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Organic selenium and vitamin E for gilts and sows bred in equatorial climate

Tiago Silva Andrade[1] | Pedro Henrique Watanabe[1] | Ingrid Barbosa de Mendonça[1] | Eloisa Helena Mendes Vieira[1] | Gabriel Gobira de Alcântara Araújo[2] | Deborah Marrocos Sampaio Vasconcelos[1] | Bruno Urach[3] | Bruno Alexander Nunes Silva[4] | Ednardo Rodrigues Freitas[1]

[1]Animal Science Department, Universidade Federal do Ceará, Fortaleza, Ceará, Brazil

[2]Animal Science Department, Universidade Federal dos Vales do Jequitinhonha e Mucuri, Diamantina, Minas Gerais, Brazil

[3]Adisseo Brasil, São Paulo, São Paulo, Brazil

[4]Agricultural Sciences Institute, Universidade Federal de Minas Gerais, Montes Claros, Minas Gerais, Brazil

Correspondence

Pedro Henrique Watanabe, Animal Science Department, Universidade Federal do Ceará, Fortaleza, Ceará, Brazil.
Email: pedrohwatanabe@gmail.com

Abstract

The aim of this study was to evaluate the dietary supplementation of organic selenium (Se) and vitamin E for sows from 1st and 2nd parity order, without adiabatic cooling on physiological parameters, reproductive performance, milk composition, litter performance and blood concentrations of antioxidant enzymes. A total of 96 sows were allotted in a 4 × 2 completely factorial design, with 4 experimental groups and 2 parity orders (1st and 2nd). The experimental groups consisted of: ACCon—sows receiving adiabatic cooling and no dietary supplementation of organic Se and vitamin E; WACCon—sows without adiabatic cooling and no dietary supplementation of organic Se and vitamin E; WACSe—sows without adiabatic cooling with dietary supplementation of 0.3 mg/kg organic Se; WACSeE—sows without adiabatic cooling with dietary supplementation of 0.3 mg/kg organic Se and 90 UI of vitamin E. ACCon Sows had lower respiratory rate, rectal temperature and body surface temperature when compared to the others sows ($p < 0.05$). Sows without evaporative cooling had lower daily milk production and weaned litters with lower weight and average daily gain when compared to the other groups ($p < 0.05$). ACCon sows presented higher weaned piglets to WACSeE sows. WACSeE Sows had higher concentrations of GSH-Px when compared to other experimental groups and higher levels of SOD than sows from ACCon and WACSe. Piglets of sows from WACSeE group presented higher levels of GSH-Px and SOD when compared to the other experimental groups. ACCon sows have higher milk yield and higher litter weight than others groups. Under equatorial climate conditions, dietary supplementation of organic Se and vitamin E from first and second parity order sows does not respond efficiently on thermoregulatory physiology and performance compared to adiabatic cooling, but modulates the enzymatic antioxidant balance of sows and piglets.

KEYWORDS

antioxidants, microminerals, oxidative stress, performance, piglets

1 | INTRODUCTION

In the swine industry, the intense selection based on reproductive parameters, such as litter size, weaning-estrus interval (WEI) and lactation efficiency, allowed greater productivity of the modern genotypes sows. However, this genetic advance made sows more sensitive to the climate and, therefore, more susceptible to heat stress, due to their greater capacity to produce endogenous heat (Wegner et al., 2014).

In high temperature environments, such equatorial conditions, gilts and sows tend to reduce consumption in order to minimise the production of metabolic heat, which can promote greater catabolism (Justino et al., 2015; Renaudeau et al., 2011; Zhao, Flowers, Saraiva, Yeum & Kim, 2011). Such adaptation can worsen the oxidative stress, which naturally occurs in hyperprolific sows during pregnancy and lactation, since the greater mobilisation of body reserves promotes an increase in circulating macromolecules, such as lipids and proteins, which can be targets of reactive species to the oxygen (Berchieri-Ronchi et al., 2011; Kim et al., 2013; Zhao & Kim, 2020).

According to Surai and Fisinin (2016), oxidative stress has deleterious effects on several physiological processes of sows, such as oocyte maturation and embryonic and fetal development. In young sows, this process can be even more intense, which can interfere with their future reproductive performance and compromise their longevity.

In this sense, there are nutritional strategies that can attenuate the deleterious effects of thermal and oxidative stress in swine matrices of modern strains, with several studies having been carried out in recent years, focusing on substances with antioxidant capacity, such as selenium (Se) and vitamin E (Chen et al., 2016; Zhou, Xu, Liu, & Zhang, 2021).

