



## ANIMAL SCIENCE

# Different protocols for piglet creep feeding in the farrowing stage and residual effects in the nursery phase

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**Abstract:** This study was aimed at the effects of different Creep-feeding protocols on piglet performance and its residual effects during the nursery phase. Experimental design used was five groups: WC (without creep); DCF (dry creep feeding); WCF (wet creep feeding); LD (additional liquid creep with automatic feed dispenser plus DCF); and LLF (additional liquid creep with linear feeder plus DCF). Ten litters per treatment were selected a total 50 sows and 645 piglets. During the first two weeks of lactation, the LD treatment (2.61 and 4.20 kg) promoted greater body weight ( $P < 0.001$ ) than the DCF (2.55 and 3.93 kg), (WFS) (2.43 and 3.69 kg) and LLF (2.50 and 4.00 kg) treatments, but did not differ from the WC treatment (2.68 and 4.09 kg). At weaning, the WC (5.22 kg), LD (5.32 kg) and LLF (5.27 kg) treatments gave higher body weights ( $P < 0.001$ ) when compared to the DCF (4.97 kg) and WCF (4.69 kg) treatments. We concluded that there was no change in the behavior of the piglets, and the use of dry feed with liquid supplements did not improve weight gain. The different creep feeding systems did not influence the weight and performance of the piglets in the nursery phase.

**Key words:** behavior, feeder, litter, piglet handling.

## INTRODUCTION

Modern pig breeds, selected for high fertility, tend to produce piglets with lower average birth weight, increased competition between animals during the lactation period, and increased variation in birth weight and weaning weight (Quesnel et al. 2008, Zotti et al. 2017). Light piglets are those less than 800 grams, even if they come from healthy females, and are usually the result of a lower supply of nutrients received during pregnancy, with smaller internal organs, characteristics that resemble premature piglets; this makes it difficult for them to adapt to the farm environment and favors the occurrence of diseases (Baxter et al. 2008, Panzardi et al. 2013).

As a result, they have lower body reserves, take longer to start the first feeding, and

increase the labor associated with raising the piglet. Hales et al. (2013) observed that the lower the piglet's birth weight, the greater the chances of death from crushing or malnutrition in the first hours. Piglets with signs of limited intrauterine growth had approximately 1.8 times greater risk of death than did normal-looking piglets. Another factor is that 20% to 25% of the variation in the weight of piglets in their life is related to birth weight, which in turn affects the homogeneity of the flock leading up to slaughter (López-Vergé et al. 2018).

Liquid supplementation can reduce this phenomenon, because, as a hypothesis, the greater intake of nutrients in the lactation phase (via supplementation) may decrease competition among piglets and result in a

higher average weight at weaning (Azain et al. 1996, Novotni-Dankó et al. 2015). Douglas et al. (2014) used liquid supplementation for piglets and observed a reduction in the weight variation of the supplemented litter, however, without effects on weight gain or mortality.

Additionally, the shape of the feeder can influence feed consumption as well as waste. In a study in which a supplement was made available for piglets between 18 and 21 days of age in three different types of feeders (tray feeder, circular feeder or circular feeder with a rotating ring) Sulabo et al. (2010) found that the circular feeder with a rotating rim provided greater feed consumption than the others, in addition to minimizing waste and reducing feed contamination by insects.

In addition to the nutritional benefits, the piglet's previous experience of feeding in feeders may, after weaning, favor greater feed consumption, decrease nutritional diarrhea, and improve their welfare; nevertheless, these phenomena have not been explored in previous studies. Our hypothesis is that the supplementation of piglets with dry feed and liquid supplementation of a milk substitute would promote greater weight gains during the maternity phase and would promote performance during the post-weaning phase. Therefore, we studied the effects of supplementation during the lactation phase, using various nutritional strategies and feeders on weight gain, pre-weaning consumption, litter homogeneity, behavior, and subsequent performance during the nursery phase.

## MATERIALS AND METHODS

The experiment was approved by the Research Ethics Committee with the Use of Animals (CEUA) of the State University of Santa Catarina – (UDESC) - (CEUA nº 5791221118, 12/12/2018).

## Farrowing housing

The test was carried out in a commercial piglet production unit located in the municipality of Abelardo Luz in the west of Santa Catarina - Brazil. The maternity rooms (with canvas lining) used were provided with 20 farrowing crate/room, with an area of 0.6 x 2.2 m for the sow and additional side areas of 0.4 x 2.2 m. The farrowing crate included floors of fully suspended iron bars, equipped with trough type feeders for the sow (manual feeding four times a day), a nipple with a minimum flow of 3 L/min. for the mother, two nipples for the piglets (minimum flow rate of 0.5 L/min), and a creep with a useful area of 0.64 m<sup>2</sup> (provided with heated floors). To help control temperature, curtains were used.

The work began in January 2019 and extended to the end of March 2019, comprising the maternity and nursery phases. The maternity and nursery facilities were equipped with a thermo hygrometer datalogger model HT-500 (collections between 30 m). In the farrowing step register dry bulb temperature (DBT) 26.1 ± 3.4°C. and relative humidity (RH) 70.1 ± 9.8%. In the nursery phase 1<sup>st</sup> step (1-7days) register 24.3 ± 3.5°C. and 70.3 ± 8.3%; 2<sup>nd</sup> step (8-20 days) 23.1±3.0°C. and 76.5±8.3%; 3<sup>rd</sup> step (21-36 days) 23.3±3.1 and 73.8±10.9% and last step (37-47 days) 22.9±2.6°C. and 78.5± 6.8% for DBT and RH, respectively.

## Treatments

Two sequential tests were carried out: 1<sup>st</sup> carried out in the maternity phase in which the consumption of liquid and feed supplement, weight gain, uniformity of piglets, and serum variables were evaluated. In the 2<sup>nd</sup> test, we measured performance, behavior, and serum variables in the post-weaning (nursery phase) of piglets from the 1<sup>st</sup> experiment.

The experimental design used was completely randomized with five treatments: WC

(without creep) without supplementation; dry creep feeding (DCF), dry food supplementation from the 7<sup>th</sup> day to the 21<sup>st</sup> day; wet creep feed (WCF) supplementation with moist feed (2x/day) from the 7<sup>th</sup> day to the 21<sup>st</sup> day; liquid dispenser (LD) additional liquid creep with automatic feed dispenser from the 2<sup>nd</sup> day to the 14<sup>th</sup> day in a dispenser-type feeder; and liquid linear feeder (LLF), additional liquid creep with linear feeder from the 2<sup>nd</sup> day to the 14<sup>th</sup> day in gutter feeders.

