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Understanding the drivers of colostrum intake and pre-weaning mortality in piglets: an exploratory analysis with focus on neonatal vitality traits

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ABSTRACT - This study examined the effect of colostrum intake on pre-weaning mortality in piglets, focusing on neonatal vitality traits. Data from 2,050 piglets and 136 sows were collected from a commercial farm. Sows were monitored during gestation (parity, body condition, backfat thickness, weight gain, and gestation duration) and farrowing was monitored (duration, live births, mummified fetuses, stillbirths, maternal glucose, birth intervals, birth order, and sex). Neonatal traits (colostrum intake, meconium presence, umbilical rupture, rectal temperature, glucose, oxygenation, and heart rate) and performance measures (birth weight, weaning weight, and mortality) were recorded. Piglets that did not survive until weaning were born to sows with a longer farrowing duration (+26%; P<0.001), higher birth orders (+14%; P = 0.047), lower birth weights (−21%; P<0.001), reduced oxygenation (−1%; P = 0.019), lower rectal temperatures (−4%; P = 0.033), and significantly lower colostrum intake (−38%; P<0.001). Mortality was associated with rectal temperatures (<38.35 °C), colostrum intake (<172 g), birth weights (<897.5 g), and farrowing durations (>301 min), as identified by a tree-based model. Low colostrum intake correlated with longer farrowing durations (+7%; P = 0.044), longer birth intervals (+32%; P = 0.013), higher birth orders (+12%; P = 0.015), lower body weights (−5%; P = 0.005), reduced umbilical rupture rates (−11%; P = 0.049), lower rectal temperatures (−1%; P = 0.046), and lighter weaning weights (−10%; P<0.001). The model suggested that low colostrum intake was linked to birth weight (<990 g), sow body condition during gestation, and farrowing durations (>343 min). These results underscore the complex factors influencing colostrum intake and mortality, critical for sustainable swine production.

Keywords: farrowing, lactation, pigs, viability

1. Introduction

In recent years, the productivity of sows has increased because of advancements in management and genetic selection (Oliviero et al., 2019). Present-day sows are capable of weaning 30 to 35 piglets per year, with the most productive sows weaning over 40 piglets annually (Agriness, 2022). However, hyperprolificacy has been associated with a decline in birth weight, which can adversely affect piglets' colostrum intake and potentially threaten their survival until weaning (Bortolozzo et al., 2023).

Colostrum is defined as the first secretion from the mammary glands, typically released within the first 24 hours after farrowing. It plays a crucial role in providing nutrients and passive immunity essential for the postnatal growth and survival of piglets (Vodolazska et al., 2023). Colostrum is a rich source of immunoglobulins, particularly IgG and IgA, which are vital for immune protection. Additionally, it supports intestinal development and maturation through its growth-promoting factors (Hurley, 2015). Compared to mature milk, colostrum contains significantly higher concentrations of immunoglobulins, trace minerals (iron, copper, iodine, and zinc), vitamins, and hormones (Hurley, 2015; Vodolazska et al., 2023). Inadequate colostrum intake is associated with increased susceptibility to disease, impaired thermoregulation, and deficits in energy metabolism (Quesnel et al., 2012; Hurley, 2015), which can compromise piglet performance, health, and welfare (Devillers et al., 2011).

Pre-weaning mortality is also a critical issue for pig producers. Piglets go through several processes until their complete physiological adaptation to extrauterine life, with the first hours being recognized as a critical period with high mortality risk (Quesnel et al., 2012). The causes of pre-weaning mortality are considered multifactorial because of the interactions among the sow, piglet, and the environment (Muns et al., 2016). Greater mortality rates may be related to low birth vitality, failures in maternal nutrition, housing issues (farrowing crates models, lack of artificial heating, and poor hygiene of the birthing site), and failures in neonatal care (Friedrich et al., 2019).

The importance of colostrum intake and the main causes of mortality have been extensively documented (Devillers et al., 2011; Quesnel et al., 2023). Nevertheless, limited data are available on the association among mortality, colostrum intake, and neonatal vitality in farm animals. Vitality traits are well established in human obstetrics, and standardized observation protocols are implemented minutes after birth. Therefore, it is reasonable to assume that similar protocols would be beneficial if applied to pigs. The hypothesis of this study was to confirm, through the database and available literature, that the complex of factors related to newborn vitality is similar to that found in neonatal animals, which determines the predisposition to mortality before weaning. Therefore, this study aimed to investigate the determinants of colostrum intake and pre-weaning mortality in piglets by focusing on neonatal vitality traits.

