Use of virginiamycin improves performance of high-prolific sows during gestation and lactation over two cycles

Uso de virginiamicina melhora o desempenho de fêmeas suínas de alta prolificidade durante a gestação e lactação em dois ciclos

El uso de virginiamicina mejora el rendimiento de cerdas de alta prolificidad durante la gestación y lactancia en dos ciclos

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Abstract
Feed additives can be used as potential strategies to enhance the efficiency of nutrient utilization by the sow can impact on the reduction of feed costs and in addition improve sow and litter health. The objective of this study was to evaluate the impact of the supplementation of virginiamycin (VM) in diets for gestating and lactating sows over two consecutive productive cycles on the animals productive and reproductive performance. Sows that received VM showed a lower BW, body protein and energy losses during both lactations when compared to control sows ($P = 0.001$). VM treatment increased ($+6\%$; $P = 0.001$) piglet weaning weight. The litter daily gain was also influenced ($P = 0.001$) by the treatments were litters from VM fed sows showed an improved daily gain when compared to control sows (2.61 *vs.* 2.24 kg d^{-1} respectively). Average daily milk production improved by 17% ($P = 0.001$) in the VM sows when compared with the control. Also, an improvement in milk fatty acid profiles were found in sows fed VM. As a conclusion, we can infer that the constant use of VM in the diets of sows during gestation and lactation improves both sow and litter performance.
Keywords: Antibiotic; Piglets; Female; Milk production.

Resumo

Os aditivos alimentares podem ser utilizados como estratégias potenciais na nutrição de fêmeas suínas para aumentar a eficiência de utilização de nutrientes e reduzir os custos de alimentação e, além disso, melhorar a saúde das matrizes e leitegadas. O objetivo deste estudo foi avaliar o impacto da suplementação da virginiamicina (VM) para desempenho produtivo e reprodutivo dos animais em dietas de fêmeas gestantes e lactantes ao longo de dois ciclos produtivos consecutivos. As porcas que receberam virginiamicina (VM) apresentaram menor peso corporal (BW), perdas de proteínas corporais e perda de energia em ambas as lactações quando comparadas com as matrizes do grupo controle ($P = 0,001$). O tratamento com VM aumentou (+6%; $P = 0,001$) o peso de desmame de leitões. O ganho diário da leitegada também foi influenciado ($P = 0,001$) pelos tratamentos com VM e o ganho diário foi melhor quando comparado com as fêmeas do controle (2,61 *vs.* 2,24 kg d^{-1} respectivamente). A produção média diária de leite melhorou em 17% ($P = 0,001$) nas porcas alimentadas com VM quando comparadas com o controle. Também foi encontrada uma melhoria nos perfis dos ácidos graxos do leite nos animais alimentados com VM. Como conclusão, podemos inferir que o uso constante de VM na dieta das porcas durante a gestação e lactação melhora tanto o desempenho das matrizes como da leitegada.

Palavras-chave: Antibiótico; Leitões; Fêmea; Produção de leite.

Resumen

Se pueden utilizar aditivos alimentarios como estratégia funcional en la alimentación de las cerdas para aumentar la eficiência de utilización de los nutrientes y reducir los costes, además, actuan mejorando su salud y la de sus camadas. El objeto de este estúdio fue evaluar el impacto de la suplementación con virginiamicina (VM) sobre el rendimiento productivo y reproductivo de los animales em dietas de cerdas gestantes y lactantes a lo largo de dos ciclos productivos consecutivos, Las cerdas que recibieron virginiamicina (VM) tuvieron menor peso corporal (PV), pérdida de proteína corporal y pérdida de energía en las dos lactaciones en comparación con las cerdas del grupo control ($P = 0,001$). Por otro lado, las cerdas con el tratamiento VM aumentaron (+6%; $P = 0,001$) el peso de destete de los lechones de sus camadas. La ganancia diária de la camada también fue afectada ($P = 0,001$) por efecto del tratamiento con VM y la ganancia diária fue mayor em comparación con las cerdas del tratamiento control (2,61 *vs.* 2,24 kg d^{-1} respectivamente). La producción média diária de leche mejoró en un 17% ($P = 0,001$) en las cerdas alimentadas con VM en comparación con las del control. También se observó una mejoría en el perfil de ácidos grasos de la leche en los animales alimentados con VM. Como conclusión, podemos deducir que el uso constante de VM en las dietas de cerdas durante la gestación y la lactación mejora tanto el rendimiento de las cerdas como el de sus camadas.

