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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

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ABSTRACT

Under heat stress, sows reduce voluntary feed intake to reduce heat production. To improve the health and performance of sows, live yeasts have been used, and may have potential to reduce heat stress. Therefore, the present study aimed to evaluate the impact of supplementation of two levels of the live yeast *Saccharomyces cerevisiae var. boulardii* CNCM I-1079 (SB) on productive and reproductive performance of sows in tropical humid climatic conditions. A total of 300 mixed-parity sows divided into 3 treatments of 100 sows each. Sows were fed the live yeast *Saccharomyces cerevisiae var. boulardii* with a minimum concentration of 2×10^{10} colony forming units (CFU)/g viable yeast cells (LB) *on top* at the following levels of inclusion: CON - 10 g of sugar on gestation (d 90 –110) and 10 g of sugar on lactation (d110 to weaning); SB1 – 10 g of sugar +150 mg of LSB on gestation (d 90–110) and 10 g of sugar +285 mg of LSB on lactation (d110 to weaning) and SB2−10 g of sugar +300 mg of LSB on gestation (d 90–110) and 10 g of sugar +570 mg of LSB on lactation (d110 to weaning). SB improved voluntary feed intake ($P < 0.001$), milk production ($P = 0.041$) and piglet average weight at weaning ($P < 0.05$). In addition, SB2 tended to improve milk fatty acids content ($P = 0.095$) when compared to SB1 and CON. Our findings lead us to believe that the strategic use of *Saccharomyces cerevisiae var. boulardii* CNCM I-1079 during gestation and lactation has the potential to enhance sow milk production and piglet performance and weaning weight.

1. Introduction

Over the past years, pig production in tropical and subtropical countries has raised due to increased population, the consumer's

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rising income and, in some countries, availability of local feed ingredients (Delgado et al., 2001; Renaudeau et al., 2012). Although many factors can be involved, climate is still the first most limiting determinant for efficient production in these tropical and subtropical regions (Silva et al., 2018). In addition, in these regions, the impacts of heat stress can be accentuated by an elevated relative humidity (Morrison et al., 1968). Under thermal stressful conditions, sows reduce their appetite in order to reduce their heat production due to the thermic effect of feed and also reducing their milk production capacity by almost 25 % (Silva et al., 2009) as part of the process of thermal heat stress adaptation, which will impact on piglet and litter performance (Silva et al., 2018). It is also well established that heat stress can alter milk composition, reducing amino acid content and affecting negatively milk fatty acid profile (Silva et al., 2017).

Proper sow nutrition during the animal's whole productive life will not only help guarantee greater longevity but also ensure more uniform litters with more viable piglets, higher piglet birth weights and improved vitality. The supplementation of live yeast in gestation and lactation diets has been shown to improve sow health status and growth performance of piglets before weaning (Jang et al., 2013). Moreover, live yeast has been shown to enhance growth performance, nutrient digestion, and immune status of nursery pigs (Di Giancamillo et al., 2007). The establishment of a beneficial bacteria population at birth may lead to healthier piglets, which can be most effectively achieved by treating sows, providing an amplification step and enhance the neonatal pigs' environment with desirable bacterial strains (Leblois et al., 2017; Thum et al., 2012). In addition, this may be sufficient to provide a supportive, protective microbiota around the time of weaning (Kenny et al., 2011). Jurgens et al. (1997), reported that the use of dry yeast supplement during late gestation and lactation increased gamma globulin content of sows' milk and improved post weaning rate and efficiency of weight gain of pigs. In this sense, the use of live yeast could improve gut health and lactation efficiency of heat stressed sows and therefore allows piglets to benefit at weaning by improving vitality, survival rates and performance. Therefore, the present study aimed to evaluate the impact of the supplementation of different levels of a commercial live yeast probiotic (*Saccharomyces cerevisiae var. boulardii*) in diets for late gestating and lactating sows on their productive and reproductive performance under tropical humid climatic conditions.

