanco, BU Food Animals, Generaal Lemanstraat 55/3 (Building D, 1st floor), 2018 Antwerpen, Belgium.
[2]Ghent University, Faculty of Veterinary Medicine, Department of Internal Medicine – Reproduction – Population Medicine, Unit of Porcine Health Management, Salisburylaan 133, 9820 Merelbeke, Belgium.

Abstract

The reproductive cycle of the sow is characterized by distinct physiological stages, each with unique metabolic requirements. During late gestation (day 70 to farrowing) and the subsequent lactation period, the sow faces the most significant oxidative challenge. Rapid fetal growth and the development of mammary glands necessitate dramatic increases in maternal digestion, absorption, and mobilization of muscle and fat tissue. This heightened metabolic activity triggers an overproduction of reactive oxygen species (ROS). In a healthy state, ROS act as essential signaling molecules, however, when the antioxidant defense system is overwhelmed, ROS exert deleterious effects on oocyte quality, fertilization rates, and embryo development. The aim of the present field study was to evaluate the efficacy of bio-active clay (Proteck®; Elanco Animal Health) on sow productivity and piglet survival. The field trial compared a baseline Control period (2024) against a Treatment period (2025), when sows were supplemented with Proteck® at a rate of 2 kg/tonne of feed in both gestation and lactation diets. The results demonstrate significant improvements in reproductive efficiency with a shorter lactation period (25.7 days vs. 26.8 days for the Treatment and the Control group, respectively), a 50% decrease in the number of mummies per litter, and optimized piglet survival rates with a lower pre-weaning piglet mortality rate (12.29% vs. 16.25% for the Treatment and the Control group, respectively). This resulted in an overall improvement of born alive piglets (31.0 vs. 30.5 piglets per sow per year), an improved farrowing index (2.30 vs. 2.25), and a better piglet production index (27.1 vs. 25.7 piglets per sow per year). Moreover, the number of cross-fostered piglets reduced from 47.26 to 34.20 piglets per week batch. Therefore, the current field trial confirms that Proteck® bio-active clay provides a multi-faceted benefit to sow herds. By significantly reducing number of mummies, lowering pre-weaning piglet mortality by approximately 4%, and improving weaning success, Proteck® enhances the economic output of the sow farm. Furthermore, the reduction in required cross-fostering suggests a more stable and high-performing maternal environment, leading to better overall animal welfare and management efficacy.

Keywords: *bio-active clay, sow productivity, piglet survival, oxidative stress, efficacy*.

INTRODUCTION

Genetic selection and advanced management practices in modern swine production have significantly increased sow productivity, with hyper prolific sow lines frequently achieving more than 30 piglets per sow per year (PSY) (Yang et al., 2023). While these improvements represent a milestone in production efficiency, they impose a substantial metabolic burden to the sow, often resulting in a shortened productive lifespan and decreased reproductive efficiency over time (Yang et al., 2023). A critical consequence of this high metabolic demand is the disruption of the physiological balance between reactive oxygen species (ROS) and the animal's antioxidant capacity, leading to a state of oxidative stress (OS) (Agarwal et al., 2005; Yang et al., 2023).

The reproductive cycle of the sow is characterized by distinct physiological stages, each with unique metabolic requirements. During early gestation (day 1-35), the focus is on embryo development, placental formation, and maternal recovery from the previous reproductive cycle (Li et al., 2022). As pregnancy progresses in the mid-stage (day 36-70), fetal organ and muscle development accelerate, requiring precise nutritional management to maintain optimal body condition (Li et al., 2022).

