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RESEARCH ARTICLE
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Enhancing Sow and Piglet Performance: Evaluation of a Probiotic Additive of *Saccharomyces boulardii* RC009 from Late Gestation through Lactation

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ABSTRACT

Nursery is a critical point in farms, involving piglets survival and growth. This study aimed to evaluate *Saccharomyces cerevisiae* var. boulardii RC009 (Sb) as a nutritional feed additive to sows and their piglets during late gestation and lactation in their productive performance. The study was conducted in three groups of 12 sows. One group received the basal diet, and the other two received a food additive of Sb during the last three weeks of gestation and all-over lactation. In the creep feeding, litter from one of the treated sow groups was administered with the same yeast food additive. Sows that received the additive had a significantly ($P<0.05$) shorter farrowing, a lower percentage of piglets with low birth weight, and less variation in birth weight. Litters from sows that consume the probiotic had a significantly ($P<0.05$) higher weight at 20 days old (5610.78±1178.1g), in comparison with litters that also consume the probiotic in the creep feeding (5270.58±999.42g) and litters from no treated sows (5079.46 ±1178.37g). Litters from the sows that did not consume the probiotic had a higher mortality rate (13.68%) during nursery as compared to litters (10, 11%, and 11.56%) from treated sows. It was concluded that the use of a probiotic additive of *Saccharomyces boulardii* RC009 in the last three weeks of gestation and during nursing had a positive impact on farrowing duration and litter performance. However, the combined administration of yeast in the sow's diet and piglet creep feeding requires more accurate studies.

Keywords: Farrowing, Nursery, Pigs, Yeast

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INTRODUCTION

Nursery is one of the stages of pig production that plays a pivotal role in determining farm efficiency. With the development of hyperprolific sows, litter sizes have increased. This development brings several benefits from a productivity perspective but also entails new challenges (Oliviero et al., 2019).

The number of stillbirths and neonatal mortality are two parameters that have been negatively impacted by the increase in litter size. Consequently, improving the health of neonatal piglets and reducing the mortality rate during the nursing stage is a current point of interest (Farmer and Edward, 2022). Although this parameter is influenced by several factors, there appears to be a close relationship between this increase and intrauterine growth restriction (IUGR), resulting in newborns with low birth weight and a lack of energy reserves that can impact survival in the hours after farrowing. Intrauterine growth restriction has also been associated with immaturity in piglets and their

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gastrointestinal system, leading to complications throughout the productive cycle (Lynegaard et al., 2020a; 2020b). Another event reported in hyperprolific sows that affects the survival of piglets is the increase in the duration of farrowing (Schoos et al., 2023). Normally, during farrowing, uterine contractions create pressure on the placenta and umbilical cord, stimulating adaptive mechanisms for the transition to extra-uterine life in the fetus. However, with the increased duration of farrowing, these repetitive and constant contractions lead to a reduction in fetal blood flow, resulting in anaerobic metabolism with lactate accumulation and a decrease in blood pH. Langendijk et al. (2018) found that when farrowing duration increased, piglets were born with varying degrees of asphyxia, and some even died in the birth canal. Asphyxiated piglets are less robust than the rest of the litter, leading to inadequate consumption of colostrum and increased susceptibility to infections.

There are numerous alternatives to improve productivity rates during the maternity period. These alternatives can be non-biological and involve the management and environment of sows, with the aim of enhancing their welfare (Zhang et al., 2020; Morgan et al., 2021; Phupaboon et al., 2024). Providing proper attention during farrowing, ensuring the piglets are dried, and promoting better colostrum consumption within the first few hours have been shown to have beneficial effects (Miguel et al., 2021). Additionally, certain nutritional strategies have been implemented in suckling piglets to enhance their performance and reduce mortality (Blavi et al., 2021). While all of these measures yield positive results, their implementation may vary depending on the operational capabilities of each farm.

Biological nutritional additives have also been used to enhance the health status of animals (Zhang et al., 2020; Ismael et al., 2022; Gul & Alsayeqh, 2023). The use of probiotics, consisting of bacteria or yeasts, in sows during gestation and throughout the lactation period has demonstrated an impact on productive parameters and modification of the microbiota in both sows and their piglets (Ma et al., 2022; Zhu et al., 2022).