Se is an essential cofactor of at least 25 selenoproteins, 16 of which have an antioxidant function (Pappas et al., 2008), with glutathione peroxidase being one of the most studied. In animal nutrition, Se can be supplemented in diets in inorganic and organic form, the latter being the most used form, due to its capacity for deposition in tissues, mainly in muscles, acting as reserve source of selenomethionine in animal body.

On the other hand, vitamin E has a non-enzymatic activity and its antioxidant effect is mainly due to its ability to donate hydrogen atoms to free radicals, generating electrically stable or less reactive products and, consequently, inhibiting the oxidation process (Lima-Verde et al., 2007; Nwose et al., 2008). Studies evaluating the use of organic Se and vitamin E in the diet of lactating sows and their possible effects on their progenies are scarce and the results have been variable (Chen et al., 2019; Chen et al. 2016; Fortier et al., 2012; Shelton et al., 2014). In turn, considering the modes of action of these additives, it is possible to observe their potential effect against the physiological conditions of the reproductive stages and oxidative stress in an equatorial climate without adiabatic cooling.

2 | OBJECTIVE

The objective of this work was to evaluate the effects of dietary supplementation of organic Se and vitamin E for sows of 1st and 2nd parity orders, without adiabatic cooling, on reproductive parameters, physiological responses, milk production and composition, productive performance of their litters and blood concentrations of antioxidant enzymes.

3 | MATERIALS AND METHODS

The experimental procedures followed the protocols approved by the Committee and Ethics in the Use of Animals (CEUA) of the Federal University of Ceará—Brazil.

A total of 96 sows (Topigs Norsvin) were distributed in a completely randomised design, in a 4 × 2 factorial arrangement, considering four experimental groups and two parity orders (1st and 2nd order), considering the sow as the experimental unit. The experimental groups consisted of: ACCon—sows receiving adiabatic cooling and no dietary supplementation of organic Se and vitamin E; WACCon—sows without adiabatic cooling and no dietary supplementation of organic Se and vitamin E; WACSe—sows without adiabatic cooling with dietary supplementation of 0.3 mg/kg organic Se; WACSeE—sows without adiabatic cooling with dietary supplementation of 0.3 mg/kg organic Se and 90 IU/kg vitamin E. Organic selenium was supplied from a product containing 2% selenohydroxymethionine, established according to the level of 0.3 mg/kg by Surai and Fisinin (2016). Vitamin E was supplemented from product containing 500 IU/g. For vitamin E, enhancements in immune response have been observed with additions above 60 IU vitamin E/kg, with levels close to 90 IU/kg being recommended in response to the widespread use of hyper-prolific sows (Gaudré & Quiniou, 2009).

Diets were formulated to meet the nutritional requirements of sows in the final third of gestation and lactation, according to the recommendations contained in the lineage manual (Table 1). Dietary supplementation of organic Se and vitamin E (Adisseo, Brazil) started at 85 days of gestation, being supplied in the first ration offer of the day, throughout the experimental period. In order to ensure the intake of organic Se and/or vitamin E, the amount of additives offered was previously diluted in part of the ration and placed in the feeder.

Adiabatic cooling used for ACCon sows was performed using a DuctoFan equipment (Axial Munters), with ventilation located at the withers of the females from the housing at maternity shed. At 110 days of gestation, sows were individually weighed and the backfat thickness was measured at point P2, obtained 6.5 cm from the lumbar midline from the last rib, in both sides, using an ultrasound device (Preg-Tone, Renco®).

During the entire experimental period, temperature and humidity data were recorded using a data logger (Didai Tecnologia Ltda.), positioned 1 m above the floor, with an average temperature and humidity of 27.8°C and 78.4%, respectively. The minimum and maximum values observed throughout the experiment were 23.5°C and 34.1°C, for temperature, and 51.8% and 97.6%, for relative humidity.

Physiological parameters were measured in four sows of each treatment, selected according to body weight and backfat thickness,

TABLE 1 Calculated and nutritional composition of experimental diets for sows during late-gestation and lactation.

