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Abstract

We studied the effects of *Saccharomyces cerevisiae boulardii* CNCM I-1079 (LSB) supplemented to lactating sows on reproductive traits and farrowing duration and to piglets from day 7 of life on post-weaning performance and IgG concentration. Ninety-six Landrace x Yorkshire sows started the trial 5 days before the expected farrowing date. Sows were distributed into 2 groups according to parity number and backfat thickness: control (CON: regular lactation diet) and LSB (CON + LSB at 2×10^9 colony forming units (CFU)/kg of feed). Seven days after birth, litters were randomly selected from each group and supplemented creep feed with or without LSB at 2×10^9 CFU/kg. At weaning, piglets from CON sows were shifted to a commercial farm and allocated to 14 pens in groups of 25 piglets/pen according to the creep feed supplemented during lactation. Piglets followed a 3-phase feeding program: creep, prestarter and starter, with or without LSB at 2×10^9 CFU/kg LSB in creep and prestarter, and 1×10^9 CFU/kg LSB in starter. The piglets were vaccinated against classical swine fever on days 41 and 72 of life. One day before each vaccination and at the end of the trial, blood samples were collected from 15 randomly selected piglets per treatment and assessed for total IgG. Supplemented sows with non-supplemented litters displayed the lowest backfat thickness loss during lactation ($p<0.05$). The LSB supplementation shortened farrowing duration ($p<0.05$) and increased feed intake ($p<0.05$) during the first week of lactation. The LSB-fed piglets were heavier at the end of creep ($p<0.05$), prestarter ($p<0.05$), and the trial ($p<0.05$); grew faster during creep ($p<0.05$), starter ($p<0.05$), and overall ($p<0.05$); and displayed an improved feed conversion ratio during creep ($p<0.05$). Total IgG content was higher at days 40 ($p<0.05$) and 71 ($p<0.05$) in LSB-fed piglets. We conclude that supplementing sows with *Saccharomyces cerevisiae boulardii* CNCM I-1079 from late gestation until weaning shortens farrowing duration, increases feed intake, and minimizes backfat losses during lactation. When supplemented to piglet diet, post-weaning performance is improved. This improvement observed could be linked to a better immune status, as suggested by the higher IgG.

Keywords: sows; weanling piglets; *Saccharomyces cerevisiae boulardii*; live yeast; farrowing duration; IgG

Introduction

From the end of gestation [1] and during lactation, sows live in a catabolic state as they are not able to meet the energy requirements of their metabolic processes (i.e., maintenance, milk production, and growth) and hence need to mobilize body reserves [2]. Therefore, any help in optimizing the utilization of nutrients is of immense importance, for example for enhanced performance of the progeny since most of the energy would be used for milk production, and during parturition, which is a process with great energy expenditures [3]. A successful farrowing implies more piglets weaned and sold [4]. Difficulties during parturition can lead to decreased milk production, which results in reduced litter performance and increased mortality during lactation [5]. A slow farrowing process leads to an increase in the proportion of stillborn piglets, and has been associated with a higher percentage of sows with high body temperature [6], which also represents an energy cost at a time when energy-saving is imperative. Colostrum production, and its intake by piglets after birth is of critical importance for their survival rate and later performance, even after weaning [7], since it is high in essential nutrients and immunoglobulins. When the piglets ingest colostrum, they uptake these compounds and, as a result, improve their immunity. Live yeast and probiotics supplementation around the time of farrowing and during lactation have proven to show positive effects on colostrum quality [8], litter performance [9], or maintenance of body reserves. More specifically, *Saccharomyces cerevisiae* var. *boulardii* CNCM-1079 (LSB) supplemented to lactating sows is reported to increase the IgG and IgA content in colostrum [10] and the average daily feed intake, thereby increasing milk production, which translates into an increased litter growth [11].

Weaning is a critical moment in the piglets' life cycle, when they are exposed to environmental, social, and nutritional changes [12]. Through nutritional means we can alleviate the weaning stress. Live yeast supplementation helps post-weaning piglets to deal with the nutritional changes. *Saccharomyces cerevisiae* var. *boulardii* has beneficial effects on immunomodulation and microbiota balance [13], with positive consequences in piglet performance. However, the effects of its supplementation in both lactation and creep feed on litter performance, as well as the impact of supplementation in the creep feed in non-supplemented sows' litters, on litter and post-weaning performance have never been investigated.

This study investigated the following effects: 1) supplementation of the live yeast LSB to sows during late gestation and lactation on farrowing duration and reproductive performance and 2) supplementation of LSB to piglets from week 1 of life until the end of weaning on post-weaning performance and IgG concentration, without the influence of the maternal dietary regime.

Materials and Methods

The experimental protocol was approved by the Ethical Committee of Guangxi Yangxiang Co., Ltd. (Ethics approval number: JN.No201805 10c1001030).