Palabras clave: Antibióticos; Lechones; Hembra; Producción de leche.

1. Introduction

Nutritional strategies used to improve the performance of sows generally are associated with dietary manipulation. Several nutrients or feed additives that increase performance (i.e., antibiotics), demonstrate an efficient amino acid and energy utilization and therefore offer potentially benefits not only as growth enhancers, but also improve sow performance and longevity. Feeding level, amino acid and energy intake during gestation and lactation represent important indicators of sow performance and have been extensively investigated and well documented by literature (Noblet & Etienne, 1989; Quiniou & Noblet, 1999; Kim et al., 2009). Therefore, the interest in feed additives, commonly used as growth promotors in other pig categories (i.e., growing-finishing pigs), is to study their effects on reproductive and productive performance of sows.

Factors that can improve the efficiency of feed utilization by the sow, can contribute to improve feed costs, which represent great proportion of the total production costs in the pig industry, and as a secondary effect improve sow and litter health status (Kyriakis et al., 1992). The use of antibiotics may result in improved economic gains in pigs living in sub-optimal conditions rather than in those reared in the highest welfare and environmental conditions. The establishment of a beneficial intestinal microbiota at birth could lead to healthier pigs, this could be achieved in an effective way by treating sows, which could potentially provide an optimized transfer of beneficial bacterial strains from the sow to the neonatal pigs' environment.

Several results from previous studies investigating the effects of different dietary levels of dietary VM supplementation on sow performance have been published in the past (Kyriakis et al., 1992; Curran et al., 1994; and Monetti et al., 1998). It is of general agreement among these later authors that the best level of inclusion observed, which improved performance traits, was of 40 mg kg^{-1} or 40 ppm. Nevertheless, current sow genotypes are high producing and have a reduced

voluntary feed intake as a consequence of the genetic selection for higher feed efficiency and therefore are much more susceptible to immunological challenges. The fact that metabolism is affected by genetic selection implies in the need of modified nutritional strategies to reach the current sow's daily needs in order to keep up with the high nutritional demands to maintain productivity. In this sense, the use of VM could improve gut health and sow feed efficiency and therefore allowing piglets to benefit at weaning by improving vitality, survival rates and performance. Therefore, the present study aimed to evaluate the impact of the supplementation of VM in diets for gestating and lactating sows over two consecutive productive cycles on their productive and reproductive performance.

2. Materials and Methods

Methods involving animal handling were performed in agreement with the regulations approved by the Institutional Animal Welfare and Ethics/Protection committee from the Universidade Federal de Minas Gerais (UFMG) under the protocol n. 307/2016.

2.1 Animals and Experimental Procedure

The study was performed between Dec 2016 and Dec 2017 and was conducted in the facilities of a sow unit commercial farm, located in a tropical climate region in the state of Minas Gerais at a Latitude: 20° 43' 13" South and Longitude: 46° 36' 36" West.

A total of 160 high-prolific multiparous sows from a commercial genetic line divided from two successive batches of 80 sows each were used in this study. Within each replicate, sows were distributed in a completely randomized experimental design among 2 dietary treatments according to parity order (1st, 2nd, 3rd to 4th, > 5th parity), body weight and backfat thickness 24 h after insemination. The sows were distributed to one of the two treatments represented by a control diet and an experimental diet with an inclusion of 40 ppm of virginiamycin (Staffac®) during the gestation and lactation phases (Table 1). Each treatment consisted of 80 repetitions, being each sow considered as an experimental unit. The sows remained in the experiment during two complete reproductive cycles, starting from d 1 post insemination until next cycle insemination.

The sows were housed individually in gestating crates until 110 d of gestation. On d 110 of gestation, sows were washed and transferred to the lactation unit and housed in individual farrowing pens (2.1 x 2.2 m) on a slatted plastic floor and fed 2 kg d^{-1} of the control or test lactation diet (Table 1) until the day of farrowing. Twenty-four hours after farrowing, the sows had their body weight and backfat thickness was measured. After farrowing, the sows were submitted to a step-up feeding program to stimulate a gradual feed intake increase up to day 7 post-farrowing. Initially sows were allowed 2 kg on day 1 post-farrowing and reached 8 kg d^{-1} on day 7. The allowance increased by 1 kg each day. The sows were fed following this feeding management to avoid over-consumption at the beginning of lactation and possible agalactia problems. After d 7 sows were allowed feed *ad libitum* and had free access to water via water nipples throughout all the experimental period.