Feedstuff (%)	Late-gestation	Lactation
Corn	72.52	59.73
Soybean meal	19.50	15.50
Extruded soybean	4.00	16.00
Sugar	–	5.00
Limestone	0.40	0.60
Dicalcium phosphate	1.60	1.60
DL-Methionine 99%	–	0.10
L-Lysine 79%	0.06	0.32
L-Threonine 98.5%	0.02	0.25
Fibre source[a]	1.00	–
Salt	0.50	0.50
Mineral and vitamin supplement[b]	0.40	0.40
Total	100.000	100.000
Nutritional composition and energy		
Metabolisable energy[c] (kcal/kg)	3226.03	3317.89
Crude protein[c] (%)	16.62	18.63
Ether extract[c] (%)	3.89	5.81
Methionine[d] (%)	0.32	0.42
Lysine[d] (%)	0.88	1.22
Threonine[d] (%)	0.66	0.95
Calcium[c] (%)	0.80	0.89
Total phosphorus[c] (%)	0.52	0.52
Sodium[d] (%)	0.22	0.22
Selenium[c] (ppm)	0.42	0.45
Vitamin E[d] (IU/kg)	30.48	30.48

[a]Opticell (Biosen—Agromed Austria GmbH).

[b]Cobalt (100,000 mg/kg), Copper (10,000 g/kg), Iron (20,000 g/kg), Iodine (250,000 mg/kg), Manganese (8,750,000 mg/kg), Selenium (90,000 mg/kg), Zinc (25,000 g/kg), Vitamin A (2,500,000,000), Vitamin D3 (450,000,000 IU/kg), Vitamin E (7,620,000 IU/kg), Vitamin K3 (625,000 mg/kg), Vitamin B1 (550,000 mg/kg), vitamin B2 (1,250,000 mg/kg), vitamin B6 (750,000 mg/kg), Vitamin B12 (7,500,000 mcg/kg), Niacin (7,500,000 mg/kg), Pantothenic acid (4250.000 mg/kg), Folic acid (750,000 mg/kg), Biotin (100.00 mg/kg), Choline (20,530 g/kg), B.H.T. (12,000 g/kg), 6-Phytase (125,000,000 IU/kg).

[c]Analyzed values.

[d]Calculated values.

at 7, 14 and 21 days after farrowing, at three different times (8, 12 and 16 h), calculating the average daily values. Rectal temperature was measured using a veterinary clinical thermometer, introduced into the rectum of the sows, for 1 min. For the respiratory rate, the females' flank movements were counted for 15 s, extrapolating the values to 1 min. The surface temperatures of the neck, ham and mammary gland of the sows were verified using an infrared laser thermometer (Raytec Minitemp MT4).

At farrowing, the weight and number of total and live born piglets were recorded. Up to 48 h after birth, litters were standardised among sows of the same treatment and piglets were counted and weighed again. During the experimental period, no feed supplementation was provided to the piglets and they had access to water ad libitum. All piglets that died were weighed in order to have an adequate estimate of litter development and milk production.

After farrowing, sows received feed according to graded feed management to encourage increased intake until the eighth postpartum day, starting with 2.0 kg on the 1st postpartum day and reaching 9.0 kg on the eighth day, remaining constant until weaning. Feed consumption was determined by the difference between the weight of the feed provided and the weight of the leftovers collected daily.

On the 18th postpartum day, milk and blood samples were collected from the sows in which the physiological parameters were determined. In the same period, two piglets were selected from each litter of these sows for blood collection. In milk collection, the litter was initially separated from the sow after suckling and waited an average of 50 min. After this period, 1.0 mL of injectable oxytocin was applied in the auricular vein and then the sow was manually milked. Milk samples were homogenised and stored in duplicate in sterile containers at −20°C for further analysis. The determination of pH, density, dry extract, lipid, protein and lactose of milk was performed using an automatic analyzer (Lactoscan Milk Analyzer, Milkotronic Ltda.).

Blood collection was performed through jugular vein puncture with Vacutainer® tubes. After this procedure, the samples were centrifuged at 4000 RPM for 5 min at room temperature, and the supernatants obtained were stored in Eppendorfs® tubes at −20°C, being later used to determine the levels of glutathione peroxidase and superoxide dismutase (SOD) using RANSEL® and RANSOD® kits (RANDOX Laboratories), expressed in IU/mg of protein.

At 24 days of age, piglets from each litter were counted, weighed and weaned. After weaning, the sows were individually weighed and the backfat thickness was measured at point P2. Then, these females were transferred to the gestation shed, where they were housed in cages and started to receive 3.0 kg/day of their respective experimental diets until estrus, then the WEI was determined.