Experimental design, animals, housing, and diets

Ninety-six Landrace x Yorkshire (LY) sows of parities 3–6 (3.98 ± 1.24; mean ± SD) started the trial when they were moved to the farrowing room 5 days prior to the expected farrowing date. In total, 5 slatted-floor farrowing rooms with 28 cages each were used in the experiment. Not all the cages in each room were used as they were reserved for the foster sows. At the beginning of the trial, the sows were equally distributed into 2 groups according to the parity number and backfat thickness (BFT) (Figure 1): control (CON: regular lactation diet) and LSB (CON + LSB at 2×10^9 colony forming units (CFU)/kg of feed). The test product was Levucell SB® (Lallemand SAS, France). All the diets utilized in the trial (Table 1) were formulated according to the National Research Council recommendations [14]. There was a total of 48 replicates per treatment, as the experimental unit was the sow. Sows were fed twice a day a total of 2.8 kg/sow/day of the lactation diet in two equal meals from the beginning of the experiment until farrowing. One hour after each meal, the sows were monitored to confirm if they had consumed all the allowance. Twenty-four hours after farrowing, the litters were homogenized to 11-13 piglets. This fostering was always made between litters in the same treatment. The sows were fed ad libitum and had free access to water during the entire period of lactation. From day 7 of life, all the litters were offered a creep feed (Table 1). There were 2 different creep feeds: with or without LSB at 2×10^9 CFU/kg. The litters from each sow group were randomly selected and equally allotted to one of the creep feeds so that half of the litters were offered the supplemented creep feed, and the other half the non-supplemented one. At weaning (22.7 ± 0.68 days), piglets from CON sows were moved to a commercial post-weaning farm (Figure 1) and allocated in 14 concrete-floor pens in groups of 25 piglets/pen according to the creep feed received during lactation (Figure 1; LSB-supplemented (LSB) or non-supplemented (CON)), so that the average initial BW was as similar as possible between pens. The building was equipped with wind blowers and water curtain cooling systems to maintain the environmental temperature. The piglets followed a 3-phase feeding program (Table 1): creep, Prestarter, and starter, for 14, 16, and 25 days, respectively, with or without the LSB at 2×10^9 CFU/kg LSB in creep and prestarter feeds, and 1×10^9 CFU/kg LSB in starter feed. Creep feed supplemented in post-weaning was the same as the one supplemented during lactation (Figure 1). The piglets had free access to feed and water throughout the experimental period. The post-weaning experimental diets (Table 1) were medicated with ZnO at 3 kg/ton, 2 kg/ton, and 1.5 kg/ton in creep, prestarter, and starter, respectively. In addition, diets included 7.5 ppm of Nosiheptide and 50 ppm of Quinocetone, as well as 300 ppm of Oxytetracycline for the creep feed only.

Sampling and measurements

Body weight (BW) and BFT (Renco Lean-Meater, Renco Corporation, Minneapolis, USA) were measured at the beginning of the trial and reassessed at day 21 after farrowing. Additionally, BW was recorded 1 day after farrowing (Figure 1). Average daily feed intake (ADFI) during the period from birth to day 21 was recorded (Figure 1), as well as the number of total piglets born, born alive, stillborn, and present at day 21 were noted. The farrowing duration in minutes was measured for each sow as the difference between the time of birth of the first piglet and the expulsion of the placenta. The suckling piglets were weighed at birth, and at days 7 and 21 after farrowing (Figure 1). After weaning, piglets were weighed at the time of the distribution in the pens, during their changes in diet and at the end of the trial (Figure 1). Total feed intake per phase was measured as the difference between feed supplied and the remaining feed at the end of each feeding phase, and the ADFI was calculated accordingly (Figure 1). Average daily gain (ADG) and ADFI were utilized to determine the feed conversion ratio (FCR) per phase and overall. All the piglets were vaccinated against porcine circovirus type 2 (Wuhan Keqian Biology Co., Ltd., China) at day 25 of life (3 days after weaning), and against the classic swine fever (CSF; Wuhan Keqian Biology Co., Ltd., China) on days 41 and 72 of life (18 and 49 days after weaning, respectively), according to the suppliers' recommendations. One day before each vaccination against CSF, and at the end of the trial (day 77 of life), blood samples of 15 randomly selected piglets per treatment were collected. The piglets were bound, and blood was collected from their anterior vena cava. To obtain the serum, the blood was left for 15 minutes at environmental temperature for natural coagulation and centrifuged for 20 minutes at 3000 rpm. The serum supernatant was collected carefully and kept at -20℃ until analysis. The samples were assessed for their total IgG content by ELISA (NJJCBIO, China).