Piglets were individually identified by tattooing in accordance with the practice adopted at the farm. The experimental group received creep feeding substitute (4.204 kcal.kg<sup>-1</sup> of metabolizable energy (ME), 185.0 g.kg<sup>-1</sup> Crude protein (CP), 961.5 g.kg<sup>-1</sup> Dry matter (DM), 145.0 g.kg<sup>-1</sup> Crude fiber (CF), 96.8 g.kg<sup>-1</sup> Ash (A) and 480.0 g.kg<sup>-1</sup> lactose) reconstituted to 1:7 (substitute: water), a value close to that recommended by Novotni-Dankó et al. (2015), in warm water (45 to 50 °C), and provided twice a day (morning and afternoon), with a dispenser-type feeder or linear feeder from the 2<sup>nd</sup> day of life until the 14<sup>th</sup> day of life.

From the 7<sup>th</sup> day, a specific creep feed for the phase (4.206 kcal/kg of gross energy, 221.4 g.kg<sup>-1</sup> CP, 941.1 g.kg<sup>-1</sup> DM, 60.9 g.kg<sup>-1</sup> CF and 68.1 g.kg<sup>-1</sup> A) was provided to the piglets of the treatments DCF, WCF, LD, LLF once a day. The other handling sows and piglets followed the farm's protocols with weaning at 21 days. The survival rate of piglets in the first and second weeks and at weaning was calculated according to ((total number of piglets - (dead and Culling pigs)) / total number of piglets \* 100).

Two types of feeders were used to supply the creep feeding and approximately 40% of creep feeding crude fat content comes from refined coconut oil, high levels of whey protein, lactose, and Imagro® (galactooligosaccharides, probiotics and organic acids), all of which may have helped the piglets gain weight. The

first type of dispenser (liquid dispenser, (LD) additional liquid creep with automatic feed dispenser plus DCF) and the second type of feeder (LLF), additional liquid creep with linear feeder plus DCF). The dispenser feed type had a storage location that prevented contamination with dust, waste, flies, or other foreign materials, and a self-supply system that released the liquid according to consumption to reduce the work with cleaning and refilling the equipment. Cleaning was performed daily with acid detergent to help remove fat, with water at 60 °C.

### Sows and litter handling

The farm worked in batch farrowing; that is, every 15 days, there were an average of 110 farrowing, 50 sows (10 /treatment) were selected (between the 1<sup>st</sup> and 6<sup>th</sup> farrowing). The cross fostering performed until the 2<sup>nd</sup> day of life according to farm protocol.

The sows were transferred to maternity with 105 days of gestation. Adjustments were made to the temperature of the creep, preparation of fomites to aid in farrowing and decreased sows feeding. After delivery, the sow feeding was increased daily (0.5 kg) until the 7<sup>th</sup> day when the feed was provided ad libitum two times per day. The sows' diets based on corn and soybean meal (4.311 kcal/kg of gross energy, 194.5 g.kg<sup>-1</sup> Crude Protein (CP), 911.6 g.kg<sup>-1</sup> Dry Matter (DM), 71.5 g.kg<sup>-1</sup> Crude Fat (CF) and 60.3 g.kg<sup>-1</sup> Ash (A)) following the nutritional program established by the farm's technical team. The usual farm procedure for piglets included a 1-mL parenteral iron dextran on the 3<sup>rd</sup> day, administration of coccidiostatic drugs, 1 mL per pig orally at birth, caudectomy, and identification of the piglets with a tattoo, up to the 3<sup>rd</sup> day after birth.

### Farrowing stage

Individual body weight was recorded at birth and at 7, 14, and 21 days of age. The intake of

Creep-feeding was recorded at each supply along with the replacement of the supplement (morning or afternoon). Dry feed consumption was recorded, and its leftovers accounted for the calculation of feed consumption.

Blood samples were collected from two male piglets per litter (approximately 5 mL) obtained by puncture of the anterior vena cava at the time of weighing. The number was defined to allow good sampling and to minimize additional handling. The samples were placed in Vacutainer tubes with coagulation activator for later obtaining of the serum that was stored in microtubes at  $-20\text{ }^{\circ}\text{C}$ , for later analysis.

The serum concentrations of aspartate aminotransferase (AST), albumin, total protein, globulins, triglycerides, glucose, cholesterol and urea were quantified using a semiautomatic analyzer BIO 2000 IL (BIO PLUS) and commercial kits (Gold Analisa Diagnóstica, Belo Horizonte - Minas Gerais - Brazil), according to the manufacturer's instructions.

### **Nursery phase**

The behaviors recording (2<sup>nd</sup> weaning day) was performed through filming, with cameras set in front of the pens (40 minutes). From the videos, the behaviors were evaluated instantly with a 3 minutes of sample interval, according to the methodology described and adapted by Middelkoop et al. (2019), which followed an ethogram tested prior to the collection period in which the behaviors were grouped into: lying, sitting, drinking water, eating, agonistic interactions, exploratory, and idle behavior. Subsequently, the behaviors were converted into percentages for statistical analysis.

In the nursery stage, the weighing of piglets and feed intake were carried out at each feed change. There were four phases: Pre-initial I (provided for 7 days); Pre-initial II (provided for 12 days); Initial I (provided for 17 days); and

Initial II (provided for 11 days), totaling 47 days of accommodation at the nursery facilities. The rations were prepared by the farm's technical team, based on the nutritional requirements established by the Brazilian Poultry and Swine Table (Rostagno et al. 2017) for piglets in the nursery phase (Table I).

The nursery stalls were located in the same production unit, with fully slatted suspended floors (high-density plastic), equipped with linear feeders positioned in front of the pens and nipple-type drinker at the center of pens (minimum flow of 2 L/min). The temperature was controlled by use of double curtains and the temperatures recorded by the same dataloggers used in the maternity phase.

### **Post-weaning variables**

Weight gain, feed intake, feed conversion, piglet behavior was evaluated. Blood samples were collected from two male piglets/pen (3<sup>o</sup> and 47<sup>o</sup> days at nursery) and the same variables as in step 1 were evaluated.