Yeast-like *S. cerevisiae* var. *boulardii* has been extensively studied for its probiotic effects in different livestock animals (Magnoli et al., 2022a; Coniglio et al., 2023a; 2023b; Parada et al., 2023; Magnoli et al., 2024). In previous studies, the consumption of this microorganism by weaning pigs showed reduced toxicity of aflatoxins (Poloni et al., 2020, 2021a) and improved production (Garcia et al., 2019). Another study that used an additive formulated with *S. cerevisiae* and *K. marxianus* in weaning pigs observed a positive impact on meat quality and certain health parameters (Magnoli et al., 2022b; Fathanah et al., 2024). However, the effect of administering the same probiotic additive, not only to the sows during the last third of gestation and throughout the lactation period but also to their litters, has not been widely studied. In this context, this study aimed to evaluate the use of a probiotic additive containing *Saccharomyces boulardii* RC009 during the last three weeks of gestation and throughout the lactation period, and its effect on the performance of the sows and their litters. Additionally, the additive effect of simultaneous administration of *S. boulardii* RC009 to both sows and their litters on piglet growth was evaluated.

MATERIALS & METHODS

Ethical Approval

All the procedures of the study that involves animals, follows the regulations of the Subcommittee on Animal Bioethics under the Ethics Committee of Scientific Research, established in Resolution 376/22 of the Superior Council of the National University of Rio Cuarto.

Probiotic Microorganism

The additive used was formulated based on a strain of *Saccharomyces cerevisiae var. boulardii* RC009, isolated from pig intestine that had demonstrated probiotic effects in vitro in previous studies (Armando et al., 2011; Poloni et al., 2021b). The yeast strain was sequenced and identified by the Yeast Identification Database (www.yeast-id.com), and the information is available in GenBank. (ID #KF447149.1). The biomass was obtained by culture in Yeast-Peptone-Dextrose broth for 24h, with 1g PO_4H_2K/L, in a BioFlo 2000 fermenter (New Brunswick Scientific Co., Inc., Enfield, CT, USA) at 4×g 28°C, pH adjusted to 5, with 1.5vvm aeration.

The biomass of the yeast was cryoprotected (10% skim milk + 5% yeast extract), with ratio a 1:1, and stored at -80°C until feed formulation. Previous to feed administration, the viability of the additive was evaluated and the diets were formulated to ensure the requirements of sows as suggested by the National Research Council (2012).

Experimental Design

The study was conducted from April to June 2021 in a commercial pig farm with 2500 sows located in Santa Eufemia, Córdoba, Argentina. Three different service groups of sows over consecutive weeks (S1, S2, S3) were selected. Due to the feeding system, all sows in each batch received the same treatment: W1 (58 sows), W2 (68 sows), W3 (80 sows).

In W1, animals received the regular farm diet. It was considered the Control Group (CG), while in W2 and W3, animals received the probiotic additive *S. boulardii* RC009 incorporated into their diets ($1x10^{12}$ UFC/T feed) during the last three weeks of gestation and throughout the lactation period. They were considered treatment groups (T1G and T2G, respectively). Additionally, to assess the additive effect on piglets, the same probiotic (*S. boulardii* RC009) at the same dose ($1x10^{12}$ UFC/T feed) was included in Phase 0 (F0) of the creep feeding in W3.

To analyze the productive parameters during lactation, 12 randomly selected sows with their litters were chosen in each week of service. To add the probiotic to the food of the sows, and then to the F0 – food of the piglets, it was well mixed in a proportion of 200g/ton, as described by Parada et al. (2023).

The sows were chosen, in each group, so that the number of farrowing (F) was similar and representative of the parity of the farm (**CG:** 4 sows 1^{st} F, 3 sows 2^{nd}-3^{rd} F, 5 sows ≥ 4^{th} F; **T1G:** 1 sow 1^{st} F, 5 sows 2^{nd}-3^{rd} F, 6 sows ≥ 4^{th} F, **T2G:** 3 sows 1^{st} F, 5 sows 2^{nd}-3^{rd} F, 4 sows ≥ 4^{th} F).

Productive Parameters Determination

To assess the effect of the probiotic additive on the reproductive efficiency of sows in each group (CG, T1G, T2G), the following parameters were evaluated: farrowing duration (the time period between the birth of the 1st piglet and the birth of the last one), the number of total piglets born (TB), the number born alive (AB), and stillborn (S). For data analysis, sows in T1G and T2G were treated as a single group (TG = 24 sows).

The piglets were identified and weighed within the first 12h of birth (BW0), at 10 days (BW1), and at 20 days (BW2). In each litter, piglets weighing under 900g were recorded, and a percentage was calculated for each treatment. Additionally, the weaning weight (WW) of all piglets for each service week was assessed in groups of ten piglets.

Mortality within the first 48h of birth (NM) and during the rest of the lactation period (2 days to 24 days) (M) was recorded for each treatment.

Statistical Analysis

The data obtained was analyzed with an analysis of variance (ANOVA), with a lineal model (InfoStat, 2020). An LSD Fisher Test was used to identify statistical differences between treatments, and significant effects were considered with a P<0.05.