Statistical analysis

The data were analyzed using SPSS Statistics 26.0 (IBM). Prior to the analysis, all the variables were assessed for normality according to the Kolmogorov-Smirnov test. When they were normally distributed, the reproductive performance variables, BFT and BW at farrowing, as well as ADFI of sows during the first week of lactation were submitted to an analysis of variance with sow dietary treatment, room, parity and their interactions as main effects. The litter performance variables between days 7 and 21, BW and BFT at weaning, BW and BFT loss during lactation, and the ADFI of sows in weeks 2, 3, and overall were analyzed submitted to an analysis of variance and analyzed according to a 2 × 2 factorial approach with sow dietary treatment, litter diet, room, parity and their interactions as main effects. For litter size variables, the number of piglets at the beginning of the analyzed period was used as a covariate. For litter performance variables, the body weight of the litter at the beginning of the analyzed period was used as a covariate. The post-weaning piglets' performances and IgG concentration were submitted to an analysis of variance with treatment as the main effect. Alternatively, if the variables were not normally distributed, data were processed using Kruskal-Wallis non-parametric test, with treatment as the main effect. The experimental unit was the sow for lactation variables, the pen for post-weaning variables, and the piglet for IgG concentration in the blood. The variability of data is expressed as the standard error of means (SEM). For all the statistical procedures a probability value lower than 0.05 was considered significant, and a probability value between 0.05 and 0.1 was considered a trend.

Results

No dietary treatment effect was depicted on the reproductive performances (Table 2). After fostering, average litter size resulted in 12.09 and 11.96 piglets/litter for CON and LSB sows, respectively, and in 12.25, 11.91, 11.68, and 12.22 piglets/litter for CON sows with non-supplemented and supplemented litters, and LSB sows with non-supplemented and supplemented litters, respectively. At day 7, the average litter size was 12.21, 11.68, 11.32, and 12.00 piglets/litter, for CON sows with non-supplemented and supplemented litters, and LSB sows with non-supplemented and supplemented litters, respectively. Moreover, average litter weight after cross fostering was 17.86 and 17.88 kg for CON and LSB sows, respectively, and 17.90, 17.82, 17.62, and 18.13 kg for CON sows with non-supplemented and supplemented litters, and LSB sows with non-supplemented and supplemented litters, respectively. At day 7, average litter weight was 27.61, 26.63, 25.37, and 25.57 kg for CON sows with non-supplemented and supplemented litters, and LSB sows with non-supplemented and supplemented litters, respectively. We found a significant interaction (p<0.05) between sow diet and litter diet in litter weight gain during lactation, suggesting that LSB supplementation to the litters improved litter gain compared to the non-supplemented litters in the LSB sows. The LSB supplementation to sows increased the ADFI during the first week of lactation (p<0.05).

Table 2. Effect of LSB supplementation on reproductive performance and lactation feed intake of sows

Sow diet	CON		LSB		SEM	*p*-value		
Litter diet	**CON**	**LSB**	**CON**	**LSB**		**SD**	**LD**	**SD × LD**
Litter size (n)								
Total born	14.32		13.74		0.433	0.313[1]	-	-
Born alive	13.30		13.01		0.393	0.574[1]	-	-
Stillborn	1.04		0.76		0.111	0.303[2]	-	-
Stillborn (%)	6.73		5.25		0.701	0.395[2]	-	-
At day 7	11.94		11.76		0.096	0.173[3]	-	-
At day 21	10.84	10.83	10.86	11.00	0.146	0.631[4]	0.717	0.705
Litter weight (kg)								
At day 7	26.93		26.00		0.461	0.165[5]	-	-
At day 21	73.87	74.19	73.28	74.82	1.176	0.989[6]	0.576	0.713
Litter gain (kg)								
Days 0-7	9.05		8.12		0.461	0.165[1]	-	-
Days 8-21	47.33	47.65	46.75	48.24	1.176	0.989[6]	0.576	0.713
Days 0-21	56.59	56.23	54.36	58.36	1.373	0.500[6]	0.498	0.038
ADFI (kg/d)								
Week 1	4.37		4.78		0.094	0.002[1]	-	-
Week 2	6.68	6.99	6.99	6.87	0.133	0.579[7]	0.573	0.216
Week 3	7.82	7.76	7.52	7.74	0.128	0.356[7]	0.625	0.402
Overall	6.32	6.38	6.37	6.47	0.114	0.626[7]	0.591	0.880

Abbreviations: CON: Control lactation/creep feed diets; LSB: Control diet + 2 × 10^9 CFU/kg of *Saccharomyces cerevisiae* var. *boulardii* CNCM I-1079; SEM: Standard Error of the Mean; SD: sow diet; LD; litter diet; ADFI: average daily feed intake
[1]Analysis of variance (with room, parity, sow diet, and their interactions as effects; the interactions were non-significant, therefore, they were removed from the model
[2]Non-parametric test (Kruskal-Wallis) with sow diet as effect
[3]Analysis of variance (with room, parity, sow diet, and their interactions as effects; number of piglets at the beginning of the period was used as covariate); the interactions were non-significant, therefore, they were removed from the model
[4]Analysis of variance (with room, parity, sow diet, litter diet, and their interactions as effects; number of piglets at the beginning of the period was used as covariate); the interactions with room and parity were non-significant, therefore, they were removed from the model
[5]Analysis of variance (with room, parity, sow diet, and their interactions as effects; litter weight at the beginning of the period was used as covariate); the interactions were non-significant, therefore, they were removed from the model
[6]Analysis of variance (with room, parity, sow diet, litter diet, and their interactions as effects; litter weight at the beginning of the period was used as covariate); the interactions with room and parity were non-significant, therefore, they were removed from the model
[7]Analysis of variance (with room, parity, sow diet, litter diet, and their interactions as effects;); the interactions with room and parity were non-significant, therefore, they were removed from the model