For the study, 50% of the piglets from the maternity phase (1<sup>st</sup> stage) were used, which were randomly selected. Piglets from each treatment were randomly divided and housed in five pens (considered as the experimental unit) in total 25 pens/replicates were implemented in which 360 piglets were housed.

### **Statistical analysis**

Prior to the analyses, the data were subjected to Kolmogorov-Smirnov error normality testing and transformed when necessary ( $P < 0.05$ ) using the Box-Cox transformation from the Microsoft Excel Action package, to meet the normality of errors. The data were then subjected to analysis of variance (ANOVA) based on a completely randomized design considering all five treatments, with ten litters for each treatment, using Statistical and Genetic Analysis System

**Table I. Ingredient and nutrient composition of experimental diets in nursery phase.**

Items, g.kg <sup>-1</sup> as fed base	Step I	Step II	Step III	Step IV
Corn	150.0	330.0	420.0	580.0
Soybean meal, 46% CP	160.0	190.0	250.0	250.0
Pre-gel corn flour	150.0	100.0	70.0	-
Swine meat and bone meal	50.0	50.0	50.0	40.0
Spray-dried whey	190.0	130.0	60.0	-
Basemix <sup>1</sup> I	300.0	-	-	-
Basemix II	-	200.0	-	-
Basemix III	-	-	150.0	-
Basemix IV	-	-	-	130.0
	Analyzed composition (g.kg <sup>-1</sup> as fed base) <sup>2</sup>			
Dry matter	931.9	923.2	914.9	902.0
Crude protein	225.7	219.7	202.8	193.8
Ash	61.3	57.4	58.6	41.9
Crude fat	69.9	48.6	65.5	52.2
Gross energy (kcal.kg <sup>-1</sup> )	4,227	4,256	4,229	4,162

<sup>1</sup>Commercial basemix <sup>2</sup>Calculated on the basis Rostagno et al. (2017).

software (version 9.1, SAEG, 2007). Specifically, for the data from the first week, the treatments WC, DCF, and WCF were grouped, because the management of the referred treatments were identical until the 8<sup>th</sup> day. At the lactation phase, each piglet was considered an experimental unit and birth weight (individual) was used in the statistical model as a covariate, for the survival rate and weight variation coefficient, the litter was used as an experimental unit. For serum variables two piglets per litter was used as an experimental unit, with a difference of  $\alpha < 0.05$  being adopted. In the case of effect, the Scott-Knott test ( $P < 0.05$ ) was used to determine the differences between treatments.

The consumptions (ingested and wasted) of feed and substitute in the maternity phase were analyzed considering the treatments, the day, and the respective interaction. In the case of significant interactions, the consumptions were divided, and specific linear equations were elaborated for each treatment. The least squares method was used to estimate the coefficients of the regression models and the verification of the

significance of each coefficient was evaluated using the t-test ( $P < 0.05$ ).

For the nursery performance experiment, the same statistical methodologies were adopted as for the previous experiment and the pens were used as experimental units (five pens per treatment).

## RESULTS

### Farrowing stage

For birth weight (1.45 (WC), 1.47 (DCF), 1.44 (WCF), 1.49 (LD), and 1.44 (LLF) kg) and weight in the first week (2.68 (WC), 2.55 (DCF), 2.43 (WCF), 2.61 (LD), and 2.50 (LLF) kg) the five treatments did not differ from one another ( $P > 0.05$ ). In the second week, the WC treatment showed significantly lower body weights (3.69 kg) ( $P < 0.001$ ) than the other treatments (4.09, 3.93, 4.20, and 4.00 kg). When weaning piglets from treatments, WC, and liquid dispenser and liquid linear feeder presented higher ( $P < 0.001$ ) body weights (5.22, 5.32, and 5.27 kg) than DC feed treatments (4.97 kg), which were superior to WC (4.69 kg) (Table II).

**Table II. Body weight (BW), piglet survival rate (%) and coefficient of variation (CV) of piglets under different feed protocols.**

Variables	Treatments					Means	CV (%) <sup>2</sup>	P-value <sup>1</sup>
	Without Creep	Dry Creep Feeding	Wet Creep Feeding	Liquid Dispenser	Liquid Linear Feeder			
	Birth							
Body weight, kg	1.45	1.47	1.44	1.49	1.44	1.46	20.5	0.210
Body weight CV %	16.24	15.71	15.72	15.38	15.44	15.71	21.8	0.998
	1 <sup>st</sup> week							
Body weight, kg	2.68	2.55	2.43	2.61	2.50	2.65	16.0	0.136
Body weight CV %	16.02	17.12	15.98	20.55	18.11	17.36	31.9	0.596
Piglet survival rate, %	88.28	85.95	86.35	87.56	81.35	85.75	12.9	0.678
	2 <sup>nd</sup> week							
Body weight, kg	4.09 <sup>a</sup>	3.93 <sup>b</sup>	3.69 <sup>c</sup>	4.20 <sup>a</sup>	4.00 <sup>b</sup>	4.06	16.2	<0.001
Body weight CV %	18.55 <sup>a</sup>	15.71 <sup>a</sup>	16.13 <sup>a</sup>	25.77 <sup>b</sup>	16.48 <sup>a</sup>	18.02	25.7	0.001
Piglet survival rate, %	83.85	82.54	80.12	83.66	78.08	81.44	16.5	0.955
	Farrowing							
Body weight, kg	5.22 <sup>a</sup>	4.97 <sup>b</sup>	4.69 <sup>c</sup>	5.32 <sup>a</sup>	5.27 <sup>a</sup>	5.13	16.4	<0.001
Body weight CV %	18.31	16.76	16.08	22.34	16.04	17.58	33.9	0.560
Piglet survival rate, %	82.99	79.89	78.64	76.50	77.32	79.14	15.2	0.508

<sup>1</sup>Averages followed by different letters in the lines differ (P <0.05) by the Scott Knott test.

<sup>2</sup>CV - Coefficient of variation.

There were no effects (P > 0.05) of the treatments on piglet survival rate in the first and second week and at weaning average of 79.1% at weaning (Table II). The coefficient of variation (CV) for body weights in the second week was higher (P <0.001) for the LD treatment (25.77%) compared to the other treatments (Table II).

