Effect of *Saccharomyces cerevisiae boulardii* on sows’ farrowing duration and reproductive performance, and weanling piglets’ performance and IgG concentration

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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 × 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 2×10⁹ 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 2×10⁹ 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, pre-starter and starter, with or without LSB at 2×10⁹ CFU/kg LSB in creep and pre-starter, and 1×10⁹ 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), pre-starter (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.
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, Immunoglobulin G

## 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 I-1079 (LSB) supplemented to lactating sows is reported to increase the IgG and IgA content in colostrum [10] and the average daily feed intake (ADFI), 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 (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) (Fig. 1): control (CON: regular lactation diet) and LSB (CON + LSB at $2 \times 10^9$ colony forming units [CFU]/kg of feed). The test product was Levucell SB® (Lallemand SAS, Blagnac, 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 $2 \times 10^9$ 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 (Fig. 1) and allocated in 14 concrete-floor pens in groups of 25 piglets/pen according to the creep feed received during lactation (Fig. 1; LSB-supplemented [LSB] or non-supplemented [CON]), so that the average initial body weight (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, pre-starter, and starter, for 14, 16, and 25 days, respectively, with or without the LSB at $2 \times 10^9$ CFU/kg LSB in creep and pre-starter feeds, and $1 \times 10^9$ CFU/kg LSB in starter feed. Creep feed supplemented in post-weaning was the same as the one supplemented during lactation (Fig. 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, pre-starter, 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.

**Fig. 1.** Schematic trial design and observations during the experimental period. LSB, control diet + $2 \times 10^9$ CFU/kg of *Saccharomyces cerevisiae* var. *boulardii* CNCM I-1079; BW, body weight; BFT, backfat thickness; FI, feed intake; PCV2, porcine circovirus type 2; CSF, classical swine fever; IgG, immunoglobulin G; CFU, colony forming units.
Table 1. Control experimental diets composition

| Items                        | Lactation | Creep  | Pre-starter | 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)                 | 3,352     | 3,454  | 3,430       | 3,226   |
| ME (kcal/kg)                 | 3,217     | 3,283  | 3,277       | 3,191   |
| 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    |

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 B1 (3.75 mg/kg); Vit B2 (1 mg/kg); Vit B3 (1 mg/kg); Vit B6 (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 (3,000 mg/kg); Vit A (2,200 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 B1 (6 mg/kg); Vit B2 (7 mg/kg); Vit B3 (20 mg/kg); Vit B6 (20 mg/kg); Pre-starter, 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 (2,000 mg/kg); Vit A (2,200 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 mg/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 (1,500 mg/kg); Vit A (1,750 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 B1 (3 mg/kg); Vit B6 (3 µg/kg); Vit B12 (15 mg/kg).

Lys, lysine; Met, methionine; Thr, threonine; Trp, tryptophane Av, available; DE, digestible energy; ME, metabolic energy; Val, valine; Ile, isoleucine; Arg, arginine; SID, standardized ileal digestibility.
Sampling and measurements

BW and BFT (Renco Lean-Meater, Renco, Minneapolis, MN, USA) were measured at the beginning of the trial and reassessed at day 21 after farrowing. Additionally, BW was recorded 1 day after farrowing (Fig. 1). ADFI during the period from birth to day 21 was recorded (Fig. 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 (Fig. 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 (Fig. 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 (Fig. 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, Wuhan, China) at day 25 of life (3 days after weaning), and against the classic swine fever (CSF; Wuhan Keqian Biology) 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 750 x g. The serum supernatant was collected carefully and kept at −20°C until analysis. The samples were assessed for their total IgG content by ELISA (NJJCBIO, Jiangsu, 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 x 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 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, the 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. 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

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

| Sow diet | CON | LSB | CON | LSB | SEM | SD | LD | SD × LD |
|----------|-----|-----|-----|-----|-----|----|----|---------|
| Litter diet |     |     |     |     |     |    |    |         |
| Total born (n) |      |     |     |     |     |    |    |         |
| Born alive |      |     |     |     |     |    |    |         |
| Stillborn |      |     |     |     |     |    |    |         |
| Stillborn (%) |      |     |     |     |     |    |    |         |
| At day 7 |      |     |     |     |     |    |    |         |
| At day 21 |      |     |     |     |     |    |    |         |

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, 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.