Table 1
Composition of the experimental diets.

Ingredients (%)	Gestation	Lactation
Corn	659.82	588.92
Wheat middling	95.00	–
Soybean meal 46	210.00	345.00
Soybean oil	–	20.00
Salt	5.00	5.00
Calcium carbonate 38 %	9.00	10.00
Monocalcium phosphate 18 %	16.00	19.00
DL-Methionine 98 %	–	2.00
L-Lysine 80 %	–	3.70
L-Threonine 98 %	–	2.20
Mycotoxin adsorbent	2.00	1.00
Feed flavour[1]	0.18	0.18
Premix Vit Min[2]	3.00	3.00
Total	1,000.00	1,000.00
Analyzed composition, as fed		
ME (kcal/kg)	3122	3362
CP (%)	15.87	20.50
Ether extract (%)	3.77	7.15
CF (%)	3.55	3.29
SID Lysine, %	0.68	1.24
SID Met + Cist, %	0.50	0.79
SID Threonine, %	0.51	0.87
SID Tryptophan, %	0.15	0.20
SID Valine, %	0.67	0.85
Total available calcium (%)	0.84	0.91
Available phosphorus (%)	0.41	0.45
Sodium (%)	0.23	0.23

[1] Feed Flavour: Saccharin sodium, silicon dioxide, propylene glycol, dextrose; [2]vitamin A (1,500,000 IU / kg), vitamin D (226,667 IU / kg), vitamin E (6667 IU / kg), vitamin K3 (33,330 mg / kg), vitamin B1 (333.30 mg / kg), vitamin B2 (1167 mg / kg), vitamin B6 (416.60 mg / kg), vitamin B12 (5,333.30 mg / kg), niacin (6000 mg / kg), acid pantothenic (3,333.30 mg / kg), folic acid (400 mg / kg), biotin (32 mg / kg), manganese (8,333.30 mg / kg), zinc (18.33 g / kg), iron (13, 33 g / kg), copper (2,333.30 mg / kg), iodine (266.70 mg / kg), selenium (100 mg / kg), chelated chromium (100 mg / kg), BHT (250 mg / kg).

2. Material and methods

2.1. Animals and experimental procedure

The study was conducted in the facilities of a 2.400 sows commercial farm located in the South-eastern part of Brazil. The trial was performed during the hot and humid season from December 2016 to March of 2017.

A total of 300 mixed parity sows of a commercial genetic line (Topigs Norsvin®) from three successive batches of 100 sows each were used in this study. Within each batch, sows were distributed in a completely randomized experimental design among dietary treatments according to parity order (1st, 2nd, 3rd to 4th, > 5th parity), body weight, backfat thickness (P2) on d 90 of gestation. The sows were allocated to one of the three treatments represented by a "top dressing" supplementation of sugar and/or the commercial product during the end of the gestation and during entire lactation phase. During the experimental period (*i.e.* d 90 of gestation until 24 d lactation) sows were fed the live yeast *Saccharomyces cerevisiae var. boulardii* (Levucell® SB20) granulated free-flowing powder with a minimum concentration of 2×10^{10} colony forming units (CFU)/g viable yeast cells (LB) *on top* at the following levels of inclusion: CON - 10 g of sugar on gestation (d 90–110) and 10 g of sugar on lactation (d110 to weaning); SB1 – 10 g of sugar +150 mg of LSB on gestation (d 90–110) and 10 g of sugar +285 mg of LSB on lactation (d110 to weaning) and SB2−10 g of sugar +300 mg of LSB on gestation (d 90–110) and 10 g of sugar +570 mg of LSB on lactation (d110 to weaning). Each treatment consisted of 100 replicates, being each animal considered as an experimental unit. The sows were housed individually in gestating cages and farrowing crates with controlled access to feed and *ad libitum* water availability.