At day 109, the average sow body weight was 265.10, 259.49, 257.80, and 265.43 kg for CON sows with non-supplemented and supplemented litters, and LSB sows with non-supplemented and supplemented litters, respectively. And after farrowing, it was 242.64, 238.91, 237.41, and 244.62 CON sows with non-supplemented and supplemented litters, and LSB sows with non-supplemented and supplemented litters, respectively. Average BFT at day 109 was 15.92, 15.91, 15.91, and 15.87 for CON sows with non-supplemented and supplemented litters, and LSB sows with non-supplemented and supplemented litters, respectively. There was a significant difference in BFT loss during lactation, where the supplemented sows displayed a lower loss compared to the CON sows (p<0.05); furthermore, the sows with non-supplemented litters tended to lose less BFT than the sows with supplemented litters (p<0.1). Overall, the non-supplemented litters from LSB sows displayed the lowest loss, however, there was no interaction between sow diet and litter diet (Table 3).

Table 3. Effect of LSB supplementation on body condition of sows

Sow diet	**CON**		**LSB**		**SEM**	***p*-value**		
Litter diet	**CON**	**LSB**	**CON**	**LSB**		**SD**	**LD**	**SD × LD**
Body weight (kg)								
At day 109	264.75		263.71		2.655	0.771[1]	-	-
After farrowing	243.72		243.42		2.755	0.936[1]	-	-
At day 21	237.88	236.13	236.49	239.53	3.225	0.817[2]	0.882	0.583
Loss	6.97	4.85	4.71	6.36	1.717	0.870[2]	0.918	0.414
Backfat thickness (mm)								
At day 109	16.42		16.34		0.269	0.827[1]	-	-
At day 21	15.27	15.46	16.24	15.43	0.345	0.308[2]	0.500	0.287
Loss	0.97	1.21	-0.04	0.95	0.226	0.048[2]	0.057	0.239

Abbreviations: CON: Control lactation/creep feed diets; LSB: Control diet + 2 × 10^9 CFU/kg of *Saccharomyces cerevisiae* var. *boulardii* CNCM I-1079; SEM: Standard Error of the Mean; SD: sow diet; LD; litter diet

[1]Analysis of variance (with room, parity, sow diet, and their interactions as effects); the interactions were non-significant, therefore, they were removed from the model
[2]Analysis of variance (with room, parity, sow diet, litter diet, and their interactions as effects); the interactions with room and parity were non-significant, therefore, they were removed from the model

The LSB supplementation to sows shortened the farrowing duration (*p*<0.05) by nearly 100 minutes (-27%; Table 4).The piglets began the post-weaning period with 7.60 ± 0.34 kg on average. The LSB-fed piglets displayed a heavier BW at the end of creep (Table 4; *p*<0.05), prestarter (*p*<0.05), and the trial (*p*<0.05). The ADG during creep (*p*<0.05), starter (*p*<0.05), and overall (*p*<0.05) was greater in the LSB-fed piglets; these differences were mainly due to a higher ADFI of the LSB-fed piglets: in the first 3 days (*p*<0.05), between days 4 and 7 post-weaning (p<0.05), during the first week post-weaning (*p*<0.05) and overall (*p*<0.05), and to a better immune status suggested by the higher total IgG concentration (Table 5) at days 40 (*p*<0.05) and 71 of life (*p*<0.05). Additionally, the LSB-fed piglets tended to a higher ADFI in starter (*p*<0.1). Growth and intake results translated into a better FCR of the LSB-fed piglets during creep (*p*<0.05), and a trend to a better overall FCR (*p*<0.1).