The loss of body composition of sows was estimated from the empty live weight (ELW, kg) and backfat thickness (P2, mm) according to the equations published by Dourmad et al. (1997): protein (kg) = 2.28 + 0.178 ELW − 0.333 P2; lipid (kg) = 26.4 + 0.221 ELW + 1.331 P2; energy (Mcal) = 257 + 3.267 ELW − 0.081 P2. The estimate of average daily milk production (DMP) was based on litter weight gain (LWG), number of piglets and milk dry matter content (19%), according to the equation of Noblet and Etienne (1986): DMP (kg/day) = ([0.718 × LWG − 4.9] × number of piglets)/0.19.

The data obtained were submitted to analysis of variance by the GLM procedure (General Linear Models) of the Statistical Analysis System (SAS, University Edition), considering the sows and their

respective litters as experimental unit. Means were compared using Tukey's test at 5% significance.

4 | RESULTS AND DISCUSSION

There was no interaction ($p > 0.05$) between the experimental groups and parity orders on physiological parameters of sows (Table 2). Sows receiving adiabatic cooling had lower respiratory rate, rectal and neck temperature compared to females not submitted to adiabatic cooling, with or without supplementation of organic selenium and vitamin E ($p < 0.05$). Pigs are homeothermic animals and, therefore, maintain their body temperature relatively constant, adjusting the heat produced in the organism with the environment. This process is efficient when the temperature is within the limits of the thermoneutrality zone, which varies from 12°C to 22°C, for pregnant and lactating sows (Quiniou & Noblet, 1999). When exposed to temperatures above this range, sows may show physiological changes, such as increased respiratory rate, to maintain thermal homeostasis (Hill et al., 2012; Rodrigues et al., 2010).

As in this study, the average and maximum temperatures reached values of 27.8°C and 34.1°C, respectively, it was observed that the sows of all groups had a respiratory rate above the range considered normal for gestation and lactating sows, which is from 15 to 25 movements per minute (Hannas, 1999; Quiniou & Noblet, 1999). It was also found that even with the increase in respiratory rate, sows were not able to dissipate heat and had a rectal temperature above normal, which is 38.6°C for lactating sows (Hannas, 1999), indicating heat stress condition. The cooler air directed at the head of the sows with adiabatic cooling probably influenced the thermal sensation of these animals (Nääs et al., 2013), explaining the difference observed in the rectal and surface temperature of these sows in relation to the other groups, corroborating Perin et al. (2016) who also observed a reduction in the temperature of sows with adiabatic cooling.

There was no interaction ($p > 0.05$) between experimental groups and parity orders on sows' performance (Table 3). However, it was observed sows receiving adiabatic cooling showed higher DMP compared to those that did not receive adiabatic cooling, with or without organic Se and vitamin E supplementation. It was also observed that the sows that received organic Se and vitamin E presented greater body losses of protein and energy, in relation to

TABLE 2 Physiological parameters of 1st and 2nd parity order sows from different experimental groups.

	Experimental group (EG)[a]				Parity order (PO)			*p* value		
Physiological parameters	ACCon	WACCo	WACSe	WACSeE	1st	2nd	CV[b] %	EG	PO	EG × OP
Temperature, °C	7 postpartum days									
Neck	34.12[b]	36.37[a]	36.64[a]	36.92[a]	35.98	36.22	3.12	0.041	0.427	0.852
Ham	35.59	36.25	36.71	36.67	36.05	36.56	2.42	0.136	0.774	0.884
Mammary gand	36.59	37.14	37.29	37.45	37.14	37.09	1.57	0.095	0.164	0.992
Rectal	38.51[b]	39.02[a]	39.03[a]	39.02[a]	38.84	38.95	1.57	0.035	0.879	0.758
Respiratory rate, movements/min.	46.83[b]	71.80[a]	79.44[a]	74.94[a]	67.45	69.05	32.06	0.031	0.132	0.479
Temperature, °C	14 postpartum days									
Neck	34.54[b]	36.61[a]	36.25[a]	36.81[a]	36.05	36.12	2.85	0.013	0.443	0.745
Ham	35.85	36.54	36.51	36.70	36.22	36.14	2.51	0.336	0.337	0.821
Mammary gland	36.93	37.51	37.61	37.85	37.45	37.51	1.82	0.156	0.169	0.967
Rectal	38.43[b]	39.53[a]	39.26[a]	39.22[a]	39.33	38.92	1.32	0.011	0.284	0.854
Respiratory rate, movements/min.	57.00[b]	82.73[a]	76.44[a]	82.80[a]	74.92	74.31	22.92	0.046	0.431	0.321
Temperature, °C	21 postpartum days									
Neck	34.31[b]	36.06[a]	36.08[a]	36.04[a]	35.44	35.82	2.11	0.001	0.724	0.687
Ham	35.41	36.51	36.94	36.95	36.41	36.67	1.79	0.103	0.682	0.792
Mammary gland	36.73	37.45	37.53	37.86	37.21	37.49	1.58	0.206	0.139	0.419
Rectal	38.50[b]	39.09[a]	39.27[a]	39.35[a]	38.97	39.25	1.82	0.009	0.233	0.354
Respiratory rate, movements/min.	47.69[b]	82.01[a]	89.38[a]	78.04[a]	73.68	75.01	19.32	0.004	0.641	0.317

Note: [a,b]Means followed by different letters on the same line differ from each other by Tukey's test ($p < 0.05$).