Table 1 - Composition of the experimental diets.

Ingredients	Gestation		Lactation	
	T1 0.0% VM**	T2 40 ppm VM	T1 0.0% VM	T2 40 ppm VM
Corn (7.8%)	566.82	566.78	671.26	671.22
Soybean meal (45%)	205.00	205.00	250.00	250.00
Soybean oil	-	-	40.40	42.80
Wheat middlings	200.00	200.00	-	-
Dicalcium phosphate	8.28	8.28	15.00	15.00
Limestone (36%)	13.05	13.05	9.50	9.50
Salt	4.55	4.55	4.99	4.99
Virginiamycin	0.00	0.08	0.00	0.08
L-Lysine HCL	-	-	3.01	3.02
DL-Methionine	-	-	0.46	0.48
L-Threonine	-	-	1.08	1.10
L-Tryptophan	-	-	0.30	0.31
Premix Mineral/Vitamin*	2.30	2.30	4.00	4.00
Total	1,000.00	1,000.00	1,000.00	1,000.00
Analysed composition				
CP (%)	16.44	16.54	16.82	16.85
CF (%)	4.33	4.31	2.86	2.82
ME (Mcal/kg)	2.95	2.95	3.40	3.40
Calcium (%)	0.818	0.818	0.85	0.85
Avail. phosphorus (%)	0.312	0.312	0.40	0.40
SID Lysine (%)	0.68	0.68	1.00	1.00
SID Met. + Cist. (%)	0.50	0.50	0.54	0.54
SID Threonine (%)	0.50	0.50	0.64	0.64
SID Tryptophan (%)	0.15	0.15	0.19	0.19
SID Arginine (%)	0.97	0.97	1.02	1.02
SID Valine (%)	0.67	0.67	0.69	0.69
Sodium (%)	0.21	0.21	0.23	0.23

*Mineral and vitamin mixture supplied (g/kg of diet): 10 of Cu (as CuSO4); 80 of Fe (as FeSO4 · 7H$_2$O); 40 of Mn (as MnO); 100 of Zn (as ZnO); 0.6 of I (as Ca(IO3)2); 0.10 of CO (as CoSO4 · 7H$_2$O); 0.15 of Se (as Na2SeO3); 5,000 IU of vitamin A; 1,000 IU of vitamin D3; 15 IU of vitamin E; 2 mg of vitamin K3; 2 mg of thiamine; 4 mg of riboflavin; 20 mg of nicotinic acid; 10 mg of d-pantothenic acid; 3 mg of pyroxidine; 0.02 mg of vitamin B12; 1.0 mg of folic acid; and 0.2 mg of biotin. Standardized digestible AA contents were calculated from the analyzed AA content and estimated standardized digestibility coefficients from Brazilian Tables for Swine and Poultry Requirements (Rostagno, 2011). **VM = virginiamycin. Source: Authors (2018).

Following the methodology described by Barrilli et al. (2017), after birth, piglets were submitted to regular animal management procedures (i.e., tooth clipping and umbilical cord treatment). On d 3, piglets received an intramuscular injection of 200 mg of iron dextran. If necessary, cross-fostering was realized within the first 48 h after birth to standardize litter size at 14 piglets. On d 10, male piglets were castrated. Piglets has access to creep feed during the entire lactation period. Supplemental heat for the piglets was provided via creep housing equipped with infrared lights during the lactation period. At weaning, sows were moved to the gestation barns and were stimulated with a mature boar twice daily to detect onset of standing estrus. Sows were inseminated when positive to the back-pressure test in the presence of the boar. During the weaning-to-estrus interval, all sows were submitted continuously to the same lactation treatments, receiving 3.0 kg d^{-1} of their respective lactation diet. After insemination sows had feed changed to the experimental gestation diets and were fed these diets until next lactation cycle where then they again received the lactation experimental treatments.