ADFI (kg/d)

|           | CON | LSB | CON | LSB | SEM | SD   | LD   | SD × LD |
|-----------|-----|-----|-----|-----|-----|------|------|---------|
| Week 1    |     |     |     |     |     | 4.37 | 4.78 |         |
| Week 2    |     |     |     |     |     | 6.68 | 6.99 |         |
| Week 3    |     |     |     |     |     | 7.82 | 7.76 |         |
| Overall   |     |     |     |     |     | 6.32 | 6.38 |         |

1) 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 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; litter weight at the beginning of the period was used as covariate); the interactions were non-significant, therefore, they were removed from the model.

3) 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 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; litter weight at the beginning of the period was used as covariate); the interactions were non-significant, therefore, they were removed from the model.

5) 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 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 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.

LSB, control diet + $2 \times 10^9$ CFU/kg of *Saccharomyces cerevisiae* var. *boulardii* CNCM I-1079; CON, control lactation/creep feed diets; SD, sow diet; LD, litter diet; ADFI, average daily feed intake.
Saccharomyces cerevisiae boulardii in sows and weanling piglets

during the first week of lactation ($p < 0.05$).

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).

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; $p < 0.05$), pre-starter ($p < 0.05$), 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 ($p < 0.1$).

**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

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

| Litter diet | Sow diet | CON | LSB | SEM | p-value |
|-------------|----------|-----|-----|-----|---------|
|             |          | 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 | 239.53 | 3.225 | 0.817$^1$ | 0.882 | 0.583 |
| Loss         |          | 6.97 | 4.85 | 4.71 | 6.36 | 1.717 | 0.870$^1$ | 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$^1$ | 0.500 | 0.287 |
| Loss         |          | 0.97 | 1.21 | -0.04 | 0.95 | 0.226 | 0.048$^1$ | 0.057 | 0.239 |

$^1$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.

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LSB, control diet + 2 × 10$^9$ CFU/kg of *Saccharomyces cerevisiae* var. *boulardii* CNCM I-1079; CON, control lactation/creep feed diets; SD, sow diet; LD, litter diet.
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

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

| Items                  | CON   | LSB   | SEM  | p-value  |
|------------------------|-------|-------|------|----------|
| 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) |

(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).

LSB, control diet + 2 × 10⁹ CFU/kg in lactation, creep and pre-starter feeds, and 1 × 10⁹ CFU/kg in starter feed of *Saccharomyces cerevisiae* var. *boulardii* CNCM I-1079; CON, control lactation/post-weaning diets; BW, body weight; ADG, average daily gain; ADFI, average daily feed intake; FCR, feed conversion ratio.

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

| Item          | CON   | LSB   | SEM  | p-value  |
|---------------|-------|-------|------|----------|
| 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    |

(3) Analysis of variance (with post-weaning treatment as effect).

LSB, control diet + 2 × 10⁹ CFU/kg in creep and pre-starter feeds, and 1 × 10⁹ CFU/kg in starter feed of *Saccharomyces cerevisiae* var. *boulardii* CNCM I-1079; IgG, immunoglobulin G; CON, control post-weaning diet.
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 hindgut, 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 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 increased 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 synthesize 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
Saccharomyces cerevisiae var. boulardii CNCM I-1079 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 BFT 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.