[a]ACCon—sows receiving adiabatic cooling and no dietary supplementation of organic Se and vitamin E; WACCon—sows without adiabatic cooling and no dietary supplementation of organic Se and vitamin E; WACSe—sows without adiabatic cooling with dietary supplementation of 0.3 mg/kg organic Se; WACSeE—sows without adiabatic cooling with dietary supplementation of 0.3 mg/kg organic Se and 90 UI of vitamin E.

[b]Coefficient of variation.

TABLE 3 Performance of 1st and 2nd parity order sows from different experimental groups.

	Experimental group (EG)[a]				Parity order (PO)			*p* value		
Parameters	ACCon	WACCo	WACSe	WACSeE	1st	2nd	CV[b] %	EG	PO	EG × OP
Total feed intake, kg	124.01	123.28	120.57	117.89	114.59[b]	128.28[a]	10.21	0.566	0.001	0.111
Daily feed intake, kg	5.16	5.13	5.02	4.91	4.77[b]	5.34[a]	10.20	0.565	0.001	0.111
Daily milk production, kg	13.77[a]	11.46[b]	11.25[b]	10.11[b]	10.94[b]	12.35[a]	19.12	<0.001	0.002	0.943
Body weight, kg										
At farrowing	230.50	235.58	232.68	234.93	220.56[b]	246.28[a]	5.65	0.545	<0.001	0.705
At weaning	189.92	188.54	192.07	191.64	176.44[b]	204.64[a]	7.29	0.831	<0.001	0.999
Body weight loss, kg	40.57	47.03	42.31	43.29	44.11	42.49	24.15	0.194	0.457	0.282
Percentage of weight loss, %	17.62	20.04	18.20	18.48	19.97[a]	17.20[b]	23.45	0.269	0.002	0.345
Backfat thickness, mm										
At farrowing	14.90	14.57	15.95	15.98	14.77[b]	15.93[a]	14.73	0.072	0.014	0.083
At weaning	12.77	12.23	13.08	12.44	11.99	12.62	0.142	0.182	0.077	0.142
Weaning to estrus interval, days	3.95	3.96	4.09	4.07	4.06	3.97	18.34	0.814	0.474	0.077
Body composition loss										
Protein, kg	5.26[b]	6.24[b]	8.68[a]	8.71[a]	8.92[a]	5.55[b]	34.98	<0.001	<0.001	0.082
Lipid, kg	11.15[b]	11.86[b]	14.58[a,b]	16.15[a]	15.29[a]	11.61[b]	31.63	<0.001	<0.001	0.331
Energy, Mcal	110.61[b]	128.49[b]	172.07[a]	178.36[a]	178.17[a]	117.02[b]	33.16	<0.001	<0.001	0.133

Note: [a,b]Means followed by different letters on the same line differ from each other by Tukey's test ($p < 0.05$).

[a]ACCon—sows receiving adiabatic cooling and no dietary supplementation of organic Se and vitamin E; WACCon—sows without adiabatic cooling and no dietary supplementation of organic Se and vitamin E; WACSe—sows without adiabatic cooling with dietary supplementation of 0.3 mg/kg organic Se; WACSeE—sows without adiabatic cooling with dietary supplementation of 0.3 mg/kg organic Se and 90 UI of vitamin E.

[b]Coefficient of variation.

the non-supplemented. Sows that received organic Se and vitamin E showed greater body lipid loss compared to non-supplemented sows, while sows that received only organic Se did not differ from those not supplemented. First parity order sows had lower feed intake and lower values for milk production, weight at farrowing and at weaning, backfat thickness at farrowing, and higher losses of weight, protein, lipids and body energy.

Sows under heat stress tend to reduce feed intake in order to minimise the production of metabolic heat, which can lead to greater mobilisation of body reserves and, consequently, to lower weight and backfat thickness (Gourdine et al., 2006; Renaudeau et al., 2011). However, in this work, there were no differences between the experimental groups on these variables, corroborating with Zhao et al. (2011), who also did not observe effects of heat stress on the productive performance of lactating sows.