2.2. Measurements and collected parameters

The variations in ambient temperature, RH, and photoperiod followed closely the outdoor conditions. Ambient temperature and RH were continuously recorded (1 measurement every 5 min) in the barns, using a datalogger connected to a probe (Didai Tecnologia Ltda., Campinas, Brazil) placed 1 m above the floor.

On d 110 of gestation the sows were housed individually in farrowing crates with controlled access to feed and *ad libitum* water availability. From d 110 until farrowing sows were allowed 2.0 kg d^{-1} of their respective lactation feed fed twice a day (*i.e.* 1 kg at 0700 and 1 kg at 1600). After farrowing sows were then submitted to a step-up feeding regime to stimulate gradual feed intake increase up to day 7 post-farrowing, starting with 2 kg on day 1 post-farrowing and reaching 8 kg d^{-1} on day 7. After d 7 until the day prior to weaning, sows were fed *ad libitum*. Every morning, feed refusals were collected when available, and fresh feed was immediately distributed once per day between 6:30 am. and 7:30 am. Feed consumption was determined as the difference between feed allowance and the refusals collected on the next morning. The day prior to weaning (*i.e.*, d 23), sows were allowed 5 kg of feed (*i.e.*, at least 1.5 kg lower than their usual feed intake) to standardize consumption for all sows for determination of sow weight at weaning. Diets used (Table 1) were isoproteic, isoenergetic, and formulated to meet the requirements of these animal categories according Rostagno et al. (2011). Every day, samples of feed and feed refusals were Individually collected daily for DM content measurement, and successive samples were pooled and stored at 4 °C for further analyses. Feed samples were analyzed for DM, ash, fat content (AOAC, 1990) and CP (N × 6.25 for feed) according to Chemists, (1990) and for crude fiber and for cell wall components (NDF, ADF, and ADL) according to Van Soest and Wine (1967) at the Animal Nutrition Laboratory of the Federal University of Minas Gerais (Montes Claros, MG, Brazil).

Sows were weighed and backfat (P2) measured at d 90 of gestation and at farrowing. Litter size was standardized, always within the same treatment to 13–14 piglets within 48 h post farrowing. At weaning (24 d), sows were again weighed and backfat measured and moved to a breeding facility to be presented to a mature boar twice daily to detect onset of standing estrus. During this period all sows were fed 3.5 kg d^{-1} of lactation diet. The following litter parameters were collected at farrowing: total number of piglets born, born alive, stillborn, and mummies. Piglets were individually weighed using a digital scale (Líder Balanças Ltda., Mod. B150, Araçatuba, SP, Brazil) 24-h post-farrowing at the most, 48-h and at weaning to determine litter birth and weaning weights, and daily weight gain during lactation. The dead piglets (*i.e.* crushed) were also weighed during lactation in order to have a proper estimation of litter development and milk yield.

Milk samples were collected manually from all the active mammary glands on each sow, from a pre-determined subsample of 20 sows per treatment, after an intravenous injection of 10 i.u. oxytocin into an ear vein on d 18 of lactation. For that, the following protocol was applied to mimic a suckling event. Piglets were separated from the dam after first suckling in the morning and 45–50 min later the sows were milked (Silva et al., 2009). The amount of milk collected (150–200 mL) was close to the estimated milk production during one suckling between farrowing and d 20. Samples were stored at -20 °C, immediately after collection. At the end of the experiment, all samples were freeze dried and analyzed for total lipid content determined by chloroform/methanol (2:1) according to (Folch et al., 1957). Fatty acid methyl esters was prepared with 20 % boron trifluoride/methanol solution according to (Morrison and Smith, 1964)), The fatty methyl esters was separated on a gas chromatograph equipped with a SP-2330 capillary column (30 m ×0.25 mm internal diameter) with a non-bonded poly (80 % biscyanopropyl/20 % cyanopropylphenyl siloxane) stationary phase (a 0.20-μm film thickness). Furnace temperature was 180 °C, and injector and detector temperatures were 240 °C. The following fatty acid profiles were measured: saturated fatty acids (Total, C16 and C18), MUFA (Total; C16:1 and C18:1) and PUFA (Total, C18:2 and C18:3).