However, it is during late gestation (day 70 to farrowing) and the subsequent lactation period that the sow faces the most significant oxidative challenge (Lee et al., 2023). Rapid fetal growth and the development of mammary glands necessitate dramatic increases in maternal digestion, absorption, and the mobilization of muscle and fat tissue (Li et al., 2022; Yang

***Corresponding Author:** F. Vangroenweghe ,* Elanco, BU Food Animals, Generaal Lemanstraat 55/3 (Building D, 1st floor), 2018 Antwerpen, Belgium
Email: vangroenweghe.frederic@telenet.be.
Received: 23-October-2026, Manuscript No. JONSFR - 6322 **; Editor Assigned:** 27-October-2026 **; Reviewed:** 11-November-2026, QC No. JONSFR - 6322 **;**
Published: 16-November-2026. **DOI:** 10.52338/jonafsr.2026.6322
Citation: F. Vangroenweghe . Impact Of Bio-Active Clay On Sow Productivity And Piglet Survival. Journal of Nutrition and Food Science Research. 2026 November; 20(1). doi: 10.52338/jonafsr.2026.6322.
Copyright © 2026 **F. Vangroenweghe .** This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

et al., 2023). This heightened metabolic activity triggers an overproduction of ROS (Lee et al., 2023). Moreover, a reduced antioxidant capacity was observed in hyper prolific sows during late gestation (Berchieri-Ronchi et al. 2011). In a healthy state, ROS act as essential signaling molecules. However, when the antioxidant defense system is overwhelmed and ROS scavenging is insufficient (Lee et al., 2023), ROS exert deleterious effects on oocyte quality, fertilization rates, and embryo and fetal development (Agarwal et al., 2005; Karowicz-Bilinska et al., 2002; Kim et al., 2013; Toy et al., 2009).

The impact of oxidative stress during gestation is particularly evident in the placenta, which serves as the vital link for nutrient and oxygen transfer between the sow and the fetus. ROS accumulation can cause vascular endothelial cell malfunction and apoptosis, leading to placental insufficiency (Yang et al., 2023). This condition restricts uterine blood flow, a problem exacerbated by large litter sizes where the blood flow per fetus is already limited (Yang et al., 2023).

The clinical outcomes of these processes include intrauterine growth retardation (IUGR), longer farrowing duration, increased stillbirth rates, and greater variation in piglet birth weights within the litter (Lee et al., 2023; Yang et al., 2023). This leads to an overall decreased reproductive performance in high prolific sows (Zhao and Kim, 2020). Furthermore, oxidative stress has been shown to damage mammary epithelial cells, reducing cell viability and potentially impairing milk production, which further compromises piglet performance during lactation and the subsequent peri-weaning period (Novais et al., 2019; Wang et al., 2018; Zhao and Kim, 2020). Notably, replacement gilts appear to be more susceptible to these oxidative conditions than multiparous sows, sustaining high levels of OS that can impact their long-term longevity and disease resistance (Roy et al., 2016). Ultimately, excessive ROS not only destroy cellular lipids, proteins or DNA with the subsequent inhibition of their function, but also has a clear impact on sow reproductive and lactation performance and sow longevity (Li et al., 2022).

Recent research has also identified a strong correlation between gut microbiota, oxidative stress, and reproductive outcomes. Specific microbial profiles, such as a higher abundance of Phascolarctobacterium, have been linked to elevated OS at parturition and higher stillbirth rates, whereas other taxa, such as Bacteriodes_f_Bacteriodaceae, are positively correlated with antioxidant capacity (Wang et al., 2018). These findings suggest that the gastrointestinal environment plays a central role in modulating the sow's systemic oxidative balance.

To mitigate these negative impacts, various nutritional interventions have been explored, including the use of probiotics, prebiotics, and specialized minerals (Li et al., 2022). Among these strategies, the inclusion of bio-active clays, such as Proteck®, represent a promising approach. In aquaculture, the dietary bio-active clay supplementation has demonstrated improved antioxidant capacity with upregulation of antioxidant enzymes such as glutathione-peroxidase (Abd El-Naby et al., 2025). Bio-active clays are designed to support the sow's metabolic health during high-stress periods by potentially stabilizing the gut environment and reducing the systemic burden of OS. By improving the sow's oxidative balance during the critical windows of late gestation and lactation, such interventions aim to enhance placental function, improve piglet birth weights, and secure the overall durability and performance of the hyper prolific sows.