On the 7<sup>th</sup> day of lactation, the serum albumin levels (2.4 g.dL<sup>-1</sup>) of the piglets were lower (P = 0.016) in the WC treatment compared to the LD (2.5 g.dL<sup>-1</sup>) and LLF (2.6 g.dL<sup>-1</sup>). Triglyceride levels were significantly lower (P <0.001) in the WC treatment (149.4 mg.dL<sup>-1</sup>) than in the LD (193.7 mg.dL<sup>-1</sup>) and LLF (206.5 mg.dL<sup>-1</sup>) treatments. On the 14<sup>th</sup> day, cholesterol values were significantly lower (P <0.030) in the WC (117.3 mg.dL<sup>-1</sup>) and LLF (110.0 mg.dL<sup>-1</sup>) treatments compared to the DCF (133.4 mg.dL<sup>-1</sup>), WC (128.5 mg.dL<sup>-1</sup>) and LD treatments (135.3 mg.dL<sup>-1</sup>). At weaning, the serum urea concentration was significantly lower (P =

0.044) in the LLF treatment (20.5 mg.dL<sup>-1</sup>) than in the WC (23.9 mg.dL<sup>-1</sup>), DCF (25.1 mg.dL<sup>-1</sup>), WCF (28.9 mg.dL<sup>-1</sup>) and LD (26.9 mg.dL<sup>-1</sup>); for the other serum variables, there were no significant differences (P >0.05) (Table III).

The use of supplement and feed (sum of consumed and wasted) showed interactions between treatments and days (P <0.001) indicating a difference in consumption over the days of supply. The best fit model for the use of liquid supplements was the root cubic model (P <0.001) (Figure 1). For feed consumption by piglets, the cubic root model (P <0.001) better adjusted the consumption of the DCF and LLF treatments; the consumption of the other treatments was better adjusted with the square root model (P <0.001) (Figure 2).

**Table III. Serum biochemical of the piglets (n= 20 per treatment) of 7, 14 and 21 days under different feed protocols.**

		Treatments						
	Variable				Liquid Dispenser	Liquid Linear Feeder	CV (%)	P-value <sup>1</sup>
		Without Creep						
7 d	AST (U.L <sup>-1</sup> )		56.2 ± 31.7		47.1 ± 15.0	55.6 ± 19.1	0.639	0.099
	Glucose (mg.dL <sup>-1</sup> )		251.3 ± 36.1		252.2 ± 39.6	265.0 ± 42.7	15.28	0.206
	Total protein (g.dL <sup>-1</sup> )		6.8 ± 1.2		7.0 ± 0.9	7.1 ± 0.8	14.99	0.098
	Albumin (g.dL <sup>-1</sup> )		2.4 ± 0.6 <sup>b</sup>		2.5 ± 0.5 <sup>a</sup>	2.6 ± 0.4 <sup>a</sup>	19.72	0.016
	Globulins (g.dL <sup>-1</sup> )		4.4 ± 1.1		4.5 ± 0.9	4.5 ± 0.8	23.07	0.660
	Cholesterol (mg.dL <sup>-1</sup> )		157.3 ± 44.0		165.8 ± 54.8	153.3 ± 43.8	0.85	0.995
	Triglycerides (mg.dL <sup>-1</sup> )		149.4 ± 55.1 <sup>b</sup>		193.7 ± 81.2 <sup>a</sup>	206.5 ± 55.8 <sup>a</sup>	30.78	<0.001
	Urea (mg.dL <sup>-1</sup> )		29.1 ± 12.9		33.3 ± 15.7	28.4 ± 15.8	12.96	0.555
		Without Creep	Dry Creep Feeding	Wet Creep Feeding	Liquid Dispenser	Liquid Linear Feeder	CV (%)	P-value <sup>1</sup>
14 d	AST (U.L <sup>-1</sup> )	60.2 ± 21.0	54.4 ± 23.6	60.4 ± 13.4	55.6±24.4	56.6 ± 20.5	3.95	0.379
	Glucose (mg.dL <sup>-1</sup> )	236.5 ± 48.6	236.2 ± 51.5	251.6 ± 47.7	217.6±48.4	239.8 ± 63.0	17.71	0.358
	Total protein (g.dL <sup>-1</sup> )	7.4 ± 1.5	7.1 ± 1.5	6.9 ± 0.9	7.5±1.5	7.3 ± 1.9	6.05	0.805
	Albumin (g.dL <sup>-1</sup> )	3.4 ± 0.6	3.3 ± 0.8	3.1 ± 0.5	3.2±0.7	3.2 ± 0.7	20.11	0.593
	Globulins (g.dL <sup>-1</sup> )	4.0 ± 1.2	3.7 ± 1.4	3.8 ± 1.1	4.2±1.2	4.1 ± 1.5	33.93	0.753
	Cholesterol (mg.dL <sup>-1</sup> )	117.3 ± 32.1 <sup>b</sup>	133.4 ± 35.5 <sup>a</sup>	128.5 ± 28.5 <sup>a</sup>	135.3±39.3 <sup>a</sup>	110.0 ± 22.3 <sup>b</sup>	2.39	0.030
	Triglycerides (mg.dL <sup>-1</sup> )	125.7 ± 64.0	129.5 ± 59.0	132.5 ± 26.5	149.9±56.5	152.2 ± 55.2	38.61	0.488
	Urea (mg.dL <sup>-1</sup> )	32.7 ± 12.6	32.6 ± 11.0	32.8 ± 17.9	30.5±14.7	34.9 ± 13.3	12.38	0.911
21 d	AST (U.L <sup>-1</sup> )	65.2 ± 29.2	65.1 ± 29.5	68.8 ± 35.5	57.1 ± 20.0	66.1 ± 25.1	1.19	0.718
	Glucose (mg.dL <sup>-1</sup> )	232.6 ± 38.3	232.1 ± 32.8	221.4 ± 42.5	234.3 ± 48.6	240.7 ± 49.1	18.18	0.596
	Total protein (g.dL <sup>-1</sup> )	7.1 ± 1.1	6.6 ± 1.2	6.4 ± 0.7	6.6 ± 1.1	6.5 ± 1.3	11.02	0.330
	Albumin (g.dL <sup>-1</sup> )	3.2 ± 0.5	3.3 ± 0.7	3.0 ± 0.4	3.3 ± 0.8	3.4 ± 1.0	10.57	0.449
	Globulins (g.dL <sup>-1</sup> )	3.9 ± 0.8	3.3 ± 0.9	3.4 ± 0.8	3.3 ± 0.8	3.8 ± 2.3	28.23	0.344
	Cholesterol (mg.dL <sup>-1</sup> )	110.5 ± 25.9	109.4 ± 30.0	102.9 ± 28.2	97.1 ± 17.5	109.0 ± 29.5	25.59	0.594
	Triglycerides (mg.dL <sup>-1</sup> )	118.7 ± 43.1	122.6 ± 52.7	128.6 ± 56.2	129.4 ± 49.4	130.1 ± 44.9	7.87	0.920
	Urea (mg.dL <sup>-1</sup> )	23.9 ± 9.4 <sup>a</sup>	25.1 ± 9.1 <sup>a</sup>	28.9 ± 12.0 <sup>a</sup>	26.9 ± 8.7 <sup>a</sup>	20.5 ± 5.7 <sup>b</sup>	36.95	0.044