RESULTS

Farrowing Duration and Reproductive Parameters

The farrowing duration was significantly shorter in TG than in CG (P<0.05), but there were no differences in TB, AB, or S. The percentage of piglets with low birth weight was lower in TG but did not show a significant difference (P>0.05). The median value of neonatal mortality in CG was almost double that of TG (Table 1).

Piglet Growth

Regarding piglet growth, the weight at birth (BW0) in T1G was lower compared to T2G and CG, with a significant difference (P<0.05). There were no differences between the three groups at BW1. However, a significant difference (P<0.05) was observed at BW2, which was higher in T1G compared to T2G and CG, with no difference between the latter two (Table 2). Additionally, the weaning weight (WW) of piglets from W1 and W2 was significantly higher than the WW of piglets from W3 (Table 3).

Piglet Mortality

In terms of piglet mortality (M) from 2 days to 24 days, it was 2.25% in T1G, 5.78% in T2G, and 6.84% in CG. The total mortality throughout the entire lactation period was 10.11% in T1G, 11.56% in T2G, and 13.68% in CG.

DISCUSSION

Farrowing is a critical point in a sow's life. In the days leading up to farrowing, the sow may experience decreased feed intake due to pain and the size of the uterus, which can also lead to constipation (Pearodwong et al., 2016). These factors can result in reduced energy for uterine contractions. An issue associated with hyperprolific sows is an extended farrowing duration, which poses a risk to piglet survival. During farrowing, the uterus is continuously at work, demanding a substantial amount of energy. If the sow's energy reserves are limited, uterine contractions may weaken, resulting in prolonged farrowing (Oliviero et al., 2010; Oliveira et al., 2020).

The reduction in farrowing duration observed in sows from the GT group aligns with findings by Sun et al. (2022), who also reported a decrease in farrowing duration in sows that received an additive of *S. cerevisiae* in the five days preceding farrowing compared to non-treated sows. The authors proposed that this reduction might be linked to lower stress and constipation levels due to the probiotic action. Similar results have been observed in sows fed high-fiber diets in the days leading up to farrowing (Papatsiros et al., 2021). Probiotic administration has also shown positive effects on sow's voluntary feed intake (Tan et al., 2015; Sun et al., 2022).

Table 1: Sows parameters in the control group and treatment group

Parameters	CONTROL (n=12)				TREATMENT(n=24)				P Value
	M (Q1-Q3)	Mín	Máx	x̄±SD	M (Q1-Q3)	Mín	Máx	x̄±SD	
Farrowing duration (minutes)	320 (210-405)	40	625	317.27±161.4B	210 (135-240)	40	375	212.21±84.31A	0.016
Born alive (number of piglets)	16 (15-17)	11	19	15.83±2.12A	14.5 (14-15)	10	18	14.63±1.5A	0.06
Stillborn (%)	2.95 (0-8.33)	0	15.79	4.8±5.61A	6.46 (0-12.5)	0	23,07	6.96±7.1A	0.36
Birth Weight (kg)	1.17(1.09-1.3)	0.88	1.61	1.24±0.22A	1.25 (1.14-1.30)	0.9	1.44	1.23±0.13A	0.97
Percentage < 900-gr	15.96(6.25-21.05)	0	50	17.61±14.8A	13.81 (0-20)	0	55.56	15.19±15.52A	0.66
Neonatal Mortality (%)	6.25 (0-6.67)	0	21.43	6.72±6.78A	3.28 (0-13.33)	0	28.57	6.98±8.73A	0.93

x̄±SD values bearing different alphabets in a row differ significantly (P<0.05); M: median; Q1: first quartile; Q3: thirst quartile; Mín: minimum; Máx: maximum.

Table 2: Piglets individual weight

	CG (n=12)	T1G (n=12)	T2G (n=12)	P Value
	x̄±SD	x̄±SD	x̄±SD	
BW0 (g)	1223.9±339.9B	1157.8±274.3A	1276.9±279.5B	0.0012
BW1 (g)	3116.3±752.6A	3228.3±717.7A	3134.1±635.3A	0.3218
BW2 (g)	5079.5±1178.4A	5610.8±1178.1B	5270.6±999.4A	0.0002

x̄±SD values bearing different alphabets in a row differ significantly (P<0.05). W0: weight birth; W1: weight at 10 d; W2: weight at 20 d.

Table 3: Group weight at weaning

	W1 (n=760)	W2(n= 880)	W3 (n= 1050)	
	x̄±SD	x̄±SD	x̄±SD	P Value
Weaning weight	52.64±8.85B	54.45±7.87B	49.9±8.47A	0.009

x̄±SD values bearing different alphabets in a row differ significantly (P<0.05).