Table 4. Effect of LSB supplementation on farrowing duration and post-weaning performance

Items	CON	LSB	SEM	*p*-value[1]
Farrowing duration (min)	317.73	221.11	31.60	0.027[1]
BW (kg)				
Day 22	7.65	7.56	0.090	-
Day 36	10.82	11.31	0.042	<0.001[2]
Day 52	18.07	18.60	0.146	0.039[2]
Day 77	35.41	36.94	0.181	<0.001[2]
ADG (g/d)				
Days 22-36	230	264	2.97	<0.001[2]
Days 37-52	453	456	10.60	0.900[2]
Days 53-77	693	734	3.62	0.012[2]
Days 22-77	618	652	3.12	<0.001[2]
ADFI (g/d)				
Days 22-36	313	340	2.43	<0.001[2]
Days 37-52	740	759	14.31	0.524[2]
Days 53-77	1206	1248	10.10	0.066[2]
Days 22-77	843	874	5.43	0.016[2]
Days 22-25	136	155	4.06	0.039[2]
Days 25 29	189	234	6.33	0.005[2]
Days 22-29	166	200	2.52	<0.001[2]
FCR				
Days 22-36	1.364	1.286	0.013	0.014[2]
Days 37-52	1.637	1.668	0.017	0.396[2]
Days 53-77	1.741	1.701	0.017	0.269[2]
Days 22-77	1.615	1.586	0.007	0.054[2]

Abbreviations: CON: Control lactation/post-weaning diets; LSB: Control diet + 2×10^9 CFU/kg in lactation, creep and prestarter feeds, and 1×10^9 CFU/kg in starter feed of *Saccharomyces cerevisiae* var. *boulardii* CNCM I-1079; SEM: Standard Error of the Mean; BW: body weight; ADG: average daily gain; ADFI: average daily feed intake; FCR: feed conversion ratio
[1]Analysis of variance (with room, parity, sow diet, and their interactions as effects); the interactions were non-significant, therefore, they were removed from the model
[2]Analysis of variance (with post-weaning treatment as effect; initial body weight was used as covariate)

Table 5. Effect of LSB supplementation on total IgG concentration in post-weaning piglets´ serum

Item	CON	LSB	SEM	*p*-value[1]
IgG (mg/ml)				
Day 40	9.51	11.32	0.267	0.002
Day 71	9.57	10.88	0.277	0.027
Day 77	10.20	9.69	0.413	0.548

Abbreviations: CON: Control post-weaning diet; LSB: Control diet + 2 × 10^9 CFU/kg in creep and prestarter feeds, and 1 × 10^9 CFU/kg in starter feed of *Saccharomyces cerevisiae* var. *boulardii* CNCM I-1079; SEM: Standard Error of the Mean; IgG: immunoglobulin G

[1]Analysis of variance (with post-weaning treatment as effect)

Discussion

The first phase of the study showed the effect of the supplementation of a specific live yeast strain to sows beginning from the last days of gestation until weaning on the farrowing duration and performance from a productivity standpoint. We did not observe any effect of LSB supplementation on reproductive performance; however, the LSB supplementation shortened the farrowing duration by nearly 100 minutes. According to Oliviero et al. [15], farrowing duration is positively correlated with the BFT at farrowing. In their study, they used Finnish Yorkshire x Finnish Landrace sows, with an average BFT at farrowing of 14.5 mm (ranging from 7.5 to 24.5), which was lower compared to our observations (15.9 mm; ranging from 12 to 23), and the farrowing duration was on average 272 minutes, which was shorter but comparable to our observations (277 minutes). The differences in the relative increase of duration by unit of backfat may be due to the different genetics of the sows in both trials. However, we did not observe any difference in the BFT at farrowing between treatments, therefore the effect on the farrowing duration might be explained through other mechanisms, for instance sow comfort and well-being, which are important to alleviate maternal stress around farrowing, as stress has adverse effects on farrowing duration and offspring´s development [16]. One of the markers of sow comfort is the degree of constipation around farrowing. Oliviero et al. [15] indicated that farrowing duration was increased in sows displaying severe constipation. Indeed, live yeast supplementation helps to minimize constipation and to increase comfort, likely through the modulation of the microbiota [9]; these authors indicated that the utilization of live yeast in the sows limits constipation. Tan et al. [17] reported better constipation score at the end of gestation when the sows were fed *Saccharomyces boulardii* alone or in combination with konjac flour for two subsequent cycles. In that study, sows supplemented with *Saccharomyces boulardii* displayed the highest percentage of non-constipated sows, and the lowest percentage of sows with extremely severe constipation. Moreover, the feed intake during lactation of the second supplementation cycle was higher in the supplemented sows than in the control sows. The mechanism behind reduced constipation may be linked to higher intestinal motility [18], which could be a consequence of a better use of the dietary fiber when live yeast is supplemented. Additionally, we hypothesize that constipation, and therefore the cumulated fecal material in the hind gut, may partially block the birth canal, hence impairing and prolonging the farrowing process. The advantageous effect of the LSB supplementation on early lactation feed intake observed in our study could be connected to potentially minor constipation, since constipation reduces feed intake in lactating sows [19]. Hence, we can further hypothesize that the benefits of the LSB supplementation in reducing constipation around farrowing resulted in a better feed consumption immediately after farrowing, which keeps stimulating the sows' feeding behavior along with lactation, as illustrated by an overall greater feed intake for the LSB-fed sows. However, in our study constipation was not measured and deserves further investigation.