<sup>1</sup>Averages followed by different letters in the lines differ (P <0.05) by the Scott Knott test Aspartate aminotransferase (AST: (UL<sup>-1</sup>), total protein (gdL<sup>-1</sup>), albumin (gdL<sup>-1</sup>), globulin (gdL<sup>-1</sup>), glucose (mgdL<sup>-1</sup>), cholesterol (mgdL<sup>-1</sup>), triglycerides (mgdL<sup>-1</sup>) and urea (mgdL<sup>-1</sup>).

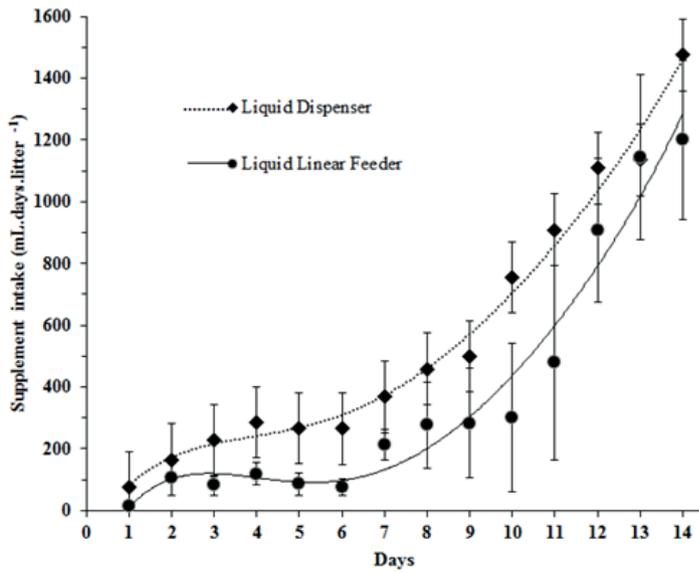
**Nursery stage**

There were no effects (P> 0.05) of treatments on body weight, feed intake, weight gain and feeding efficiency in the nursery phase (Table IV).

On the 3<sup>rd</sup> day after weaning of piglets, AST levels were significantly higher (P = 0.005) in the WC treatment (58.4 U.L<sup>-1</sup>) than in the other treatments. On the 47<sup>th</sup> day of the nursery phase,

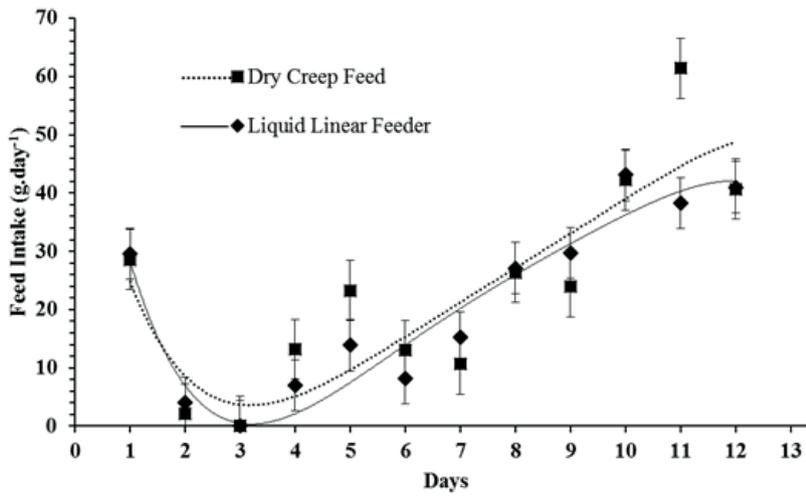
the piglets in the WC (23.3 mg.dL<sup>-1</sup>) and LLF (21.1 mg.dL<sup>-1</sup>) groups showed lower (P = 0.026) serum urea concentration than those in the other groups (Table V).

There were no effects of treatments (P >0.05) on the behavioral variables (Table VI).



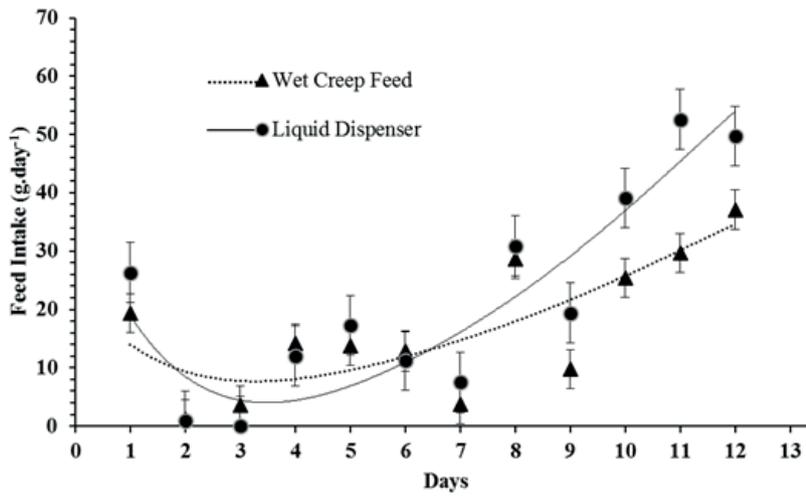
**Figure 1. Supplement intake (mL.days<sup>-1</sup>) Treatment Liquid Dispenser, and Treatment Liquid Linear Feeder. The error bars represent ± SD \*, Interaction between types of supplement feeders and intake (P<0.001).**