The increase in amino acids and energy levels in the diet of sows during the last gestational period has been used to enhance litter size and birth weight (Che et al., 2019). Some probiotics have also demonstrated the ability to improve nutrient digestibility (Hou et al., 2021). Lan et al. (2016) observed an increase in the apparent total tract digestibility of dry matter in weaning pigs that consume a multi-strain food additive of *Bacillus* and *Clostridium*. Considering these results, it was expected that litters from the treated group would be heavier and larger than those from the control group. However, no differences were observed. These results align with those of Han et al. (2022), who administered different strains of *Bacillus* spp. from the 85th gestational day until farrowing and did not observe differences in the number of piglets born or birth weight between treated and non-treated sows. The size of the piglets is not solely determined by the mother's feed intake but also by uterine capacity and placental irrigation (Che et al., 2017), particularly significant in hyperprolific sows due to the number of fetuses and their energy demands. Since placental formation occurs during the first month of gestation, influencing piglet growth throughout gestation, future research is needed to investigate the influence of probiotic additives on piglet birth weight when administered throughout the entire gestational period.

Although the administration of a probiotic in the third period of gestation may not be directly related to heavier piglets, it was observed that treated sows had a higher degree of litter homogeneity and a lower percentage of piglets with low birth weight. Both of these factors impact colostrum consumption, an essential factor for thermoregulation and passive immunity, directly related to piglet survival (Declerck et al. 2016; Oliviero, 2022).

Litters with homogeneous birth weights tend to exhibit reduced variation in weaning weight, as observed in this study, particularly in the reduced variation in weaning weight of piglets from sows that had received the probiotic (W2). The reduced piglet mortality within the first 48 h of life in litters from sows that consumed the probiotic is likely associated with the greater degree of litter homogeneity and the lower percentage of piglets with low birth weight in these sows. Studies have shown that a high variation in birth weight is associated with low survival rates in the nursery stage (Milligan et al., 2002; Huting et al., 2017). In addition, piglets with birth weights below 900 g have a lower chance of survival due to a lack of resources to adapt to the external environment (Opschoor et al., 2012). Furthermore, in this study, it was found that sows that received the probiotic during the last three weeks of gestation had a significant reduction in farrowing duration, which may have also influenced the survival of their offspring. The relationship between long farrowing periods and piglet survival has been demonstrated (Oliviero et al., 2010; Langendijk et al., 2018). These authors associated farrowing duration with a higher risk of piglets suffering hypoxia, especially those born during the later stages of farrowing.

The effects of probiotics and their derivatives on growth have been widely studied with varying results (Liang et al., 2021; Kang et al., 2021; Parada et al., 2023; Srifani et al., 2024). In this study, litters from T1G started with a significantly lower weight than CG and T2G but finished with the highest weaning weight. Similar results were observed by Chen et al. (2020), who administered *Saccharomyces cerevisiae* to sows in late gestation and during lactation, resulting in sows with a greater number of litter weights at weaning and a higher pre-weaning average daily gain of piglets. Gu et al. (2019) administered a *Bacillus* sp. additive to sows during lactation, also positively impacting piglet growth. They postulated that this improvement was due to higher milk production in sows that received the probiotic. In the present study, litters from sows that were administered with the probiotic additive and that also received the probiotic in the creep feeding had better results in BW2 than litters from CG but worse than the ones from T1G. These results may be related to those of Kiros et al. (2019), who administered additives with different concentrations of *S. cerevisiae* to suckling piglets, observing that litters that received the highest concentration of the yeast had the worst performance, even compared to piglets that received no treatment. A similar situation might have occurred in the present study with piglets from T2G, this group could have experienced an additive effect of the probiotic present in both the piglet's creep feeding and the lactation diet of the sows, resulting in excessively high *S. boulardii* concentrations and an imbalance in their intestinal microbiota. In the analysis of all the piglets of the service week, the WW of piglets from W3 was the lowest, underneath piglets that did not receive any food additive this can be explained by the lack of homogeneity that could exist between the sows and their litters different service groups of each week.

Conclusion

In summary, based on the results of this study, the use of a probiotic additive of *Saccharomyces boulardii* RC009 in the last three weeks of gestation and during nursing had a positive impact on farrowing duration, litter homogeneity, the percentage of piglets with low birth weight, and piglet mortality within the first 48 h of life. Additionally, better growth was observed in piglets whose mothers had consumed *S. boulardii* RC009 in their feed. However, more studies that evaluated different doses of *Saccharomyces boulardii* are necessary for the combined administration of yeast in the sow's diet and piglet creep feeding, to avoid a possible negative impact due to an additive effect of the probiotic.

Conflicts of Interest: The authors declare no conflict of interest.

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Author's Contribution: JP, MCI, LC designed the experiment. MCI, JP, LR performed the study. MCI, JL, VP, AC and LR made lab analyses. MCI, JP and LC performed statistical analyses of experimental data. MCI and JP prepared the draft of the manuscript. All authors critically revised the manuscript and approved the final version.

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