Regarding the effects of parity orders, it was observed that primiparous sows had lower average and total feed intake than 2nd parity order sows, which is justified by the fact that gilts have feed intake capacity of up to 20% lower when compared to sows (Young et al., 2004). As in this study, gilts had lower birth and weaning weights, in addition to greater percentage of weight loss, it can be inferred that the amount of feed consumed was not able to meet the nutritional requirements of these females, which caused greater mobilisation of body reserves, corroborating the data reported by Andrade et al. (2016).

In this study, sows not subjected to adiabatic cooling had lower estimated milk production than sows that received localised cooling. This can be explained by the redirection of blood flow from the mammary gland to the skin that occurs, under conditions of heat stress, in an attempt to regulate body temperature, causing a decrease in the availability of nutrients for milk synthesis (Barb et al., 1991; Black et al., 1993). According to Chen et al. (2019), milk production is also affected by oxidative stress, as the synthesis of milk peptides can be blocked when reactive oxygen species are produced beyond the cellular antioxidant capacity of sows. When evaluating the effects of selenium and vitamin E supplementation at the end of pregnancy in cows and sheep, respectively, Moeini et al. (2009) and Meyer et al. (2011) found an increase in milk production. In this work, as sows supplemented with organic Se and vitamin E (WACSe and WACSeE) did not differ from those that did not receive adiabatic cooling (WACCon), it can be inferred that the levels of Se and vitamin E provided may have been insufficient to reduce the deleterious effects of thermal and oxidative stress in these sows. In addition, according to Pharazyn et al. (1990), the interpretation regarding the vitamin E requirement for gilts and sows based on conventional reproductive criteria can lead to underestimation of the

values, and thus the absence of effect can be attributed to the level of vitamin E that may have been insufficient to improve the performance of the sows.

There was no interaction ($p > 0.05$) between experimental groups and parity orders on litter performance (Table 4). Significant effects between the experimental groups were observed on litter size and weight at weaning and on average daily litter gain. The litter size at weaning of sows that received adiabatic cooling was greater than sows supplemented with the association of organic Se and vitamin E without cooling. In relation to litter weight at weaning and average daily litter gain, there was a better performance of sows that received adiabatic cooling, differing from the other experimental groups. Regarding parity orders, it was observed that primiparous sows had a greater number of piglets born total and alive, and 48 h after farrowing, although litters with lower weight were observed (at farrowing, 48 h after postpartum and at weaning) and average daily weight gain in relation to sows of 2nd parity order ($p < 0.05$).

Hu et al. (2011) and Shelton et al. (2014) reported that sows supplemented with Se and vitamin E weaned litters with greater weight gain compared to the control group. In this study, however, no beneficial effects of the dietary supply of these additives on the performance of piglets were observed. Sows submitted to adiabatic cooling presented litters with higher weaning weight and ADG than the sows of the other groups, corroborating Justino et al. (2015), who found that sows with adiabatic cooling weaned heavier piglets compared to sows under heat stress. When there is no supply of any type of dietary supplementation for piglets, the performance of these animals directly reflects the quantity and nutritional quality of the sow's milk (Hurley, 2015). Thus, as no significant differences were observed in the nutritional composition of milk, this result may be related to the higher milk production of sows receiving adiabatic cooling.

In other studies, it was observed that the level of supplementation may have an effect due to the basal level of Se and vitamin E in the sows' diet (Yoon & McMillan, 2006). While Mahan and Peters (2004) observed the effect of supplementation on organic and inorganic Se in sows that received a basal diet with a reduced level of the mineral (0.07 and 0.067 mg/kg in late gestation and lactation, respectively), even considering the level of 0.42–0.45 mg/kg (late-gestation and lactation) from inorganic source of Se in the present study, supplementation at 0.3 mg/kg may not have had an effect because the basal diet level was already sufficient to meet the mineral requirement.

Evaluating increasing levels of Vitamin E for sows, Mahan (1994) also found no effect on the reproductive and productive parameters of litters up to the level of 66 IU/kg. In turn, Wang et al. (2017) observed higher weaning weight in sows that received 250 IU/kg of vitamin E. Thus, even considering the basal level of the diets in the

TABLE 4 Littter performance of 1st and 2nd parity order sows from different experimental groups.