Liquid Dispenser =  $- 804.82 - 811.045X + 1544.296X^{0.5} + 149.7199 X^{1.5}$  (P <0.001; R2 0.869)  
 Liquid Linear Feeder =  $- 1262.18 - 1229.49X + 2283.338 X^{0.5} + 214.0774 X^{1.5}$  (P <0.001; R2 0.818)



**Figure 2. Daily feed intake (suckling phase) of piglets – treatments (Dry Creep Feeding, Wet Creep Feeding, Liquid Dispenser, and Liquid Linear Feeder) (Observed values ± SD).**

Dry Creep Feeding =  $140.10 - 179.05X^{0.5} + 71.96X - 8.05X^{1.5}$  (P<0.001; R2 0.609)  
 Liquid Linear Feeder =  $187.73 - 251.39X^{0.5} + 105.33X - 12.96X^{1.5}$  (P<0.001; R2 0.705)



Wet Creep Feeding =  $39.45 - 35.16X^{0.5} + 9.75X$  (P<0.001; R2 0.389)  
 Liquid Dispenser =  $72.69 - 73.27X^{0.5} + 19.60X$  (P<0.001; R2 0.704)

**Table IV.** Feed intake and feed:gain ratio of piglets in nursery phase under different feed protocols across the suckling phase.

Days	Treatment					CV (%)	P-value
	Without Creep	Dry Creep Feeding	Wet Creep Feeding	Liquid Dispenser	Liquid Linear Feeder		
	Initial body weight, kg						
Start	5.52	5.10	5.04	5.55	5.34	17.81	0.855
7	5.91	5.45	5.64	5.98	5.70	4.10	0.466
20	9.73	8.98	9.10	9.74	9.21	6.61	0.932
36	16.20	15.66	15.33	16.56	14.85	6.77	0.278
47	22.61	22.00	21.40	23.33	20.63	6.49	0.154
	Daily feed intake, kg/pig/phase						
0-3	0.127	0.154	0.148	0.136	0.135	28.58	0.910
0-20	0.224	0.261	0.246	0.239	0.238	14.35	0.406
0-36	0.362	0.380	0.356	0.387	0.351	13.77	0.721
0-47	0.487	0.491	0.498	0.516	0.474	10.79	0.622
	Daily weight gain (pens). kg/pig/phase						
0-7	0.056	0.051	0.087	0.061	0.051	55.28	0.466
0-20	0.221	0.204	0.214	0.220	0.204	14.35	0.406
0-36	0.297	0.293	0.286	0.306	0.264	13.77	0.721
0-47	0.363	0.360	0.348	0.378	0.325	10.79	0.622
	Feed efficiency, pig/phase						
0-7	0.449	0.317	0.601	0.449	0.313	55.80	0.302
0-20	0.996	0.797	0.872	0.918	0.884	19.82	0.635
0-36	0.827	0.778	0.806	0.793	0.761	11.94	0.846
0-47	0.749	0.726	0.713	0.735	0.717	8.43	0.916

## DISCUSSION

### Farrowing phase

The study was based on the hypothesis that supplementation with milk substitutes plus dry feed would improve the performance of the piglets in the lactation phase, reduce mortality and weight variation at weaning. For the first week, the treatments did not show any effect on weight gain. An important factor to be considered is that the piglet must first learn to consume the supplement when consumed immediately after supply and we observed great demand of the supplement. Probably, the piglet used it as a means of environmental enrichment, followed by a loss of interest. Another hypothesis is that breast milk for the lineage and for the number of piglets in the litter were sufficient to meet the

nutritional demand of the piglets. Pedersen et al. (2016) reported milk production close to 9 kg/day in the first postpartum week, which associated with the litter size after homogenization (12.7 piglets/female) were sufficient to not cause nutritional limitation (Missotten et al. 2015, Zhang et al. 2018) and thereby to minimize the effects of treatments. Another point to be considered is that in the first week, only the liquid supplement was provided in the LD and LLF treatments; the other treatments were not managed and the nutritional contribution was exclusively from breast milk.

At the end of the second week (14<sup>th</sup> day), piglets with additional liquid supplementation via LD and WC had higher body weights (4.20 and 4.09 kg), respectively, when compared to DCF (3.93 kg), WC treatments feed (3.69 kg)

**Table V. Serum biochemical of the piglets in a nursery phase of 3 and 47 days under different feed protocols across suckling phase.**

Variables	Without Creep	Dry Creep Feeding	Wet Creep Feeding	Liquid Dispenser	Liquid Linear Feeder	CV (%)	P-Value <sup>1</sup>
<b>Serum variables on day 3</b>							
AST (U.L <sup>-1</sup> )	58.4 ± 15.9 <sup>a</sup>	41.7 ± 7.9 <sup>b</sup>	49.9 ± 11.8 <sup>b</sup>	47.5 ± 10.3 <sup>b</sup>	49.7 ± 10.7 <sup>b</sup>	23.44	0.005
Glucose (mg.dL <sup>-1</sup> )	118.6 ± 13.3	126.9 ± 13.8	124.6 ± 30.1	118.8 ± 17.1	119.1 ± 14.4	14.89	0.628
Total protein (g.dL <sup>-1</sup> )	6.1 ± 1.1	6.0 ± 1.0	6.2 ± 1.1	6.3 ± 1.0	6.2 ± 0.8	3.27	0.670
Albumin (g.dL <sup>-1</sup> )	3.5 ± 0.5	3.5 ± 0.5	3.5 ± 0.6	3.9 ± 0.7	3.8 ± 0.5	15.36	0.228
Globulins (g.dL <sup>-1</sup> )	2.6 ± 1.2	2.4 ± 1.0	2.7 ± 0.9	2.5 ± 1.0	2.4 ± 0.8	51.52	0.903
Cholesterol (mg.dL <sup>-1</sup> )	74.3 ± 15.2	80.5 ± 18.8	88.6 ± 21.5	81.2 ± 23.5	78.6 ± 20.7	22.53	0.274
Triglycerides (mg.dL <sup>-1</sup> )	51.5 ± 17.5	53.5 ± 9.1	59.2 ± 16.1	57.1 ± 21.6	57.0 ± 19.2	3.65	0.804
Urea (mg.dL <sup>-1</sup> )	19.6 ± 6.7	27.0 ± 10.9	20.6 ± 6.7	23.1 ± 8.3	27.8 ± 8.8	35.84	0.058
<b>Serum variables on day 47</b>							
AST (U.L <sup>-1</sup> )	42.8 ± 7.4	45.2 ± 7.1	46.8 ± 15.0	47.1 ± 10.7	45.6 ± 11.3	23.80	0.840
Glucose (mg.dL <sup>-1</sup> )	84.6 ± 28.2	81.1 ± 22.6	75.0 ± 15.9	79.7 ± 19.1	73.4 ± 19.1	0.52	0.660
Total protein (g.dL <sup>-1</sup> )	6.3 ± 1.2	6.3 ± 1.0	6.1 ± 1.0	6.7 ± 1.0	6.5 ± 0.7	15.17	0.826
Albumin (g.dL <sup>-1</sup> )	2.3 ± 0.6	2.4 ± 0.3	2.3 ± 0.4	2.5 ± 0.6	2.4 ± 0.5	23.56	0.939
Globulins (g.dL <sup>-1</sup> )	4.0 ± 1.4	4.0 ± 1.0	3.8 ± 0.8	4.2 ± 1.2	4.1 ± 0.6	9.21	0.926
Cholesterol (mg.dL <sup>-1</sup> )	78.4 ± 23.2	77.8 ± 17.6	70.6 ± 10.7	82.4 ± 18.2	72.2 ± 15.2	20.85	0.430
Triglycerides (mg.dL <sup>-1</sup> )	67.2 ± 21.4	74.9 ± 22.3	73.9 ± 20.6	71.8 ± 23.8	68.1 ± 26.0	29.04	0.806
Urea (mg.dL <sup>-1</sup> )	23.3 ± 3.8 <sup>b</sup>	28.1 ± 8.9 <sup>a</sup>	25.4 ± 2.8 <sup>a</sup>	25.6 ± 5.3 <sup>a</sup>	21.1 ± 6.0 <sup>b</sup>	23.12	0.026