The aim of the present field study was to evaluate the efficacy of a bio-active clay (Proteck®; Elanco Animal Health) on sow productivity and piglet survival under Belgian field conditions in a 350-sow farm.

MATERIALS & METHODS

Experimental farm

The longitudinal study was performed on a 350-sow farm with Genesus sows managed in 3-week batch management system. Sows remained in the farrowing room for an average of 3.5 weeks prior to weaning. The sows were vaccinated against *Mycoplasma hyopneumoniae*, Porcine Reproductive and Respiratory Sydrome Virus, Parvovirus, *Erysipelothrix rhusiopathiae*, and atrophic rhinitis (*Pasteurella multocida* and *Bordetella bronchiseptica*) during each consecutive reproductive cycle. Gilts were introduced following an 8-week quarantine and adaptation period, and were vaccinated or boostered for all pathogens. Sows are housed in pens during the first 4 weeks of their reproductive cycles (weaning, insemination, 28 d pregnancy check) and subsequently transferred to group housing facilities with free range pens. During farrowing and throughout lactation, the sows were housed in confinement in standard farrowing crates. Sow reproductive performance is given in **Table 1**.

Table 1. Overview of actual sow reproductive performance at the start of the field trial.

Parameter	Actual data
Number of productive sows	400
Number of cycles per month	76.3
Number of productive cycles per month	68.1
Number of abortions per month	0.6
Number of re-matings per month	11.2
Extra days per cycle	10.4
Sows culled after mating	7.6
Non-productive days per culled sow	45.9
Average sow parity on farm	2.9
Extra (= non-productive) sows per month	6.8
Number of farrowings per 100 matings	79.8

Duration of reproductive cycle (d)	162.6
Duration of gestation (d)	115.4
Duration of lactation period (d)	26.8
Interval weaning – 1st (d)	4.7
Interval 1st mating – (d)	3.9
Interval weaning – (d)	8.6
Farrowing index	2.25
Live born piglets per litter	13.64
Dead born piglets per litter	1.64
Mummified piglets per litter	0.22
Pre-weaning mortality	16.25
Weaned piglets per litter	11.48
Cross-fostered piglets per month	47.25
Piglets born per sow per year	30.5
Piglets weaned per sow per year	25.7

Experimental design

Prior to the start of the inclusion of the bio-active clay (Proteck®; Elanco Animal Health, Indianapolis, IN, USA), sow reproductive performance was closely monitored for a reference period of 1 year as a benchmark (2024). Subsequently, sows were supplemented with a bio-active clay (Proteck®) at an inclusion rate of 2 kg/tonne of feed throughout the subsequent year (2025). Data from sows supplemented with Proteck® throughout their entire reproductive cycles (from weaning to their next weaning) were collected to evaluate the efficacy of Proteck® supplementation on the negative consequences of OS during the reproductive cycle.

Data capture

Data on sow productivity was captured from the standard sow management program used on farm for registration and evaluation of sow performance. The following parameters were collected: number of productive sows, total number of cycles per month, number of productive cycles per month, number of abortions per month, number of re-matings per month, extra (non-productive) days per cycle, sows culled after mating, non-productive days per culled sow, average sow parity on farm, extra (non-productive) sows per month, number of farrowings per 100 matings, duration of reproductive cycle, duration of gestation, duration of lactation period, interval weaning – 1st mating, interval 1st mating – conception, interval weaning – conception, farrowing index, live born piglets per litter, dead born piglets per litter, mummified piglets per litter, pre-weaning mortality, weaned piglets per litter, cross-fostered piglets per litter, piglets born alive per sow per year, piglets weaned per sow per year.

Statistical analysis

All data were analyzed with a T-test using JMP 18.0 at a significance level of 0.05.