It might be surprising that the lowest BFT loss was observed in the non-supplemented litters from the LSB-fed sows. This could be explained keeping in view 2 possible reasons: first, the growth of these litters was numerically the lowest during lactation; and second, higher milk production can be linked to a higher backfat mobilization and a higher feed intake [20]. In our study, we could assume that the milk production of the supplemented sows with supplemented piglets was higher, as alluded by the upsurge in litter weight gain during lactation, as well as an increased backfat loss compared to supplemented sows with non-supplemented litters. In both supplemented and non-supplemented sows, the supplemented litters provoked a bigger backfat loss, although only significant in the supplemented sows. In the supplemented sows, the increased backfat loss could be explained by the numerically heavier litter weight, implying an increased milk production and body reserves mobilization. However, in the non-supplemented sows, it is possible that milk production was not enough, and they needed to mobilize body reserves. The faster farrowing process in the study may have also contributed to the conservation of body reserves of the LSB-fed sows, both during the farrowing *per se* and after the process. Indeed, Tummaruk and Sang-Gassanee [6] reported that when farrowing was prolonged, the percentage of sows with fever increased as well, and a rise in body temperature had a detrimental effect on energy expenses. Owing to a quicker farrowing, the LSB-fed sows likely spared some energy, minimizing body reserves mobilization. Thongkhuy et al. [21] found a positive correlation between BFT at the end of gestation and milk yield, and a negative correlation with backfat loss during lactation. This could imply that the more backfat at farrowing is preserved, the more the sow prioritizes the use of the body reserves for milk production, and therefore the piglets' performances during lactation are improved. Since all sows in our study showed the same BFT at farrowing, the analogous litter performance found during lactation would follow [21]'s hypothesis. However, the energy-saving operated by the LSB-fed sows could be precluding a longer-term effect on the next reproductive cycle but requires a repeated reproductive cycles study to confirm it.

Supplementing the sows with LSB implies a more efficient use of the feed through the modulation of the microbial ecosystem since it is proven to increase the relative abundance of *Fibrobacter* family in the piglets´ feces [22], using fiber for their own metabolism, releasing short chain fatty acids (SCFA) into the intestinal lumen, and leaving more energy available for the metabolism of the sow [23]. More efficient use of the energy from the feed together with the higher feed intake of the LSB-fed sows during the first week of lactation are probably the two main reasons why supplementing sows with LSB helped them to diminish backfat loss during lactation. Such observation strongly suggests improved management of the body reserves and a higher efficiency in the utilization of nutrients. In summary, the lower backfat loss observed in our study may be explained by the greater overall feed intake, the higher feed efficiency caused by LSB, and the quicker farrowing process.

The second step of the study aimed at assessing the effect of the live yeast supplementation to piglets from day 7 of life, without the influence of the maternal dietary regime on post-weaning performance. The piglets fed live yeast responded better than the non-supplemented piglets as demonstrated by their greater growth, feed intake, and feed efficiency. The faster ADG is in line with previous studies in weanling piglets fed *Saccharomyces cerevisiae* var. *boulardii* [24]. In our study, the ADG seems to be directly related to the higher ADFI especially right after weaning, as we could observe a higher ADFI in the first 3 days of study, between days 4 and 7, and as a result in the whole first week post-weaning. However, the possible hypothesis to explain a faster growth and feed intake is an increased apparent total tract digestibility of dry matter and gross energy [25], caused by a better integrity of the intestinal epithelium [24]. On one hand, higher digestibility leaves more nutrients available for growth; on the other, feed intake capacity can be earlier restored as the nutrients are absorbed leaving space in the intestinal lumen. Besides, the effects of *Saccharomyces cerevisiae* var. *boulardii* on the microbial ecosystem, leaving more energy available and suppressing harmful bacteria, might be the cause for the positive effects on the piglets' performance. Furthermore, since supplementation started from day 7 of life, piglets benefited from the live yeast for a longer period than just during the post-weaning stage.

A factor that may have helped to enhance the piglets´ performance was the environmental temperature. The upper critical temperature of a piglet varies from around 31°C at weaning until 24°C at 30 kg [26], provided they are housed on a concrete floor as in our study. The minimum and maximum temperatures inside the facilities were 28°C and 35°C, respectively. We observed increased ADG and ADFI in the LSB-fed piglets compared to CON piglets, indicating that LSB could alleviate some of the heat stress' negative impact on piglets in the late post-weaning stage, which is in line with the findings of Labussière et al. [27] in finishing pigs fed LSB.