2.3. Calculations and statistical analyses

Daily maximum, minimum, mean, and variance of daily ambient temperatures and relative humidities were averaged for each replicate. Body protein, fat, and energy contents at farrowing and at weaning were estimated according to the equations of (Dourmad

et al., 1997). Protein, lipid, and energy losses during lactation were estimated as the difference between calculated values determined at farrowing and at weaning. Average daily milk production estimation was based on litter growth rate and size during lactation, according to the equations of (Noblet and Etienne, 1989). Data were submitted to normality tests and analysed using a mixed linear model (PROC MIXED of SAS statistical package; SAS Inst., Inc, Cary, NC; version 9.2), considering the effects of treatment, replicate, parity number, and their interactions on performance of sows and litters. The effect of lactation stage on daily feed intake was tested with a mixed linear model (MIXED procedure of SAS) for repeated measurements with diet, parity number and replicate as main effects. The least squares mean procedure (PDIFF option of SAS) was used to compare means when a significant F-value was obtained. The number of sows returning into estrus before and after 5 d post weaning were compared using a $\chi 2$ test (FREQ procedure of SAS). Milk composition data was submitted to a mixed model including the effect of diet, parity number and sow replicate as main effects. Means comparison was performed according to the Pdiff option of SAS procedure using Tukey-Krammer test for contrasts.

3. Results

Average minimum and maximum temperatures and RH levels measured during the experimental period were 23.2 and 35.2 °C, and 53.4 and 96.6 %, respectively. A total of 30 sows (10 from CON; 11 from SB1; and 9 from SB2) were removed from the study due to low litter size at birth and/or weaning (<9 piglets) and/or health problems. According to the experimental design, average parity was 3.5, and did not differ between treatments. No differences in lactation length were observed between treatments (22.4 d on average).

The treatments did not influence the total number born, mummified, stillborn, average birth weight and average litter weight at birth (Table 2). However, treatments tended to increase the number of born alive for sows treated with SB1 and SB2 ($P = 0.10$). There was no significant difference for sow body weight and backfat thickness at farrowing and at weaning. However, treatments tended to influence the body mobilization during lactation, where sows from CON showed the highest body mobilization when compared to SB1 and SB2 ($P = 0.075$). Similarly, sows treated with SB tended to have lower body chemical composition losses (lipids and energy) when compared to CON ($P = 0.067$ and $P = 0.085$, respectively; Table 3). However, the chemical composition of protein was not affected ($P = 0.163$).

Sow voluntary feed intake, was highest for SB1, followed by SB2 and finally CON (7.0 *vs.* 6.5 *vs.* 6.2 kg/ d; respectively for SB1, SB2 and CON; $P = 0.001$; Table 3). Consequently, lactation total feed intake repeated the same dynamics, with SB1 being higher than SB2 followed by CON (156.7 *vs.* 145.9 *vs.* 138.2 kg/ d; respectively for SB1, SB2 and CON; $P = 0.005$; Table 3). Sows receiving live yeast showed a higher milk yield when compared to control diet (10.6 *vs.* 11.6 *vs.* 11.4 kg/ d; respectively for CON, SB1 and SB2; $P < 0.041$). Milk fatty acids profile tended ($P < 0.10$) to differ among treatments, whereas SB2 showed a higher concentration of total (6.6 *vs.* 6.2 *vs.* 7.6 mg/ ml respectively for CON, SB1 and SB2), saturated (2.5 *vs.* 2.4 *vs.* 2.9 mg/ ml respectively for CON, SB1 and SB2), monounsaturated (2.6 *vs.* 2.4 *vs.* 2.9 mg/ ml respectively for CON, SB1 and SB2), polyunsaturated (1.5 *vs.* 1.4 *vs.* 1.7 mg/ ml respectively for CON, SB1 and SB2) and unsaturated (4.2 *vs.* 3.8 *vs.* 4.8 mg/ ml respectively for CON, SB1 and SB2) fatty acids when compared to the control and SB1 treatments (Tables 4 and 5). No influence of the treatments on the weaning-estrus interval was observed ($P = 0.111$; Table 3).