<sup>1</sup>Averages followed by different letters in the lines differ (P <0.05) by the Scott Knott test Aspartate aminotransferase (AST: (UL<sup>-1</sup>), total protein (gdL<sup>-1</sup>), albumin (gdL<sup>-1</sup>), globulin (gdL<sup>-1</sup>), glucose (mgdL<sup>-1</sup>), cholesterol (mgdL<sup>-1</sup>), triglycerides (mgdL<sup>-1</sup>) and urea (mgdL<sup>-1</sup>).

and Liquid Linear Feeder (4.00 kg). This result may be associated with higher supplement consumption by the LD treatment. Similar results were obtained by Van Oostrum et al. (2016) who found higher body weight for piglets with liquid supplementation combined with dry food.

Our results with body weights higher in the LD treatment suggest a possible nutritional benefit of substitute substitution and greater ease of consumption via a dispenser for litter sizes close to 12 piglets. The supplement derived 40% of its fat content from refined coconut oil, high levels of whey protein, lactose, and Imagro® (galactooligosaccharides, probiotics and organic acids), all of which may have helped the piglets gain weight. Probably, its use in hyper-prolific lineages may have greater beneficial effects than those obtained in the present study (De Vos et al. 2014), because, with the greater competition in larger litter, the supplement can overcome nutritional limitations in litters with

high numbers of piglets with exclusive milk consumption.

The lower BW of the LLF treatment (4.00 kg) when compared to the LD (4.20 kg) may be related to the type of feeder used (trough type feeder) which was designed for use in animals over 12 days of age, and which may have made it difficult for piglets to access and consume the supplement (Figure 1). However, at weaning, the piglets in the LLF group (5.27 kg), obtained body weights similar to the LD (5.32 kg) and WC (5.22 kg) groups, suggesting that, after the piglets reach the age above 12 days, they were able to properly consume the supplement.

It is noteworthy that the management used for supplementation, completed at 14 days of age, 7 days before the predicted weaning date (according to the manufacturer's recommendations), when consumption was 571 and 378 mL.day.litter<sup>-1</sup> for LD and LLF groups, respectively, they may have limited weight gain and possible benefits associated with the use of

**Table VI. Behavior of piglets (%) after weaning and transfer to the nursery on day 2.**

Items, %	Without Creep	Dry Creep Feeding	Wet Creep Feeding	Liquid Dispenser	Liquid Linear Feeder	CV (%)	P-value
Sleeping	26	12	48	25	37	96.35	0.280
Seated	5	3	6	2	2	115.63	0.399
Drinking	5	6	3	7	5	70.12	0.459
Eating	18	27	20	17	14	63.34	0.464
Agonistic	3	3	1	1	3	105.49	0.661
Exploring	37	40	22	41	34	38.31	0.104
Idleness	7	9	1	6	5	100.86	0.184

the substitute. The consumption of substitutes was higher than those reported by Douglas et al. (2014), who reported 167 mL.day.litter<sup>-1</sup>. If we compare our results with those reported by Azain et al. (1996) of 471 mL.day.litter<sup>-1</sup> when using liquid supplement for piglets in the maternity phase, the LD group showed higher consumption and the LLF group showed less consumption. The higher consumption of feed and liquid substitute observed on the first day of supply (Figures 1 and 2) are associated, as previously discussed, with the exploration of the feed/substitute in a playful way by the pig (non-nutritional), similar to what occurs with the availability of new objects in the pen, followed by a reduction in the piglet's interactions with the new object.

This behavior, loss of interest in the new object, was observed by Van De Weerd et al. (2003) who, when studying different objects in environmental enrichment, found reduced piglet interactions with new objects at intervals that varied between 1 hour to 3 days after exposure.

The lower mean in the BW for the WCF group (2<sup>nd</sup> and 3<sup>rd</sup> weeks, 3.69 and 4.69 kg) may be associated with the fact that the humidification of the feed had compromised its nutritional and sanitary quality, because the feed was developed for use in the dry form and when humidifying it, it increased the attraction of insects to the feeders with the moistened diet, and this may have led to the non-recommendation of

hydration (1:2) for the type of feed used in the present study.

The consumption of supplements of lower nutritional quality compared to milk, in the DCF and WCF treatments, and the difficulty of consumption in the trough-type feeder may have contributed to the results. Another point to be highlighted is that the absence of supplementation in the farrowing pen and the reduced handling of animals in the WC group may have minimized the spread of enteric diseases.