RESULTS

Data on sow productivity and piglet survival is given in **Table 2 and Table 3**.

The inclusion of Proteck® in sow gestation and lactation diets led to several significant improvements in sow reproductive efficiency and piglet outcomes. While many parameters remained numerically similar, a few key metrics demonstrated statistically significant differences ($P < 0.05$) between the Control and the Treatment groups.

Reproductive efficiency and cycle management

The Treatment group demonstrated a significantly shorter duration of lactation, decreasing from 26.8 days in the Control group to 25.7 days in Treatment group. Efficiency was further enhanced by a significant reduction in the interval from weaning to conception, which dropped from 8.6 days in the Control group to 8.0 days in the Treatment group. These combined improvements contributed to a significantly higher farrowing index for the Proteck®-supplemented sows, rising from 2.25 to 2.30.

Piglet survival and litter management

Inclusion of Proteck® into sow gestation and lactation diets had a profound impact on piglet health markers. The number of mummified piglets per litter was significantly reduced by 50%, falling from 0.22 in the Control group to 0.11 in the Treatment group. Piglet survival significantly improved in the Treatment group with a lower pre-weaning mortality of 12.29% as compared to 16.25% in the Control group. Furthermore, the need for intervention to optimize litter size and reduce the number of runt piglets at weaning was reduced, as evidenced by the decrease in cross-fostered piglets per month, which dropped from 47.25 piglets in the Control group to 34.20 piglets in the Treatment group. This indicated a more uniform and robust piglet population in the Treatment group.

Overall annual productivity

The most critical outcome of the field trial was the significant increase in annual productivity. The number of weaned piglets per sow per year improved from 25.7 piglets in the Control group to 27.1 piglets in the Treatment group.

Table 2. Data on sow productivity and piglet survival from a field trial comparing a standard Control group to a Treatment group including a bio-active clay (Proteck®) at 2 kg/tonne of feed in sow gestation and lactation diets to improve the negative impact of oxidative stress during gestation and lactation.

Parameter	Control	Treatment	P-value
Number of productive sows	400	355	> 0.05
Number of cycles per month	76.3	68.8	> 0.05
Number of productive cycles per month	68.1	60.6	> 0.05
Number of abortions per month	0.6	0.2	> 0.05
Number of re-matings per month	11.2	8.0	> 0.05
Extra days per cycle	10.4	10.3	> 0.05
Sows culled after mating	7.6	8.0	> 0.05
Non-productive days per culled sow	45.9	43.0	> 0.05
Average sow parity on farm	2.9	2.8	> 0.05
Extra (= non-productive) sows per month	6.8	6.5	> 0.05
Number of farrowings per 100 matings	79.8	68.2	> 0.05
Duration of reproductive cycle (d)	162.6	159.0	> 0.05
Duration of gestation (d)	115.4	115.4	> 0.05
Duration of lactation period (d)	26.8	25.7	< 0.05
Interval weaning – 1st mating	4.7	4.8	> 0.05
Interval 1st mating – conception	3.9	3.2	> 0.05
Interval weaning – conception	8.6	8.0	< 0.05
Farrowing index	2.25	2.30	< 0.05
Live born piglets per litter	13.64	13.51	> 0.05
Dead born piglets per litter	1.64	1.57	> 0.05
Mummified piglets per litter	0.22	0.11	< 0.05
Pre-weaning mortality	16.25	12.29	< 0.05
Weaned piglets per litter	11.48	11.54	> 0.05
Cross-fostered piglets per month	47.25	34.2	< 0.05
Piglets born per sow per year	30.5	31.0	> 0.05
Piglets weaned per sow per year	25.7	27.1	< 0.05

Table 3. Interpretative summary of significant results from a field trial comparing a standard Control group to a Treatment group including a bio-active clay (Proteck®) at 2 kg/tonne of feed in sow gestation and lactation diets to improve the negative impact of oxidative stress during gestation and lactation.