Regarding piglets' performance, there was no statistical difference for litter size, and weight equalized at 48 h ($P > 0.10$; Table 4). However, treatments influenced piglet weight at 14 d ($P = 0.05$) and weaning ($P = 0.001$). The diets containing live yeast showed higher values than the control treatment (3.99 *vs.* 4.10 *vs.* 4.22 kg, respectively for CON, SB1 and SB2 at 14 d; and 5.88 *vs.* 6.30 *vs.* 6.46 kg, respectively for CON, SB1 and SB2 at weaning; Table 4). Similarly, the average daily weight gains of the piglets also differed statistically (218 *vs.* 236 *vs.* 245 g/ d, respectively for CON, SB1 and SB2; $P = 0.021$). The use of live yeast also improved litter daily weight gain (2.50 *vs.* 2.78 *vs.* 2.86 kg/ d; respectively for CON, SB1 and SB2; $P < 0.015$).

4. Discussion

Farrowing is a challenging phase in pig production for both, sows and piglets. Yeast-based products have been used in agriculture as

Table 2
The effects of *Saccharomyces Cerevisiae var. Boulardii* CNCM I-1079 in late gestation on sow performance at farrowing (LS means).

Parameters	CON[3]	SB1[4]	SB2[5]	RSD[1]	P value[2]
Number of sows	90	89	91	–	
Parity	3.6	3.5	3.4	–	
Total Number born, n	14.21	14.44	14.70	1.01	0.326
Total Number born alive, n	13.37	13.87	14.10	1.00	T (0.100)
Mummies, n	0.12	0.06	0.09	0.44	0.632
Stillborn, n	0.71	0.58	0.50	0.66	0.366
Average piglet birth weight, kg	1.314	1.325	1.324	0.29	0.117
Average litter birth weight, kg	17.50	18.30	18.55	1.24	0.262

[4]SB1 – 10 g of sugar +150 mg of LSB on gestation (d 90 –110) and 10 g of sugar +285 mg of LSB on lactation (d110 to weaning) and [5]SB2 - –10 g of sugar +300 mg of LSB on gestation (d 90–110) and 10 g of sugar +570 mg of LSB on lactation (d110 to weaning).

[1] RSD = residual standard deviation.

[2] Obtained by analysis of variance (including the effects of parity (P), treatment (T), and sow replicate (G) and their interactions).

[3] CON - 10 g of sugar on gestation (d 90 –110) and 10 g of sugar on lactation (d110 to weaning).

Table 3
The effects of *Saccharomyces Cerevisiae var. Boulardii* CNCM I-1079 in late gestation and lactation on sowperformance (LS means).

Parameters	CON[5]	SB1[6]	SB2[7]	RSD[1]	P value[2]
Number of sows	90	89	91	–	
Parity	3.6	3.5	3.4	–	
Lactation duration, d	22.2	22.3	22.4	0.8	0.480
ADFI (d 1until weaning), kg d^{-1}	6.20c	7.00a	6.49b	0.65	T (0.001)
Total feed intake (d 1until weaning), kg	138.2c	156.7a	145.9b	3.5	T (0.005)
Body weight, kg					
At farrowing	235.9	229.8	234.3	6.2	0.121
At weaning	215.4	222.0	222.9	8.7	0.131
Weight variation	−20.5	−7.8	−11.4	3.7	0.075
Backfat thickness, mm					
At farrowing	17.1	17.3	17.0	1.3	0.868
At weaning	14.8	15.1	14.2	1.2	0.176
Back thickness variation	−2.3	−2.2	−3.0	1.0	0.192
Chemical composition of body loss[3]					
Protein, kg	−4.74	−2.75	−2.64	2.07	0.163
Lipids, kg	−7.17	−5.63	−5.02	1.76	0.067
Energy, MJ	−364	−272	−246	13	0.085
Body change, %	−8.6	−3.4	−4.8	2.4	0.123
Weaning-to-estrus interval, d	4.9	4.8	4.4	0.5	0.111

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

[1] RSD = residual standard deviation.