REFERENCES

1. Kim SW, Weaver AC, Shen YB, Zhao Y. Improving efficiency of sow productivity: nutrition and health. J Anim Sci Biotechnol. 2013;4:26. https://doi.org/10.1186/2049-1891-4-26
2. Leman AD. Diseases of swine. 6th ed. Ames, Iowa: Iowa State University Press; 1986.
3. Oliveira RA, Neves JS, Castro DS, Lopes SO, Santos SL, Silva SVC, et al. Supplying sows energy on the expected day of farrowing improves farrowing kinetics and newborn piglet performance in the first 24 h after birth. Animal. 2020;14:2271-6. https://doi.org/10.1017/S1751731120001317
4. Ison SH, Jarvis S, Hall SA, Ashworth CJ, Rutherford KMD. Periparturient behavior and physiology: further insight into the farrowing process for primiparous and multiparous sows. Front Vet Sci. 2018;5:122. https://doi.org/10.3389/fvets.2018.00122
5. Peltoniemi OAT, Oliviero C. Housing, management and environment during farrowing and early lactation. In: Farmer C, editor. The gestating and lactating sow. Wageningen: Wageningen Academic Publishers; 2015. p. 231-52.
6. Tummaruk P, Sang-Gassane K. Effect of farrowing duration, parity number and the type of anti-inflammatory drug on postparturient disorders in sows: a clinical study. Trop Anim Health Prod. 2013;45:1071-7. https://doi.org/10.1007/s11250-012-0315-x
7. Declerck I, Dewulf J, Sarrazin S, Maes D. Long-term effects of colostrum intake in piglet mortality and performance. J Anim Sci. 2016;94:1633-43. https://doi.org/10.2527/jas.2015-9564
8. Peng X, Yan C, Hu L, Huang Y, Fang Z, Lin Y, et al. Live yeast supplementation during late gestation and lactation affects reproductive performance, colostrum and milk composition, blood biochemical and immunological parameters of sows. Anim Nutr. 2020;6:288-92. https://doi.org/10.1016/j.aninu.2020.03.001
9. Chaucheyras-Durand F, Durand H. Probiotics in animal nutrition and health. Benef Microbes.
10. Guillou D, Chevaux E, Rosener D, Le Treut Y, Le Dividich J. Feeding live Saccharomyces cerevisiae boulardii to sows increases immunoglobulin content in colostrum and milk. J Anim Sci. 2012;90.
11. Domingos RL, Silva BAN, Bravo de Laguna F, Araujo WAG, Gonçalves MF, Rebordões FIG, et al. Saccharomyces cerevisiae var. boulardii CNCM I-1079 during late gestation and lactation improves voluntary feed intake, milk production and litter performance of mixed-parity sows in a tropical humid climate. Anim Feed Sci Technol. 2021;272:114785. https://doi.org/10.1016/j.anifeedsci.2020.114785
12. Campbell JM, Crenshaw JD, Polo J. The biological stress of early weaned piglets. J Anim Sci Biotechnol. 2013;4:19. https://doi.org/10.1186/2049-1891-4-19
13. Stier H, Bischoff S. Influence of Saccharomyces boulardii CNCM I-745 on the gut-associated immune system. Clin Exp Gastroenterol. 2016;9:269-79. https://doi.org/10.2147/CEG.S11003
14. National Research Council. Nutrient requirements of swine. Washington, DC: National Academies Press; 2012.
15. Oliviero C, Heinonen M, Valros A, Peltoniemi O. Environmental and sow-related factors affecting the duration of farrowing. Anim Reprod Sci. 2010;119:85-91. https://doi.org/10.1016/j.anireprosci.2009.12.009
16. Muns R, Nuntapaitoon M, Tummanruk P. Non-infectious causes of pre-weaning mortality in piglets. Livest Sci. 2016;184:46-57. https://doi.org/10.1016/j.livsci.2015.11.025
17. Tan CQ, Wei HK, Sun HQ, Long G, Ao JT, Jiang SW, et al. Effects of supplementing sow diets during two gestations with konjac flour and Saccharomyces cerevisiae boulardii on constipation in peripartal period, lactation feed intake and piglet performance. Anim Feed Sci Technol. 2015;210:254-62. https://doi.org/10.1016/j.anifeedsci.2015.10.013
18. Oliviero C, Kokkonen T, Heinonen M, Sankari S, Peltoniemi O. Feeding sows with high fibre diet around farrowing and early lactation: impact on intestinal activity, energy balance related parameters and litter performance. Res Vet Sci. 2009;86:314-9. https://doi.org/10.1016/j.rvsc.2008.07.007
19. Tabeling R, Schwier S, Kamphues J. Effects of different feeding and housing conditions on dry matter content and consistency of faeces in sows. J Anim Physiol Anim Nutr. 2003;87:116-21. https://doi.org/10.1046/j.1439-0396.2003.00423.x
20. Strathe AV, Bruun TS, Hansen CF. Sows with high milk production had both a high feed intake and high body mobilization. Animal. 2017;11:1913-21. https://doi.org/10.1017/S1751731117000155
21. Thongkhuy S, Chuaychu SB, Burarrnak P, Ruangjoy P, Juthamanee P, Nuntapaitoon M, et al. Effect of backfat thickness during late gestation on farrowing duration, piglet birth weight, colostrum yield, milk yield and reproductive performance of sows. Livest Sci. 2020;234:1
22. Achard C, Bravo de Laguna F, Castex M, Combes S, Agazzi A, Bontempo V, et al. Effect of Saccharomyces cerevisiae boulardii supplementation on gut microbiota in postweaning piglets in a context of antibiotics and ZnO removal. Poster session presented at Zero Zinc Summit 2019; 2019 June 17-18; Copenhagen, Denmark.
23. Jha R, Berrocoso JFD. Dietary fiber and protein fermentation in the intestine of swine and their interactive effects on gut health and on the environment: a review. Anim Feed Sci Technol. 2016;212:18-26. https://doi.org/10.1016/j.anifeedsci.2015.12.002
24. Di Giancamillo A, Bontempo V, Savoini G, Dell’Orto V, Vitari F, Domenechini C. Effects
of live yeast dietary supplementation to lactating sows and weaning piglets. Int J Probiotics Prebiotics. 2007;2:55-66.