The potential benefits of the use of live yeast in swine production result partially from the sow (transfer of IgGs from colostrum and milk [10, 28, 29], or colonization of the piglets' gastrointestinal tract from sow feces), and partially from the live yeast intake of the piglets. We found differences in the IgG concentration in piglets at days 40 and 71 of life. However, given that the sows did not receive live yeast during lactation and, therefore, could not be the agent of the immunoglobulin transfer to the piglets, the explanations lie within the piglets. One is based on piglets´ capacity to synthetize specific antibodies after vaccination when they are fed yeast products, and the other relies on their ability to produce more IgG´s [30]. These authors found that feeding recombinant yeast *Pichia pastoris* to post-weaning piglets increased plasma IgG concentration and the specific antibodies to porcine reproductive and respiratory syndrome virus. Hence, the extra synthesis would be in addition to the basal concentration. Kogan and Kocher [31] have also indicated the immunomodulatory properties of yeast compounds from *Saccharomyces cerevisiae*. In addition, the BW change of the yeast-fed piglets was bigger than that of the non-supplemented ones, which is consistent with our findings. There are no references in the literature about the effect of supplementing live yeast to weanling piglets on plasma IgG concentration; however, White et al. [32] found a higher IgG level in serum in post-weaning piglets that were fed a combination of brewer's yeast and citric acid. The fact that in our study there are no differences at day 77 could be due to the animals´ exposure to the farm environment, which contributed to the leveling of immune status over time.

Conclusion

We conclude that supplementing sows with *Saccharomyces cerevisiae* var. *boulardii* CNCM I-1079 from late gestation until weaning shortens the farrowing duration, increases feed intake of sows in the first week after farrowing, and reduces backfat thickness losses during lactation. When the same is supplemented to piglets, post-weaning growth performance is improved under these trial conditions. This improvement could be due to a better immune status, as suggested by the higher IgG concentration of the LSB-fed piglets.

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Tables and figures

Table 1. Control experimental diets composition

Items	Lactation	Creep	Prestarter	Starter
Ingredients (%)				
Corn	60.01	19.39	49.79	57.59
Extruded corn	-	19.90	10.00	-
Sorghum	10.00	-	-	15.00
Fermented soybean meal	-	9.00	5.00	3.00
Soybean meal 43	24.10	-	-	-
Soybean meal 46	-	13.90	19.30	18.96
Lecithin powder	-	1.50	0.50	-
Soy oil	1.66	1.60	1.80	0.72
Whey (low protein)	-	15.28	7.64	-
Fat powder	-	1.11	-	-
Fish meal	-	6.67	-	-
White sugar	-	2.5	-	-
Glucose	-	2.75	-	-
Lys	0.32	0.43	0.52	0.52
Met	0.06	0.29	0.23	0.18
Thr	-	0.24	0.23	0.21
Trp	-	0.08	0.07	0.05
Limestone	1.58	0.61	0.82	0.95
Monocalcium phosphate	1.11	-	-	-
Dicalcium phosphate	-	0.62	0.81	0.89
Sodium chloride	0.5	0.23	0.39	0.43
Other[1]	0.66	3.9	2.9	1.5
Calculated nutrients				
Moisture (%)	12.50	9.20	10.40	11.20
Crude protein (%)	16.20	18.10	17.90	17.10
Ash (%)	4.90	6.80	5.50	4.70
Ca (%)	0.60	0.46	0.70	0.61
Total phosphorous (%)	0.60	0.62	0.58	0.54
Av. P (%)	0.448	0.456	0.438	0.388
Salt (%)	0.49	0.78	0.63	0.50
Crude fiber (%)	2.60	2.40	2.30	2.20
Crude fat (%)	4.00	5.10	4.30	2.90
DE (kcal/kg)	3352	3454	3430	3226
ME (kcal/kg)	3217	3283	3277	3191
Lys (%)	1.05	1.35	1.30	1.20
Met (%)	0.31	0.54	0.49	0.43
Met + Cys (%)	0.59	0.81	0.78	0.70
Thr (%)	0.70	0.89	0.87	0.80
Trp (%)	0.21	0.28	0.27	0.24
Val (%)	0.75	0.90	0.89	0.80
Ile (%)	0.67	0.73	0.71	0.66
Arg (%)	1.02	0.96	1.08	1.00
SID Lys (%)	0.95	1.25	1.20	1.10
SID Met (%)	0.29	0.52	0.47	0.41
SID Met + Cys (%)	0.52	0.75	0.72	0.64
SID Thr (%)	0.61	0.81	0.78	0.72
SID Trp (%)	0.18	0.25	0.24	0.21