[2] Obtained by analysis of variance (including the effects of parity (P), treatment (T), and sow replicate (G)).

[3] Calculated based on the equations of Dourmad et al. (1997).

[5] CON - 10 g of sugar on gestation (d 90–110) and 10 g of sugar on lactation (d110 to weaning); [6]SB1 – 10 g of sugar +150 mg of LSB on gestation (d 90–110) and 10 g of sugar +285 mg of LSB on lactation (d110 to weaning) and [7]SB2−10 g of sugar +300 mg of LSB on gestation (d 90–110) and 10 g of sugar +570 mg of LSB on lactation (d110 to weaning).

Table 4
The effects of *Saccharomyces Cerevisiae var. Boulardii* CNCM I-1079 in late gestation and lactation on litter performance (LS means).

Parameters	CON[3]	SB1[4]	SB2[5]	RSD[1]	P value[2]
Number of sows	90	89	91	–	
Parity	3.6	3.5	3.4	–	
Lactation duration, d	22.2	22.3	22.4	0.8	0.480
Litter size					
At 48 h equalized	12.6	12.6	12.6	0.7	0.802
At d 14	11.5	11.8	11.7	0.7	0.348
At weaning	11.4	11.5	11.6	0.7	0.515
Piglet average weight, kg					
At 48 h equalized	1.52	1.58	1.56	0.38	0.107
At d 14	3.99a	4.10b	4.22c	0.11	T (0.050)
At weaning	5.88a	6.30b	6.46c	0.42	T (0.001)
Piglet weight gain, g d^{-1}	218a	236b	245c	6	T (0.021)
Litter weight gain, kg d^{-1}	2.50b	2.78a	2.86a	0.05	T (0.015)
Milk production[6], kg d^{-1}	10.6b	11.6a	11.4a	1.1	T (0.041)

[1] RSD = residual standard deviation.

[2] Obtained by analysis of variance (including the effects of parity (P), treatment (T), and sow replicate (G)).

[3] CON - 10 g of sugar on gestation (d 90–110) and 10 g of sugar on lactation (d110 to weaning); [4]SB1 – 10 g of sugar +150 mg of LSB on gestation (d 90–110) and 10 g of sugar +285 mg of LSB on lactation (d110 to weaning) and [5]SB2−10 g of sugar +300 mg of LSB on gestation (d 90–110) and 10 g of sugar +570 mg of LSB on lactation (d110 to weaning).

gut and immunity-modulating agents, mitigating the effects of production stress (Broadway et al., 2015). In our study, it was observed that sows treated with SB improved lactation performance (daily feed intake, total feed intake, increased milk production, tendency to reduce weight loss, energy and lipid content in body composition). It was also observed better performance of piglets (weaning weight, daily weight gains and sow milk yield). Similar to our findings, Kim et al. (2008) evaluating the use of live yeast (*Saccharomyces cerevisiae*) for sows also reported improvements in sow and litter performance traits.

Treatments tended to increase the number of born alive (+0.5 and +0.73 for SB1 and SB2 treatments respectively). This observed improvement in the number of born alive could be related to the fact that the use of live yeast can reduce the duration of the farrowing process (Zhang et al., 2020). Piglet vitality is an important aspect for post-farrowing survival rates, and is correlated with the easiness of the farrowing process. Treut et al. (2012) studying the use of SB for sows during late gestation reported that the piglets from SB-fed sows showed a higher vitality score and consequently a higher survival rate, resulting in more piglets born alive. Still, these same authors reported that piglet birth weight was not influenced by the treatments.