2. Material and methods

2.1. Data collection

Data collection was conducted on a commercial farm in Southern Brazil, in compliance with the prevailing regulations of the institutional animal care and use committee (Universidade Federal do Rio Grande do Sul - UFRGS, protocol number 43565). One hundred and thirty-six sows (Agroceres-PIC, São Paulo, Brazil) with parity ranging from 1 to 9 were randomly selected from the commercial farm for assessment.

The sows were observed and evaluated daily from mating to parturition. Observations included the appearance of clinical signs and medication use. Body condition was assessed periodically during the gestational phase (1, 30, 60, 80, and 110 d of gestation). The analysis was performed using a caliper device (which assesses the angularity on the back of the sow by simply superimposing the lumbar area), with measurements ranging from 1 to 30. The measurement was carried out in the dorsal region, the equipment was positioned in the midline of the loin between the 10th and 11th, this area is chosen because it has a layer of subcutaneous fat representative of the animal's finishing condition. The caliper was inserted perpendicular to the skin's surface centered on the spine, with the appendix of the equipment positioned without exerting pressure on the sow's skin so as not to compress the fat, as it can reduce the measurement.

After this step-by-step procedure, the sows' body condition score was obtained. Body condition scores below the minimum desirable were considered lean, within the desirable limit (good), and above the upper limit (fat). Sows with measurements ranging from 13 to 15 were considered 'ideal'. Sows that did not receive at least three 'ideal' assessments (out of five) were classified as having 'inadequate body condition.' Backfat thickness was simultaneously evaluated using an ultrasound device (Renco Lean Meter; MS-Schippers, São Paulo, Brazil).

All the sows were weighed at the time of transfer, from gestation to farrowing, and at weaning. Changes in body condition during the gestational period were used to determine the amount of feed provided, following the recommendations of the genetic company (PIC nutrition and feeding guidelines). The composition and daily supply of gestation and lactation diets followed standard operating procedures of the farm. Water was provided *ad libitum* throughout the study. Later, the sows were transferred to farrowing rooms approximately one week before the predicted farrowing date.

The vitality response of 2,050 piglets (live births) was evaluated immediately after birth. At birth, some characteristics were classified as the presence or absence of meconium along the piglet's body, the integrity of the umbilical cord was recorded with the (presence or absence of rupture). Oxygenation and heart rate were measured using a veterinary oximeter (RZVet, São Paulo, Brazil), which was positioned on the piglet's forelimb. A small blood sample was collected from the umbilical cord for glucose quantification (Accu-chek Performa Monitor, Roche, São Paulo, Brazil) and pH assessment (Akso, Rio Grande do Sul, Brazil). Farrowing was individually monitored, and data regarding litter size, number of piglets born alive, stillborn and mummified fetuses, and the occurrence of interventions (such as farrowing induction, vaginal palpation, or oxytocin administration) were recorded. The duration of farrowing was associated with the birth time of each piglet in the respective litter, considering the expulsion of the first and last piglets. The delivery duration was converted into minutes.

Glucose quantification was also performed in fasting sows (12 hours of fasting) (Accu-chek Performa Monitor, Roche, São Paulo, Brazil). The rectal temperature of each piglet was measured in the first 24 hours of the piglet's life with a digital thermometer (Accumed-Glicomed, RJ, Brazil) to identify conditions that disfavor the piglet's survival.

The piglets were individually identified with ear tags and weighed using a digital scale with an accuracy of 1 g for up to 12 h after birth (including stillborn and mummified piglets). Piglets were weighed again 24 h after birth to estimate colostrum intake. Colostrum intake was estimated on the basis of body weight measurements performed at birth and after 24 h. Colostrum intake was estimated using a validated formula (Devillers et al., 2004), considering birth weight, weight 24 h after birth, and breastfeeding time.