Parameters	Experimental group (EG)[a]				Parity order (PO)		CV[b] %	*p* value		
	ACCon	WACCo	WACSe	WACSeE	1st	2nd		EG	PO	EG × OP
Litter size, *n*										
At farrowing	15.14	14.70	15.48	14.20	15.81[a]	13.95[b]	20.60	0.513	0.004	0.124
Born alive	14.10	13.33	13.97	13.38	14.34[a]	13.06[b]	22.64	0.775	0.047	0.233
48 h postpartum	13.73	13.58	13.53	13.16	13.69[a]	13.31[b]	5.65	0.074	0.015	0.097
At weaning	12.59[a]	11.93[a,b]	11.81[a,b]	11.16[b]	11.82	11.93	10.17	0.001	0.657	0.813
Average piglet weight, kg										
At farrowing	1.44	1.43	1.45	1.48	1.31[b]	1.59[a]	13.13	0.821	<0.001	0.096
48 h postpartum	1.62	1.57	1.59	1.56	1.42[b]	1.75[a]	17.02	0.879	<0.001	0.233
At weaning	6.63	6.43	6.12	6.31	6.01[b]	6.74[a]	10.27	0.072	<0.001	0.692
Piglet's average daily gain, kg	0.227	0.219	0.206	0.216	0.208[b]	0.226[a]	12.73	0.084	0.002	0.837
Litter weight, kg										
At farrowing	19.57	19.07	20.54	19.24	18.55[b]	20.66[a]	19.89	0.578	0.010	0.092
48 h postpartum	22.39	21.35	21.47	20.51	19.53[b]	23.32[a]	16.88	0.372	<0.001	0.715
At weaning	83.55[a]	74.14[b]	73.40[b]	70.20[b]	70.35[b]	80.29[a]	12.98	<0.001	<0.001	0.910
Average daily litter gain, kg	2.77[a]	2.39[b]	2.35[b]	2.20[b]	2.27[b]	2.58[a]	16.38	<0.001	0.004	0.995

Note: [a,b]Means followed by different letters on the same line differ from each other by Tukey's test ($p < 0.05$).

[a]ACCon—sows receiving adiabatic cooling and no dietary supplementation of organic Se and vitamin E; WACCon—sows without adiabatic cooling and no dietary supplementation of organic Se and vitamin E; WACSe—sows without adiabatic cooling with dietary supplementation of 0.3 mg/kg organic Se; WACSeE—sows without adiabatic cooling with dietary supplementation of 0.3 mg/kg organic Se and 90 UI of vitamin E.

[b]Coefficient of variation.

TABLE 5 Milk composition of 1st and 2nd parity order sows from different experimental groups.

	Experimental group (EG)[a]				Parity order (PO)			*p* value		
Parameters	ACCon	WACCo	WACSe	WACSeE	1st	2nd	CV[b] %	EG	PO	EG × OP
Density, g/cm^3	1.00	1.01	1.03	1.02	1.02	1.01	4.51	0.803	0.896	0.667
Dry extract, %	18.49	18.60	18.79	19.10	18.75	18.74	7.63	0.886	0.976	0.605
Lipid, %	9.88	9.92	9.97	10.37	10.03	10.04	12.35	0.892	0.976	0.427
Protein, %	5.50	5.53	5.59	5.67	5.58	5.57	7.01	0.884	0.963	0.643
Lactose, %	5.08	5.14	5.22	5.15	5.16	5.13	3.88	0.696	0.767	0.223
pH	5.58	5.59	5.70	5.74	5.63	5.68	4.57	0.643	0.626	0.666

Note: [a,b]Means followed by different letters on the same line differ from each other by Tukey's test ($p < 0.05$).

[a]ACCon—sows receiving adiabatic cooling and no dietary supplementation of organic Se and vitamin E; WACCon—sows without adiabatic cooling and no dietary supplementation of organic Se and vitamin E; WACSe—sows without adiabatic cooling with dietary supplementation of 0.3 mg/kg organic Se; WACSeE—sows without adiabatic cooling with dietary supplementation of 0.3 mg/kg organic Se and 90 UI of vitamin E.

[b]Coefficient of variation.

TABLE 6 Serum glutathione peroxidase (GSH-Px) and superoxide dismutase (SOD) of 1st and 2nd parity order sows from different experimental groups.