Abbreviations: Av: available; DE: digestible energy ; ME : metabolic energy ; SID : standardized ileal digestibility
[1]Includes minerals and vitamins: Lactation: Na (0.2%), Cl (0.16%), Mg (0.06%), K (0.2%), Cu (20 mg/kg), I (0.14 mg/kg), Fe (80 mg/kg), Mn (25 mg/kg), Se (0.15 mg/kg), Zn (100 mg/kg), Vit A (2000 IU/kg), Vit D3 (800 IU/kg), Vit E (44 IU/kg), Vit K (0.50 mg/kg), Biotin (0.20 mg/kg), Choline (1 g/kg), Folic acid (1.30 mg/kg), Niacin (10

mg/kg), Pantothenic acid (12 mg/kg), Vit B2 (3.75 mg/kg), Vit B1 (1 mg/kg), Vit B6 (1 µg/kg), Vit B12 (15 mg/kg); Creep: Na (0.4%), Cl (0.5%), Mg (0.04%), K (0.3%), Cu (6 mg/kg), I (0.14 mg/kg), Fe (100 mg/kg), Mn (4 mg/kg), Se (0.30 mg/kg), Zn (3000 mg/kg), Vit A (2200 IU/kg), Vit D3 (220 IU/kg), Vit E (16 IU/kg), Vit K (0.50 mg/kg), Biotin (0.08 mg/kg), Choline (0.60 g/kg), Folic acid (0.30 mg/kg), Niacin (30 mg/kg), Pantothenic acid (12 mg/kg), Vit B2 (4 mg/kg), Vit B1 (1.5 mg/kg), Vit B6 (7 µg/kg), Vit B12 (20 mg/kg); Prestarter: Na (0.35%), Cl (0.45%), Mg (0.04%), K (0.28%), Cu (6 mg/kg), I (0.14 mg/kg), Fe (100 mg/kg), Mn (4 mg/kg), Se (0.30 mg/kg), Zn (2000 mg/kg), Vit A (2200 IU/kg), Vit D3 (220 IU/kg), Vit E (16 IU/kg), Vit K (0.50 mg/kg), Biotin (0.05 mg/kg), Choline (0.50 g/kg), Folic acid (0.30 mg/kg), Niacin (30 mg/kg), Pantothenic acid (10 mg/kg), Vit B2 (3.50 mg/kg), Vit B1 (1 mg/kg), Vit B6 (7 µg/kg), Vit B12 (17.50 mg/kg); Starter: Na (0.28%), Cl (0.32%), Mg (0.04%), K (0.26%), Cu (5 mg/kg), I (0.14 mg/kg), Fe (100 mg/kg), Mn (3 mg/kg), Se (0.25 mg/kg), Zn (1500 mg/kg), Vit A (1750 IU/kg), Vit D3 (220 IU/kg), Vit E (11 IU/kg), Vit K (0.50 mg/kg), Biotin (0.05 mg/kg), Choline (0.40 g/kg), Folic acid (0.30 mg/kg), Niacin (30 mg/kg), Pantothenic acid (9 mg/kg), Vit B2 (3 mg/kg), Vit B1 (1 mg/kg), Vit B6 (3 µg/kg), Vit B12 (15 mg/kg)

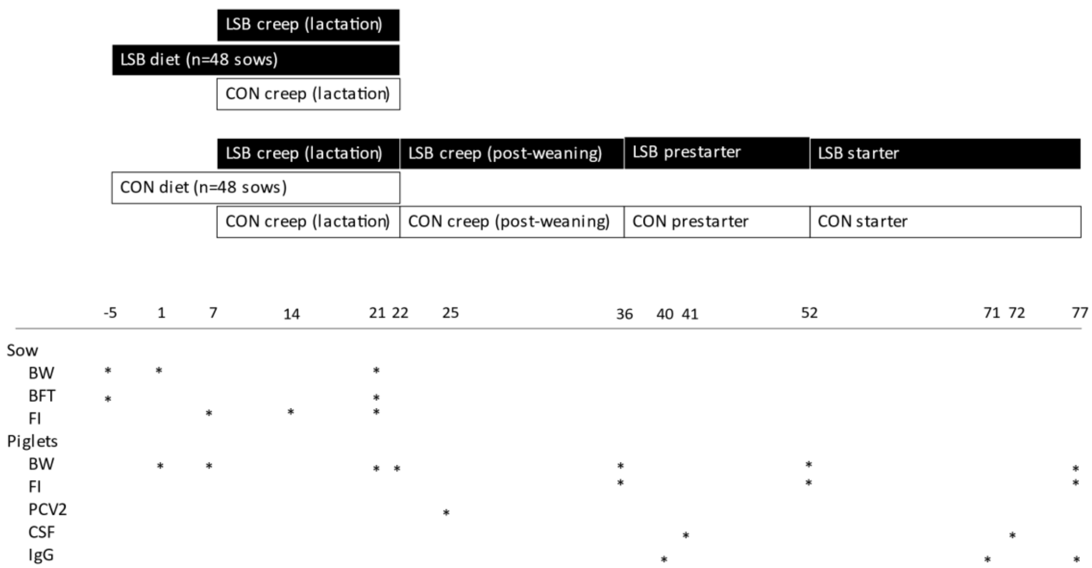

Figure 1. Schematic trial design and observations during the experimental period

Abbreviations: BW: body weight; BFT: backfat thickness; FI: feed intake; PCV2: porcine circovirus type 2; CSF: classical swine fever; IgG: immunoglobulin G