25. Lu H, Wilcock P, Adeola O, Ajuwon KM. Effect of live yeast supplementation to gestating sows and nursery piglets on postweaning growth performance and nutrient digestibility. J Anim Sci. 2019;97:2534-40. https://doi.org/10.1093/jas/skz150

26. Muirhead MR, Alexander TJL, Carr J. Managing pig health: a reference for the farm. 2nd ed. Sheffield: 5M; 2013.

27. Labussière E, Achard C, Dubois S, Combes S, Castex M, Renaudeau D. Saccharomyces cerevisiae boulardii CNCM I-1079 supplementation in finishing male pigs helps to cope with heat stress through feeding behaviour and gut microbiota modulation. Br J Nutr. 2021;1-16. https://doi.org/10.1017/S0007114521001756

28. Jang YD, Kang KW, Piao LG, Jeong TS, Auclair E, Jonvel S, et al. Effects of live yeast supplementation to gestation and lactation diets on reproductive performance, immunological parameters and milk composition in sows. Livest Sci. 2013;152:167-73. https://doi.org/10.1016/j.livsci.2012.12.022

29. Zanello G, Meurens F, Serreau D, Chevaleyre C, Melo S, Berri M, et al. Effects of dietary yeast strains on immunoglobulin in colostrum and milk of sows. Vet Immunol Immunopathol. 2013;152:20-7. https://doi.org/10.1016/j.vetimm.2012.09.023

30. Luo G, Yang L, Liang G, Wan X, Chen C, Wang B, et al. Construction and synergistic effect of recombinant yeast co-expressing Pig IL-2/4/6 on immunity of piglets to PRRS vaccination. Procedia Vaccinol. 2015;9:66-79. https://doi.org/10.1016/j.provac.2015.05.011

31. Kogan G, Kocher A. Role of yeast cell wall polysaccharides in pig nutrition and health protection. Livest Sci. 2007;109:161-5. https://doi.org/10.1016/j.livsci.2007.01.134

32. White LA, Newman MC, Cromwell GL, Lindemann MD. Brewers dried yeast as a source of mannan oligosaccharides for weanling pigs. J Anim Sci. 2002;80:2619-28. https://doi.org/10.1093/ANSCl/80.10.2619