2.2 Measurements and collected parameters

Following the methodology described by Barilli et al. (2017), ambient temperature and relative humidity inside the gestation barns and lactation rooms were continuously recorded (1 measurement every 60 s), using a probe (Model Log Tag

HAXO-8, Auckland, New Zealand) installed 1 m above the floor. Sows were weighed 24 h post-insemination, at 84 and 110 d of gestation, post-farrowing and at weaning using a digital scale (Líder Balanças Ltda., Mod. LD 2000E, Araçatuba, SP, Brazil) and backfat thickness measurements were taken ultrasonically (Renco Lean-Meater, Renco Corporation, Minneapolis, USA) at 65 mm from the dorsal line at the last rib on each flank 24 h post-insemination, at 84 and 110 d of gestation, post-farrowing and at weaning in order to measure body weight and backfat thickness variation. Piglet and litter measurements were: total number of piglets born, born alive, stillborn, and mummies. Twenty-four hours post-farrowing and at weaning the piglets were individually weighed using a digital scale (Líder Balanças Ltda., Mod. B150, Araçatuba, SP, Brazil) in order to determine litter birth and weaning weights, and daily weight gain during lactation. All piglets that died during the lactation phase were weighed so that proper estimates of growth rates and milk production could be obtained during lactation. Every morning, feed refusals were collected from the feeding troughs (i.e., 06h30m), and fresh feed was immediately distributed once per day between 07h00m and 08h00m. Feed consumption was calculated as the difference between offered feed and the refusals collected on the next day.

Everyday, 1 sample of feed was collected for DM content measurement, and stored at 4°C for further analyses. The feed samples were analyzed for DM, ash, fat content (AOAC, 1990) and CP (N · 6.25 for feed) according to Dumas method (AOAC, 1990) and for crude fiber and for cell wall components (NDF, ADF, and ADL) according to van Soest and Wine (1967) at the Animal Nutrition Laboratory of the Universidade Federal de Minas Gerais (Montes Claros, MG, Brazil). The dietary treatments (table 1) were mash and formulated based on corn, soybean meal (45% CP), soybean oil, and were supplemented with synthetic trace minerals, vitamins, and industrial amino acids. The ratios between digestible lysine and the essential amino acids were estimated to guarantee that they were not below that of the ideal protein ratio and to supply the nutritional requirements for gestating and lactating sows according to Rostagno (2011, table 1).

On d 18 of lactation, milk samples were collected manually from all the active mammary glands on each sow, from a pre-determined subsample of 30 sows per treatment, after an intravenous injection of 10 i.u. oxytocin into an ear vein. For that, the following protocol was applied to mimic a suckling event. Piglets were separated from the dam after suckling and 45 to 50 min later the sows were hand milked (Silva et al., 2009). The amount of milk collected (150 to 200 mL) was close to the estimated milk production during one suckling between farrowing and d 21. Samples were stored at -20°C, immediately after collection. At the end of the experiment, all samples were freeze dried and analyzed for moisture, ash, and N contents according to (AOAC, 1990) methods. Lactose content was measured using an enzymatic method (ENZYPLUS EZS784, BioControl Systems, Inc.). The total lipid content was determined by chloroform/methanol (2:1) according to Folch et al. (1967). Fatty acid methyl esters was prepared with 20% boron trifluoride/methanol solution according to Morrison and Smith, (1964) The fatty methyl esters were separated on a gas chromatograph equipped with a SP-2330 capillary column (30 m × 0.25 mm internal diameter) with a non-bonded poly (80% biscyanopropyl/20% cyanopropylphenyl siloxane) stationary phase (a 0.20-µm film thickness). Furnace temperature was 180°C, and injector and detector temperatures were 240°C. The following fatty acid profiles were measured: total saturated fatty acids (Total, C16 and C18), MUFA (Total; C16:1 and C18:1) and PUFA (Total, C18:2 and C18:3).