Parameter	Control	Treatment	Interpretation
Duration of lactation period (d)	26.8	25.7	Decreased
Interval weaning – conception	8.6	8.0	Decreased
Farrowing index	2.25	2.30	Increased
Mummified piglets per litter	0.22	0.11	Decreased
Pre-weaning mortality	16.25	12.29	Decreased
Piglets weaned per sow per year	25.7	27.1	Increased

Economic calculation and return-on-investment

Based on several imput variables, such as number of sows, feed consumption per sow per year, inclusion rate of Proteck®, cost of Proteck®, extra piglets per sow per year, and the market value of weaned piglets under Benelux conditions, we calculated the return-on-investment (ROI) of Proteck® inclusion into the sow gestation and lactation feed (Table 4). Following subtraction of the total cost of Proteck® inclusion from the gross economic benefit of € 24,500, a net economic benefit of € 17,360 was obtained. When we divide this net economic benefit by the cost of Proteck® inclusion, we could calculate a net ROI of + 2.43 for the intervention.

Table 4. Economic calculation of the return-on-investment of inclusion of a bio-active clay (Proteck®) in sow gestation and lactation diets.

Parameters **Imput variables**	**Data**	**Calculation**
Number of sows	350	
Feed consumption per sow per year (kg)	1.200	
Inclusion rate of Proteck® (kg/tonne)	2	
Costs of Proteck® (€/kg)	8.5	
Extra piglets per sow per year	+ 1.4	
Market value weaned piglet (€)	50	
Calculation of return-on-investment		
Total number of extra piglets		490
Total value of extra piglets (€)		24,500
Total amount of feed consumed per year (kg)		420,000
Total amount of Proteck® inclusion (kg)		840
Total cost of Proteck® inclusion (€)		7,140
Return-on-investment Proteck® inclusion		+ 2.43

DISCUSSION

Modern swine production relies heavily on genetic selection to achieve hyper prolificacy, with modern sow lines frequently exceeding 30 piglets per sow per year (Yang et al., 2023). However, this efficiency comes at a significant metabolic cost for the animals. The disruption of the balance between ROS and the animal's antioxidant capacity leads to a state of OS, which is particularly acute during late gestation and lactation (Agarwal et al., 2005; Lee et al., 2023; Yang et al., 2023).

The results of the current field study suggest that the inclusion of bio-active clay (Proteck®) at 2 kg/tonne of feed serves as an effective nutritional intervention to migitate these oxidative impacts on sow productivity. By potentially stabilizing the gastrointestinal environment – a centra modulator of the systemic oxidative balance - Proteck® appears to support the sow during the high stress windows of fetal growth and mammary development (Wang et al., 2018). The significant reduction in mummified piglets and improved weaning outcomes support the hypothesis that improving oxidative balance enhances placental function and nutrient transfer (Yang et al., 2023).

One of the most important findings of the field study was the significant improvement in reproductive cycle management. The Treatment group demonstrated a significantly shorter duration of lactation (25.7 days vs. 26.8 days) and a reduced interval from weaning to conception (8.0 days vs. 8.6 days). In hyper prolific production systems, even marginal reductions in non-productive days can yield substantial cumulative benefits for the overall farm throughput.

These efficiencies culminated in a significant improved farrowing index, which rose from 2.25 to 2.30. This suggests that sows supplemented with the bio-active clay recovered more effectively from the metabolic demands of lactation, allowing a faster and more successful transition into the subsequent reproductive cycle. As OS has been shown to impair oocyte quality and fertilization rates (Agarwal et al., 2005), the reduction in the weaning-to-conception interval indicates a more robust return-to-estrus and an improved early embryonic environment, although the sows were weaned approximately 1 day earlier in the Treatment group.