Table 5
Effects of *Saccharomyces Cerevisiae var. Boulardii* CNCM I-1079 in late gestation and lactation on milk fatty acid profile of sows on d 18 of lactation (LS means).

Treatments Number of sows	CON[2] 20	SB1[3] 20	SB2[4] 20	RSD[1]	P value
Fatty acids (FA), mg/mL	6.69	6.22	7.63	0.9	T (0.095)
Saturated FA					
Total, mg/mL	2.51	2.42	2.90	0.4	T (0.093)
Monounsaturated FA					
Total, mg/mL	2.62	2.38	2.98	0.5	T (0.094)
Polyunsaturated FA					
Total, mg/mL	1.56	1.42	1.75	0.4	T (0.085)
Unsaturated FA					
Total, mg/mL	4.22	3.81	4.81	0.6	T (0.097)

[1] RSD = residual standard deviation. [2] Obtained by analysis of variance (including the effects of parity (P), treatment (T), and sow replicate (G)).
[2] CON - 10 g of sugar on gestation (d 90–110) and 10 g of sugar on lactation (d110 to weaning); [3]SB1 – 10 g of sugar +150 mg of LSB on gestation (d 90–110) and 10 g of sugar +285 mg of LSB on lactation (d110 to weaning) and [4]SB2−10 g of sugar +300 mg of LSB on gestation (d 90–110) and 10 g of sugar +570 mg of LSB on lactation (d110 to weaning).

Different from the previous findings, Jurgens et al. (1997) that evaluated the inclusion of live yeast (*Saccharomyces cerevisiae*) in diets for sows during gestation and lactation did not observe a significant difference in the number of piglets born alive. Similarly, Zanello et al. (2013) evaluating the inclusion of *Saccharomyces cerevisiae and Saccharomyces cerevisiae var. boulardii (SB)* from 86 days of gestation to 18 days of lactation, also reported that the inclusion of different levels of SB in diets for sows did not influence the number of piglets born alive. The differences between our findings and Jurgens et al. (1997) could be due to the fact that the later authors used a low number of sows per treatment (*i.e.*, 10) and also the live yeast strains were different. As for the difference between Zanello et al. (2013) and our findings, this can also be related to the fact that these authors used a small number of sows per treatment (*i.e.*, 4 sows) in their study compared to ours (*i.e.*, 100 sows per treatment).

The use of SB improved sow voluntary daily feed intake (+13 % and +5% for SB1 and SB2 treatments, respectively) and total feed intake during lactation (+18.5 kg and +7.7 kg for SB1 and SB2 treatments, respectively) when compared to control fed sows. In agreement to our findings, Tan et al. (2015) also observed that the supplementation of *Saccharomyces cerevisiae boulardii (SB)* to lactating sows also improved voluntary feed intake (+10 %) in comparison to the control. In our study, when compared among SB fed treatments, sows fed SB1 showed a higher daily feed intake (+7.8 %) and total intake (+10.8 kg) when compared to SB2. Corroborating our findings, Jang et al. (2013) also observed a numerical reduction in voluntary feed intake when sows received a higher dosage of live yeast (*Saccharomyces cerevisiae* Sc47). One may infer that using dietary live yeast "top dressing" could have an impact on diet palatability and therefore reduced voluntary feed intake at a higher level of inclusion. In contrast to the previous studies, Kim et al. (2010 and 2008) and Shen et al. (2011) reported that supplementing live yeast (*Saccharomyces cerevisiae)* in diets for sows did not influence the voluntary feed intake during lactation. The differences observed between studies can be related to the different live yeast strains used in our study and the later authors.