2.3 Calculations and Statistical Analyses

Daily maximum, minimum, mean, and variance of daily ambient temperatures and relative humidities were averaged for each replicate and cycle. Body protein, fat, and energy contents at farrowing and at weaning were estimated according to the equations of Dourmad et al. (1997). Protein, lipid, and energy losses during lactation were estimated as the difference between calculated values determined at farrowing and at weaning. Daily milk production over the lactation period was

calculated from litter growth rate, litter size between d 2 and 24, and milk DM using the equation from Noblet and Etienne (1989). The effects of diet composition, replicate, parity number, and their interactions on sows and litter performance were tested according to a general linear procedure analysis of variance (GLM procedure of SAS). The effect of gestation and lactation on daily feed intake was tested with a mixed linear model (Mixed procedure of SAS) for repeated measurements with diet composition and replicate as main effects. The least square means procedure (PDIFF option) was used to compare means when a significant F-value was obtained. The number of sows returning into oestrus before and after 5 d post-weaning was compared using a χ2 test (Freq procedure of SAS). Milk composition data was submitted to a linear mixed model including the effect of diet and batch as main effects. In this later model, the sow was considered as a random effect and the repeated measurement option of the mixed procedure of SAS was used with an autoregressive covariance structure to take into account the correlations between repeated measurements on the same animal. Means comparison was performed according to the Pdiff option of SAS procedure using Tukey test for contrasts. Residual values were computed from the preceding models (without the random sow effect) and residual correlations between lactating performance and mean milk composition parameters were calculated using the CORR Procedure of SAS/STAT. Milk fatty acid profile was analysed using SAS GLM procedure, considering as fixed effects the cycle, treatments, parity order and possible interactions between these parameters. Least square means were compared via Tukey test and considered significant at P<0.05.

3. Results

Average maximum and minimum temperatures and relative humidity levels measured during the experimental period were 32.6 and 19.8 ˚C, and 94.1 and 46.2%, respectively. A total of 9 sows (4 from control and 5 from virginiamycin treatments) were removed from the study due to low litter size at weaning (i.e., <9 piglets) and/or health issues. According to the experimental setup, average parity was 3.5 for the first cycle and 4.5 for the second cycle, and did not differ between treatments. No difference in gestation length nor lactation length was observed between treatments (114.5 and 22.0 d, respectively on average).

The use of virginiamycin (VM) during gestation tended to influence (P = 0.06) the total number of born and born alive when compared to control fed sows in both cycles (14.04 $vs.$ 13.22 and 13.35 $vs.$ 12.64, respectively; Table 2). Litter birth weight tended (P = 0.06) to be influenced by the use of VM in both cycles (19.0 $vs.$ 17.8 kg, respectively; Table 2). Sow body changes during lactation were influenced (P = 0.0001) by the treatments. Sows that received VM showed a lower BW loss during both lactations when compared to control sows (7.9 kg $vs.$ 9.6 kg, respectively average for both cycles; Table 2). Body protein and energy losses were also influenced by treatments, whereas sows that received VM lost less body protein mass (1.0 kg $vs.$ 1.35 kg, respectively average for both cycles; P = 0.001; Table 2) and energy (228 $vs.$ 247 kcal, respectively average for both cycles; P = 0.03; Table 2). Treatments did not influence voluntary feed intake during lactation (averaged 7.22 kg d^{-1}; P = 0.918).

Litter size (P = 0.127) and average piglet weight (P = 0.269) at 48 hours were not influenced by the treatments (13.7 and 1.42 kg, on average; Table 3). The treatments influenced (P = 0.006) the litter size at weaning, it was observed that sows receiving VM weaned more piglets when compared to the control fed sows (+0.55 piglets). There was an effect of treatment (P = 0.001) on piglet weaning weight, were sows from VM showed higher weights when compared to control (5.85 $vs.$ 5.52 kg, respectively). The litter daily gain was also influenced (P = 0.001) by the treatments were litters from VM fed sows showed a higher daily gain when compared to control sows (2.61 $vs.$ 2.24 kg d^{-1} respectively; Table 3). Average daily milk production was 17% higher (P = 0.001) in the VM sows when compared with the control (12.95 $vs.$ 11.05 kg d^{-1}; Table 3). The fatty acids composition of milk fat is presented in Table 4. Sows fed VM improved milk fatty acid profiles. An improvement in Paullinic acid (C20:1; P = 0.048), Linoleic acid (C18:2; P = 0.03) and total PUFA (Polyunsaturated fatty acids; P = 0.03) profiles were

observed in sows fed VM when compared to control fed sows. The weaning-to-insemination interval was influenced ($P =$ *0.029*; Table 2) by treatments. In both cycles the use of VM reduced the number days from weaning-to-insemination (6.4 *vs.* 7.4 d respectively for first cycle; and 6.9 *vs.* 7.4 d respectively for second cycle).