The impact of oxidative stress during late gestation often manifests as placental insufficiency, restricted uterine blood flow, and IUGR (Yang et al., 2023). These conditions typically lead to increased stillbirth rates and higher mortality, resulting in overall decreased reproductive performance (Zhao and Kim, 2020). In this trial, Proteck® supplementation led to a 50% reduction in the number of mummified piglets per litter (0.11 vs. 0.22). This reduction is a clear indicator of enhanced fetal viability during the critical early-gestation phase.

Furthermore, piglet survival significantly improved, with pre-weaning mortality dropping from 16.25% to 12.29%. This nearly 4% improvement is vital for farm profitability. As OS is known to damage mammary epithelial cells and impair milk production (Novais et al., 2019), the improved survival rate may be attributed to better colostrum and milk quality, providing piglets with a stronger start of life. This is further evidenced by the significant reduction in required cross-fostering (34.20 vs. 47.25 piglets), suggesting that the piglets in the Treatment group were more uniform and robust, requiring fewer management interventions to reach weaning.

Since hyper prolific sows experience heightened stress levels during lactation, primarily due to intensified teat competition and heat-related stress arising from elevated piglet body temperature, this triggers OS through an elevation in ROS-inducing proinflammatory cytokines (Roelofs et al., 2019). Therefore, supplementation of Proteck® in our study reduced the OS and the subsequent negative impact of ROS during the

early lactation period, resulting in better piglet quality and a reduced need for cross-fostering.

To assess the practical implications of these findings, an economic calculation was performed based on a 350-sow farm capacity and the primary significant productivity markers. The trial demonstrated an increase of 1.4 weaned piglets per sow per year, which implies an additional 490 piglets weaned per sow per year. Assuming an average market value of € 50, - per weaned piglet under Benelux conditions, this results in € 24.500 additional revenue per year. In addition, a reduced labor cost due to less cross-fostered piglets and a reduction in pre-weaning mortality should be calculated. The higher farrowing index allows the farm to produce approximately 17.5 more farrowings per year for the same sow population, therefore maximizing the utilization of fixed assets such as farrowing crates. Subtracting the cost of the Proteck® inclusion at 2 kg/tonne of feed (€ 8.5 / kg) from the gross economic benefit of increased weaning numbers (€ 24.500 per year) resulted in a substantial ROI of + 2.43 for the producer.

CONCLUSIONS

In conclusion, the results of this field study confirm that the bio-active clay Proteck® provides a multi-faceted benefit to hyper prolific sow herds. By mitigating the deleterious effects of OS, Proteck® supplementation significantly optimizes the reproductive cycle, reduces fetal loss (mummies), and improves piglet survival through the weaning phase. The resulting increase of 1.4 weaned piglets per sow per year represents a substantial improvement in both animal welfare and economic sustainability with a ROI of +2.43 for the modern swine producer.

Acknowledgements

The author acknowledges the assistance of the farm personnel in collecting the raw sow production data and entering these data into the sow production management system for monthly analysis. The author also acknowledges the diligent support of the feed company nutritionist for the correct and consistent supplementation of Proteck® into all sow gestation and lactation diets for a predetermined period.

Funding

No funding was received for the conduct of the field trial.

Competing / Conflicts of Interest

The author declares no conflict of interest.

Ethics approval and consent to participate

No ethics approval was needed since no specific interventions were performed during the collection of the data. The farm owner specifically gave his consent to participate in the field study.

Data availability

Data are available upon reasonable request from the author.

Author contributions (CRediT)

The author was responsible for all steps from protocol preparation, data collection and analysis to writing and reviewing the manuscript.

Use of generative-AI tools

Generative AI was only used to check the finalised publication for English language improvements. All content has been double-checked by the author, who is fully responsible for the manuscript content.

REFERENCES

1. El-Naby, A.S.A., El Asely, A.M., Hussein, M.N., Khattaby A.E.A., Abo-Al-Ela H.G. 2025. Impact of dietary Biocide clay on growth, physiological status, and histological indicators of the liver and digestive tract in Nile tilapia (Oreochromis niloticus). Nature Scientific Reports 15: 5311. doi.org/10.1038/s41598-025-89042-9.