The survival rate of the piglets did not differ among treatments, similar to results reported by Miller et al. (2012), who, when studying the supply of pre-weaning substitutes, found no difference in the survival rates in the maternity phase and in the subsequent nursery phase; similarly, Douglas et al. (2014) used dairy supplements for low weight piglets and found no differences in piglet survival.

The weight coefficient of variance (CV%), an important indicator of litter homogeneity, was higher for the LD group at 2<sup>a</sup> week, suggesting greater unevenness of the litter, a result different from that found by Novotni-Dankó et al. (2015), who, when using liquid milk supplement for litter in the maternity, found no differences in CV% of the piglets' weights. The result obtained is probably associated with the uneven consumption of the supplement by the individuals in the litter, such that some

animals showed higher consumption in relation to the average, causing the greater degree of heterogeneity. Nevertheless, our hypothesis needs to be better explored in future works by correlating individual substitute consumption with the piglet's respective performance.

The lower levels of albumin in the WC group in relation to the others during the first week may be associated with the lower hepatic metabolism/nutrient transport in that group, because it is related to liver functions (Gonzalez & Silva 2003). We also highlight the higher levels of blood triglycerides in treatments with liquid supplements (LD and LLF) are associated with the consumption of the substitute because the lipid content of the supplement used is close to 40%.

The absence of effects on AST level ( $P > 0.05$ ), an important indicator of muscle cell damage or more severe damage to hepatocytes (Niu et al. 2019), suggests that treatments did not influence this variable sufficiently to change its values while remaining within the range of normal for the species. Perri et al. (2017) noted the reference range for piglets at 21 days of age was  $18.0 - 83.5 \text{ U.L}^{-1}$  for AST; however, at different ages and at different times of collection, healthy piglets showed substantial variation in serum levels.

The results of the serum biochemistry variables were considered normal for the phase, for piglets 21 days of age (Perri et al. 2017). Urea is an important indicator of protein quality (Meijer et al. 1990) and its serum levels are correlated with the catabolism of excess amino acids or those with lower quality protein profiles. Changes in normal levels of urea in the blood suggest possible disorders in the renal, hepatic, nervous, and blood circulatory systems (Dervisevic et al. 2017). Thus, lower blood concentrations of urea (end of the first week) and cholesterol (end of the second week) in the WC

group may be associated with the higher quality (better biological value) of milk protein when compared to supplemented treatments. The results of the LLF group may be associated with greater difficulty in consuming the supplement, caused by the technical characteristics of the trough-type feeder.

### Nursery phase

The absence of effects on the subsequent zootechnical performance (nursery phase) was not expected. This may have occurred because the previous presentation of the piglets to the feed and the substitute could minimize the stressful effects of weaning and could have resulted in greater consumption and, consequently, better gains and greater feeding efficiency. Similar results (absence of residual effects of supplementation) were reported by Park et al. (2014) in a study with similar characteristics, in which they assessed creep feeding and milk substitute in hot and cold seasons and found no effects on the performance of pre- and post-weaning piglets.

One hypothesis for the result obtained is that, although the numerical differences in the CP were maintained until the end, these differences were relatively small and showed substantial variability, making it difficult to detect differences (Wellock et al. 2009). Another factor to be considered is that the commercial production environment can cause challenges, including cold stress. In the experimental period, especially during the first week, the piglets were subjected to temperatures below the critical lower temperature for the phase (NRC 2012).

Pigs are homeothermic animals that maintain body temperature within narrow limits, even under varying environmental conditions (Miller 2012). When exposed to temperatures below the lower critical limit, they produce additional heat to return to the comfort

zone, with consequent diversion of energy and nutrients for maintaining homeothermic condition, resulting in impaired weight gain (Li & Patience 2017). This leads to the need for greater nutrient intake (NRC 2012). The greater need for nutrient intake, in addition to the limitation of feed intake in the post-weaning period, may have limited the gains and residual effects of the management carried out in the previous phase.

The lack of difference in behavior on the second day after weaning may have been caused by the same factors discussed previously in terms of performance. Another point to be highlighted is that the different treatments were randomly distributed in the nursery rooms. In this way, the animals of the WC group were positioned in pens neighboring those of other treatments (piglets with previous consumption experience). The act of observing piglets without previous experience of consumption to piglets from other groups previously experienced in consuming feed may have favored the learning of the location of feeders and consequently minimized the differences in feed consumption of the group without creep compared to other treatments.

In a study that evaluated the learning between piglets, Nicol & Pope (1994) found that untrained piglets found it easy to find the feeder when they observed animals with previous training, supporting our hypothesis of learning the piglets in the groups without creep. By contrast, Gieling et al. (2011) performed an observational learning study in which they investigated social behavior in pigs and did not clearly demonstrate the ability of pigs to imitate behavior. Therefore, our hypothesis needs to be better studied in future works under different production conditions.

The function of AST is to catalyze the transamination of L-aspartate and 2-oxoglutarate

to oxaloacetate and glutamate (Evans 2009). It serves as an important indicator of impaired liver function. The higher levels of AST in the WC group (negative control) than in the other treatments on the 3<sup>rd</sup> day after weaning suggests greater hepatic activity associated with this treatment and suggests that, soon after weaning, the animals had greater difficulty initiating the feed intake, causing a reduction in hepatic reserves. The change obtained in this indicator for the WC group may be associated with the difficulty of abrupt adaptation to the solid diet in the first hours after weaning and reinforces the importance of supplementation in the maternity phase.

## CONCLUSIONS

The use of dry food with liquid supplements did not promote an increase in weight gain compared to treatment without the use of dry food for litter of up to 12.9 piglets. The various feeding systems did not influence weight and performance in the subsequent phase.

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#### Author contributions

Fernando Zimmer, Keysuke Muramatsu and Diovani Paiano conceived of the presented idea. Keysuke Muramatsu provided facilities and animals for the experiment. Fernando Zimmer, Gabriela M. Galli, Davi F. Alba, Hiam J. Marcon, Luis Gustavo Griss and Diovani Paiano performed the measurements and were involved in planning and supervised the work, Fernando Zimmer, Aleksandro S. Da Silva and Diovani Paiano processed the experimental data, performed the analysis, drafted the manuscript and designed the figures. Fernando Zimmer and Diovani Paiano developed the theory and performed the computations. Aleksandro S. Da Silva and Diovani Paiano verified the analytical methods. All authors discussed the results and contributed to the final manuscript.