4. Discussion

In the present study, sows treated with VM increased productivity (higher litter size at births and weaning, fat content in milk also increased) and improved piglet and litter performance (higher piglet weight gains at birth and during lactation) over two consecutive cycles, thus confirming previous findings (Kyriakis et al., 1992; Kantas et al., 1998; Alexopoulos et al., 1998).

In our experiment sow weight gain during gestation increased in both cycles (+5 kg and +17.4 kg respectively for 1st and 2nd) when sows were fed VM. Similar to our findings Ilori (1984) supplementing streptomycin/ penicillin mixture and Kyriakis et al. (1992), Kantas et al. (1998) supplementing VM to sows observed that weight gain was higher during gestation when compared to control fed sows (i.e., +19.4 kg on average for both cycles). The mode of action of VM consists on impacting the microbiota of the gastrointestinal tract of the pig (Dierick et al., 1986). Reducing the population of pathogenic organisms in the foregut will allow to leave the function of the hindgut bacteria essentially intact. Therefore, changes in the intestinal microbiota could have contributed to the improvement of metabolzible energy availability, also enhancing nitrogen retention via reduction of amino acid degradation and increasing the availability of essential amino acids such lysine for body growth (Dierick et al., 1986).

Table 2 - Impact of Virginiamycin on the performance of sows during gestation and lactation over two cycles (least-square means).

Parameters	Cycle 1		Cycle 2		RSD[1]	Statistics[2]
	Control	VM*	Control	VM		
Number of sows	76	75	76	75	-	-
Parity	3.5	3.6	4.5	4.6	-	-
Body weight, kg						
After insemination	223.1	227.4	240.3	247.6	0.1	0.864
At Farrowing (net)	252.5	257.5	243.4A	260.8B	4.2	0.0001 (T)
Litter performance						
Total number born	13.37a	14.13b	13.08A	13.95B	1.85	0.06 (T)
Total number born alive	12.77a	13.35b	12.52A	13.35B	1.81	0.06 (T)
Mummies	0.18	0.21	0.19	0.14	0.67	0.646
Stillborn	0.41	0.57	0.36	0.44	0.85	0.178
Litter weight (total born), kg	18.4a	19.0b	17.7A	19.7B	2.1	0.06 (T)
Litter weight (born alive), kg	18.2	18.6	17.5A	19.4B	2.1	0.08 (T)
Piglet weight (born alive), g	1442	1437	1419	1467	434	0.532
Lactation Performance						
Sow BW loss, kg	8.8a	7.5b	10.5A	8.1B	1.3	0.0001 (T, C)
Sow BW loss, %	3.5a	2.9b	4.3A	3.2B	0.8	0.0001 (T, C)
Protein loss, kg	1.2a	1.0b	1.5A	1.1B	0.8	0.001 (T, C)
Lipid loss, kg	5.0	4.7	5.3	5.1	1.5	0.815
Energy loss, Kcal	237a	220b	257A	237B	9.0	0.03 (T, C)
Lactation ADFI**, kg d^{-1}	7.35	7.31	7.09	7.25	0.8	0.918
Interval weaning to insemination, d	8.0a	6.4b	7.4A	6.9B	2.4	0.029 (T)

[1]RSD= residual standard deviation. [2]Obtained by analysis of variance (GLM including the effects of treatment (T), cycle (C)). *VM = virginiamycin. **ADFI = average daily feed intake. Source: Authors (2018).

Table 3 - Impact of Virginiamycin on the performance of litters during lactation over two cycles (least-square means).

Parameters	Cycle 1		Cycle 2		RSD[1]	Statistics[3]
	Control	VM*	Control	VM		
Lactation, d	21.6	21.7	22.0	21.9	1.5	0.254
Litter size						
At 48 hours	13.9	13.8	13.9	13.5	0.8	0.127
At weaning	11.9a	12.4b	12.1A	12.7B	1.2	0.006 (T)
Piglet average weight, kg						
At 48 hours	1.376	1.378	1.435	1.488	0.36	0.269
At weaning	5.50a	5.97b	5.54A	5.73B	0.85	0.0001 (T)
Litter average weight, kg						
At 48 hours	19.2	19.1	19.9	20.1	1.4	0.738
At weaning	65.5a	74.0b	67.4A	72.5B	3.3	0.0001 (T)
Piglet weight gain, g d^{-1}	211a	235b	180A	195B	187	0.0001 (T, C)
Litter weight gain, kg d^{-1}	2.40a	2.82b	2.09A	2.40B	0.73	0.0001 (T)
Milk production[2], kg d^{-1}	11.8a	14.0b	10.3A	11.9B	1.7	0.001 (T, C)

[1]RSD= residual standard deviation.