	Experimental group (EG)[a]				Parity order (PO)			*p* value		
Parameters (UI/mg of protein)	ACCon	WACCo	WACSe	WACSeE	1st	2nd	CV[b] %	EG	PO	EG × OP
Sow										
GSH-Px	25.19[b]	23.27[b]	28.42[b]	35.64[a]	28.83	27.43	2.15	0.001	0.593	0.236
SOD	104.92[b]	103.54[b]	111.82[a,b]	126.64[a]	112.19	111.27	7.29	0.015	0.893	0.968
Piglet										
GSH-Px	21.96[b]	20.53[b]	24.15[b]	31.58[a]	24.53	24.55	3.12	<0.001	0.654	0.663
SOD	101.69[b]	99.55[b]	103.88[b]	109.96[a]	104.07	103.47	6.14	0.008	0.654	0.651

Note: [a,b]Means followed by different letters on the same line differ from each other by Tukey's test ($p < 0.05$).

[a]ACCon—sows receiving adiabatic cooling and no dietary supplementation of organic Se and vitamin E; WACCon—sows without adiabatic cooling and no dietary supplementation of organic Se and vitamin E; WACSe—sows without adiabatic cooling with dietary supplementation of 0.3 mg/kg organic Se; WACSeE—sows without adiabatic cooling with dietary supplementation of 0.3 mg/kg organic Se and 90 UI of vitamin E.

[b]Coefficient of variation.

present study (30.48 IU/kg), supplementation at 90 IU/kg did not result in a benefit on the productive response in piglets.

There was no interaction ($p > 0.05$) between the experimental groups and parity orders, nor isolated effects ($p > 0.05$) on sow milk composition (Table 5). According to Vieira et al. (2020), gilts have a genetic potential for milk production similar to 2nd parity order sows. However, in this study, there was a lower milk production and, consequently, a worse performance of the litters of gilts. Considering that the metabolic state of sows directly affects the distribution of energy and/or protein to the mammary tissue (Bierhals et al., 2011), the lower milk production of gilts may be related to the greater lactational catabolism observed in these animals.

There was no interaction effect ($p > 0.05$) between experimental groups and parity order on blood concentrations of antioxidant enzymes (Table 6). Sows supplemented with organic Se and vitamin E showed higher serum levels of glutathione peroxidase (GSH-Px) in relation to the other experimental groups ($p < 0.05$). Furthermore, supplementation of organic Se and vitamin E also resulted in higher levels of blood SOD content compared to non-supplemented sows (ACCon and WACCon). The litters of sows supplemented with organic Se and vitamin E showed higher levels of GSH-Px and SOD ($p < 0.05$) in relation to the other experimental groups.

In this study, organic Se and vitamin E supplementation for sows without adiabatic cooling promoted a higher concentration of the enzymes SOD and glutathione peroxidase at 18 days of lactation, indicating that the supply of these nutrients favours a superior antioxidant status even in sows receiving adiabatic cooling. This result corroborates Chen et al. (2019), who found an improvement in the antioxidant activity of sows supplemented with 0.3 and 1.2 mg/kg of Se, both in climate-controlled and non-air-conditioned sheds. In this sense, it is also observed that the enzymatic antioxidant response in the blood of piglets is related to the source of organic Se, and it is observed that in studies with Selenomethionine the effect on serum GSH-Px is more evident, compared to Se yeast (Yoon & McMillan, 2006). According to

Surai & Fisinin (2016), Se yeast presents variation in the level of Selenomethionine due to the possible presence of Selenocysteine, which action in increasing the level of Se in the tissues is reduced. Other forms of organic Se have also been evaluated, with a positive effect of supplementation in sows with 2-hydroxy-4-methylselenobutanoic acid being observed (Mou et al., 2020), showing that the bioavailability of this mineral can be greater and with a long-term effect.

With the improvement of the antioxidant status of sows, the piglets also showed higher serum levels of glutathione peroxidase and SOD. This indicates that, even under heat stress conditions, dietary supplementation of organic Se and vitamin E during late gestation and lactation can increase the activity of antioxidant enzymes not only in sows, but also in their litters, at 18 days of age, favoring a better antioxidant status of these animals in the period close to weaning, characterised by critical indices of stress and oxidative imbalance. Future complementary studies on the response of dietary supplementation of organic Se and vitamin E in sows and piglets on TBARS values, capacity and serum antioxidant potential (DPPH and $ABTS^{o+}$) may help in understanding beyond the endogenous action, indicating possible responses to stress oxidative in animals.

5 | CONCLUSION

Under equatorial climate conditions, dietary supplementation of organic Se and vitamin E from first and second parity order sows does not respond efficiently on thermoregulatory physiology and performance compared to adiabatic cooling, but modulates the enzymatic antioxidant balance of sows and piglets.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Pedro Henrique Watanabe http://orcid.org/0000-0002-1010-2305

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