2. Agarwal A., Gupta S., Sharma R.K. 2005. Role of oxidative stress in female reproduction. Reproductive Biology and Endocrinology, 3: 28. doi.org/10.1186/1477-7827-3-28.

3. Berchieri-Ronchi C.B., Kim S.W., Zhao Y., Correa C.R., Yeum K.J., Ferreira A.L.A. 2011. Oxidative stress status of highly prolific sows during gestation and lacation. Animal 5:1774-1179. doi.org/10.1017/S1751731111000772.

4. Karowicz-Bilinska A., Suzin J., Sieroszewski P. 2002. Evaluation of oxidative stress indices during treatment of pregnant women with intrauterine growth retardation. Medical Science Monitor: International Medical Journal of Experimental and Clinical Research 8: CR211-216.

5. Kim S.W., Weaver A.C., Shen Y.B., Zhao Y. 2013. Improving efficiency of sow productivity: nutrition and health. Journal of Animal Science 4: 1-8. doi.org/10.1186/2049-1891-4-26.

6. Lee J., Shin H., Jo J., Lee G., Yun J. 2023. Large litter size increases oxidative stress and adversely affects nest-building behavior and litter characteristics in primiparous sows. Frontiers in Veterinary Science, 10: 1219572. doi.org/10.3389/fvets.2023.1219572.

7. Li Q., Yang S., Chen F., Guan W., Zhang S. 2022. Nutritional strategies to alleviate oxidative stress in sows. Animal Nutrition, 9: 60-73. doi.org/10.1016/j.aninu.2021.10.006.

8. Novais A.K., Martel-Kennes Y., Roy C., Deschêne K, Beaulieu S., Bergeron N., Laforst J.-P., Lessard M., Matte J.J., Lapointe J. 2020. Tissue-specific profiling reveals modulation of cellular and mitochondrial oxidative stress in normal- and low-birthweight piglets throughout the peri-weaning period. Animal, 14: 1014-1024. doi.org/10.1017/S1751731119002829.

9. Roelofs S., Godding L., de Haan J.R., van der Staay F.J., Nordquist R.E. 2019. Effects of parity and litter size on cortisol measures in commercially housed sows and their offspring. Physiology and Behavior 201: 83-90. doi.org/10.1016/j.physbeh.2018.12.014.

10. Roy C., Lavoie M., Richard G., Archambault A., Lapointe J. 2016. Evidence that oxidative stress is higher in replacement gilts than multiparous sows. Journal of Animal Physiology and Animal Nutrition, 100 : 911-919. doi.org/10.1111jpn.12462.

11. Toy H., Camuzcuoglu H., Arioz D.T., Kurt S., Celik H., Aksoy N. 2009. Serum prolidase activity and oxidative stress markers in pregnancies with intrauterine -growth restricted infants. Journal of Obstetrics and Gynecology 35: 1047-1053.

12. Wang H., Ji Y., Yin C., Deng M., Tang T., Deng B., Ren W., Deng J., Yin Y., Tan C. 2018. Differential analysis of gut microbiota correlated with oxidative stress in sows with high or low litter performance during lactation. Frontiers in Microbiology, 9: 2665. doi.org/10.3389/fmicb.2018.01665.

13. Yang X., Hu R., Shi M., Wang L., Yan J., Gong J., Zhang Q., He, J., Wu S. 2023. Placental malfunction, fetal survival and development caused by sows metabolic disorder: the impact of maternal oxidative stress. Antioxidants, 12: 360. doi.org/10.3390/antiox12020360.

14. Zhao Y., Kim S.W. 2020. Oxidative stress status and reproductive performance of sows during gestation and lactation under different thermal environments. Asian-Australian Journal of Animal Science 33: 722. doi.org/10.5713/ajas.19.0.334.