[2]Daily milk production calculated considering litter weight gain (DWG), litter size, and milk dry matter content (19%) applied to the equation of Noblet and Etienne (1989). MP (kg/d) = ([0.718 × DWG − 4.9] × n. piglets)/ 0.19.

[3]Obtained by analysis of variance (GLM including the effects of treatment (T) and cycle (C).

*VM = virginiamycin.

Source: Authors (2018).

In our study sows treated during gestation with VM during both cycles increased the number of total born (+0.76 and +0.87 piglets, respectively for 1st and 2nd) and born alive (+0.58 and +0.83 piglets, respectively for 1st and 2nd). In agreement with our results, Hsu et al. (1980) feeding lincomycin and Kyriakis et al. (1992), Kantas et al. (1998) feeding VM to gestating sows also reported an increased number of piglets born alive (i.e., +0.99 piglets, on average for two cycles). Controversially to our findings, Monetti et al. (1998) supplementing sows with 40 ppm VM during two consecutive cycles did not find effects on sow productivity nor piglet performance. According the later authors, the lack of clear results in comparison to previous studies could have been due to the higher variability of the sows that were randomly assigned to their trial. Still in a similar way to the later authors, Frolich et al. (1974) evaluating the effects of seven different antibiotics, including VM, stated that there was no justification for feeding antibiotics to sows for short treatment periods (i.e., 7 wks.), being justifiable only for longer durations.

Table 4 - Impact of Virginiamycin on milk fatty acid profile of sows on d 18 of lactation over two cycles (least-square means).

Treatments/ Cycle	Control		VM*		Statistics[2]		
	1	2	1	2	RSD[1]	C	T
Number of sows	31	25	29	28			
Saturated FA, %							
C12:0	0.26	0.36	0.25	0.36	0.07	0.0001	0.259
C14:0	3.23	3.74	3.09	3.92	0.12	0.0001	0.419
C15:0	0.10	0.10	0.12	0.12	0.03	0.0424	0.434
C16:0	31.36	32.92	30.38	34.51	0.36	0.0037	0.167
C18:0	3.46	3.66	3.38	3.54	0.01	0.0001	0.860
C20:0	0.06	0.07	0.06	0.07	0.01	0.0208	0.715
Total Saturated FA	39.24	42.51	37.86	43.43	10.60	0.001	0.871
Monounsaturated FA, %							
C14:1	0.25	0.34	0.22	0.34	0.01	0.0002	0.452
C16:1	8.96	11.99	8.45	12.29	0.00	0.0002	0.608
C18:1	23.60	27.50	23.43	27.63	0.72	0.0001	0.506
C20:1	0.41A	0.17a	0.45B	0.19b	0.01	0.0006	0.040
Total MUFA	38.97	42.67	38.10	42.96	6.87	0.0001	0.607
Polyunsaturated FA, %							
C18:2	17.84A	11.13a	20.11B	11.04b	0.69	0.0001	0.030
C18:3	0.89A	0.53a	1.06B	0.48b	0.01	0.0001	0.080
C20:2	0.14	0.15	0.14	0.14	0.01	0.0001	0.439
C20:4	0.33	0.42	0.32	0.42	0.00	0.0001	0.241
Total PUFA	19.33A	12.10a	21.75B	12.38b	8.18	0.0001	0.030

[1]RSD= residual standard deviation. [2] Obtained by analysis of variance (including the effects of cycle (C) and treatment (T)). *VM = virginiamycin. Source: Authors (2018).