During our study, the environmental temperatures remained above the thermoneutral zone for sows (*i.e.* 18–20 °C; Quiniou and Noblet, 1999), thus indicating that our animals were exposed to heat stress during the experiment. When under heat stress, lactating sows will reduce productive performance (Prunier et al., 1997; Silva et al., 2009; Renaudeau et al., 2012) and become more susceptible to a stressed immune system (Morrow-Tesch et al., 1994). He et al. (2019) stated that late gestational heat stress can cause profound changes in the gut microbial composition, especially in the abundance and diversity of some SCFAs (short chain fatty acids) producing species. These bacteria will alter the SCFA formation and nitrogen degradation and therefore influence the gut homeostasis and inflammatory response. Sow performance under challenging climatic conditions may be affected in part by altered gut microbiota and metabolism, which may further affect piglet gut microbiota and immune response. According to several authors (Broadway et al., 2015; White et al., 2002) the ingestion of live yeast could improve the production of cytokines, reduce the colonization of pathogenic bacteria throughout the gastrointestinal tract and improve the health status, therefore reducing the effects caused by heat stress and reflecting in an increased voluntary feed intake and nutrient absorption.

As a consequence of the improved voluntary feed intake among live yeast treated animals, sows from SB in our study tended to reduce body weight loss during lactation when compared to the control treatment. Similarly, Di Giancamillo et al. (2007) also observed that the supplementation of live yeast (*Saccharomyces cerevisiae* ssp. *Boulardii* SB - CNCM I-1079) reduced body weight loss in lactating sows, but without a significant difference on voluntary feed intake. Our findings can be directly correlated not only with the higher voluntary feed intake of the SB treated sows, which reached nutrient demands for productivity from an increased feed intake, but possibly from an enhanced nutrient absorption due to microbiota modulation promoted by the live yeast. In agreement with our statement, Shen et al. (2011) reported that the beneficial effects of the use of live yeast for lactating sows can come from the improvement in health and metabolism rather than from an increase in voluntary feed consumption alone.

An increase in milk production (+9% and +7.5 % for SB1 and SB2, respectively) was also observed for sows treated with live yeast. Similar to our findings Kim et al. (2008), also reported that sows fed live yeast increased milk production. Several studies have shown

that diets containing live yeast derivatives were associated with an increase of beneficial microbiota (Hasan et al., 2018; Liu et al., 2008; Rekiel et al., 2007; White et al., 2002), contributing to an increased SCFAs production (Hasan et al., 2018; Nochta et al., 2010) reflecting in a higher availability of energy for the production of colostrum (Hasan et al., 2018) and improvement of the milk yield. In addition, to the observed increase in milk production, milk fatty acid profile was higher in the SB2 treated sows. Indicating that the higher level of inclusion (SB2) improved nutrient availability for milk synthesis *via* enhancement of microbiota as these sows showed a lower feed intake when compared to SB1. Similar to our findings, Peng et al. (2020) feeding *Saccharomyces cerevisiae* (strain CNCM I-4407) to lactating sows also reported an improvement in milk total fatty acid composition.

In our study, the inclusion of live yeast improved the daily weight gain of the piglets (+18 g and +27 g) which reflected in the increased piglet weight at 14 days (+110 g and +230 g) and at weaning (+420 g and +580 g) for the SB1 and SB2 sows respectively. The increased sow milk yield and improvement of milk composition due to the supplementation of SB, reflected on the higher litter weight gain and piglet weaning weight. It is well established that the increase in sows milk production and piglets milk consumption are highly correlated with the daily weight gain of the piglets (Strathe et al., 2017), therefore corroborating the results in our study. In conclusion, our findings lead us to believe that the strategic use during lactation of *Saccharomyces cerevisiae var. boulardii* can be a viable strategy to increase the sows' voluntary feed intake and benefit milk production and as a consequence improve litter performance under tropical humid climatic conditions.

Authorship statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication before its appearance in the *Animal Feed Science and Technology Journal*.

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Ethics statement

All methods involving animal handling were realized in accordance with the regulations approved by the Institutional Animal Welfare and Ethics/Protection committee from the Universidade Federal de Minas Gerais (UFMG – CETEA), Brazil under the protocol n°. 107/2016.

Software and data repository resources

Data and models used in this study are not applicable for deposition in an official repository

Declaration of Competing Interest

The authors declare no conflict of interest.

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