Treatments did not influence sow voluntary feed intake during lactation in both cycles. Nevertheless, significant improvements were observed for average daily litter weight gain (i.e., +16% on average for both cycles), average weaning weight of piglets (i.e., +6% on average for both cycles) and litters (i.e., +11% on average for both cycles) and number of weaned piglets (i.e., +0.55 piglets on average for both cycles) for the sows fed the VM. Several studies (Mayrose et al., 1962; Hsu et al., 1980; Haydon & Hale, 1988; Kyriakis et al., 1992; Kantas et al., 1998) testing different antibiotics added to the feed of the sow during lactation phase have indicated improvements in piglet and litter weight gain and higher number of weaned piglets. This improvement in litter and piglet performance could be related to reduction of pathogen pressure and/ or to the fact that the piglets benefitted from the increased milk yield and higher milk fatty acid profile of the sows fed VM. Gram-positive bacteria such as *Clostridium difficile*, that represent a risk to neonatal piglets and are present via environmental spores originated from the sows (Lobato et al., 2013), can also be controlled with the use of VM in the diet. As the metabolism of

specific Gram-positive bacteria in the foregut can be inhibited by the use of VM, an increased absorption of nutrients such as: glucose, proteins and amino acids in the small intestine can be expected, improving nutrient efficiency utilization for milk synthesis (Henderickx et al., 1981).

Sows receiving VM showed a higher daily milk production during both cycles (i.e., +17% on average for both cycles). With reference to milk production, the impact of antibiotics on this trait has been shown in several papers. Using VM, Kyriakis et al. (1992) reported that the supplementation during lactation enhanced milk yield and milk composition. In a similar way using lasalocid, Kadamanova (1984) and Haydon and Hale (1988) obtained improvements in milk production. The increase in milk yield observed across all studies could be due to the beneficial impact of reducing the impacts of detrimental microbiota and therefore, with less pathogen pressure improving metabolizible energy and amino acid availability for milk synthesis. Our hypothesis is confirmed by Kyriakis et al. (1992) that stated that the enhancement of the nutritional efficiency from using VM is mainly related to a change in the metabolic activity and efficiency of the gut microbiota, improving amino acid availability and leading to a reduced energy wastage.

Our findings are in agreement with results previously published in the literature, where more than 80% of the fatty acids in sow's milk fat is composed by palmitic (16:0), oleic (18:1) and linoleic acids (18:2) (Miller et al., 1971; Csapó et al., 1996; Gerfault et al., 1999; Silva et al., 2017). In our study, the improved growth rates of the piglets until weaning, are not only related to a higher sow milk yield, but also to an increased energy content of the milk.

According to Darragh and Moughan (1988) and Silva et al. (2017) blood triacylglycerol reflect closely most of the fatty acids found in milk, which are influenced by the dietary type of fat ingested by the sow and/or the amount of fat tissue mobilized by the sow. Nutrients such as glucose that are not absorbed in the small intestine can be fermented in the caecum and the large intestine, having as end products volatile fatty acids, which can be absorbed and redirected towards milk fatty acid synthesis. However, according to Alexopoulos et al. (1998), the use of VM does not influence the microbiota which acts on fermentation of fibre to soluble volatile fatty acids in the hindgut. Therefore, our findings regarding improvements in milk fatty acid composition could be related to a nutrient-sparing effect on energy utilization (Kyriakis et al., 1992; Kantas et al., 1998; Alexopoulos et al., 1998). Moreover, our findings indicated that the continuous use of VM throughout two consecutive parities significantly improved milk quality of sows by increasing milk C18:2, C20:1 and total PUFA content. Similar to our findings, Alexopoulos et al. (1998), Haydon ad Hale (1988), Kyriakis et al. (1992) observed significant variations in milk fatty acid composition over more than one parity. Data from the previous studies and from our research indicate that the continuous use of VM in the diet has constantly positive effects on sow's milk quality. In our study the VM treated sows showed weaning-to-insemination intervals always lower than control fed sows in both cycles. Similar to our findings, Monetti et al. (1998) and Kantas et al. (1998) also reported reduced weaning-to-estrus and weaning-to-conception intervals for sows that received VM. According to the later authors, this improvement in reproductive performance could be related to improvement of the health status promoted by the use of VM and/ or to the increase of weight condition and more specifically to the reduction of body weight loss during the lactation period.

5. Conclusion

In conclusion, our study demonstrates that the constant use of VM in the diets of sows during both gestation and lactation improves both sow and litter performance. Our results confirm that the sow can increase productivity and remain in ideal body conditions for the next parity. The higher the longevity, the more productive the sow is, this being of beneficial importance to commercial pig producers. Furthermore, additional studies are necessary to better understand the impacts of different feed additives on productive and reproductive performance of modern high producing sows.

Acknowledgements

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