Equation proposed by Devillers et al. (2004) was used:

$$CI = -217.4 + 0.217 \times t + 1861019 \times (BW_{24} / t) + BW_b \times (54.8 - 1861019 / t) \times (0.9985 - 3.7 \times 10^{-4} \times t_{FS} + 6.1 \times 10^{-7} \times t_{FS}^2)$$

in which CI = colostrum intake (g); t = time from birth to weight measurement (min); t_{FS} = time from birth to first suckling (min); BW_{24} = body weight at 24 h (kg); BW_b = body weight at birth (kg).

The management practices were maintained during lactation. Lactating sows were fed five times daily *ad libitum*. Creep-feeding was not provided to the piglets. The mortality events were recorded. Piglets were individually weighed again on day 20 (for most piglets, one day before weaning), and the weight gain during lactation was calculated.

2.2. Statistical analysis

The datasets were organized using Microsoft Excel. The data were analyzed using Minitab (version 21, Minitab Inc. State College, PA, USA) and SAS (version 9.3, SAS Institute Inc., Cary, NC, USA). Descriptive statistics were obtained for each variable. A comprehensive understanding of the relationships among all the variables in the data was obtained using Principal Component Analysis. The classification and regression tree (CART) method was applied to further understand the two main factors (mortality and colostrum intake) using *k*-fold cross-validation (k = 10).

The variable split points were automatically generated by the CART algorithm to maximize the separation between response groups by minimizing the within-node impurity (e.g., variance for continuous outcomes). Thus, the thresholds for variables such as rectal temperature (38.35 °C), colostrum intake (172 g), birth weight (897.5 g), and farrowing duration (301 min) were determined as the most informative values for predicting pre-weaning mortality or low colostrum intake within the dataset.

The animals were classified according to two main factors (mortality and low colostrum intake) and compared using the GLIMMIX procedure. The piglet was considered the experimental unit but was grouped by sow (random effect). All the statistical models included two main factors as fixed effects. In addition, the effects of parity order, litter size (transformed into classes), and their interactions were tested and maintained in the final models when P<0.10. Age was also tested as a covariate of body weight at weaning. Data are presented as least squares means and interpreted considering probabilities of 5 and 10%. Finally, regression procedures were used to test linear and quadratic fittings between birth weight and colostrum intake and between colostrum intake and body weight at weaning.

3. Results

3.1. Exploratory analyses

Descriptive statistics were used to analyze the data (Table 1). Sows and piglets performed as expected for modern genotypes, and no severe health problems were observed.

The cumulative proportion of the first two principal components was 55% (Figure 1). The first principal component had a large positive association with birth weight and colostrum intake, while the second component was positively associated with mortality rate. Piglet mortality was grouped with farrowing duration, birth interval, umbilical rupture, presence of meconium, and sow weight gain during gestation. These variables were in the opposite direction of oxygenation, heart rate, parity order, and glucose levels measured in both sows and piglets. Colostrum intake was grouped by birth weight, in the opposite direction of inadequate sow body condition, litter size, number of mummified and stillborn piglets, and birth order.

3.2. Understanding the drivers of pre-weaning mortality

Piglets that did not survive until weaning (which occurred on day 21 of life) were born to sows with a +26% longer farrowing duration (P<0.001; Table 2). Higher birth order (+14%; P = 0.047) and lower birth weight (−21%; P<0.001) were also observed in piglets that did not reach weaning age. Additionally, these piglets showed lower oxygenation (−1%; P = 0.019) and rectal temperature (−4%; P = 0.033) at birth. Compared with piglets that had been weaned, those that died during the lactation period tended to have lower glucose levels (−7%; P = 0.074), lower heart rate (−4%; P = 0.086), and a higher presence of umbilical rupture (+14%; P = 0.104). The birth interval, maternal glucose level, rectal temperature, and meconium presence did not differ among piglets that survived or did not until weaning. In contrast, colostrum intake differed markedly between the two groups, being 38% lower (P<0.001) in piglets that died during lactation, which deserves further investigation.

A tree-based model for identifying factors associated with pre-weaning mortality in piglets is shown in Figure 2. The initial node considered the rectal temperature of the piglets at birth. The cut-off point of 38.35 °C was generated by the CART algorithm as the optimal threshold to classify piglets into two groups (temperature < 38.35 °C and ≥ 38.35 °C), based on its ability to maximize the separation in pre-weaning mortality outcomes. The pre-weaning mortality rate among piglets with rectal temperatures below 38.35 °C was 9.5%, which was considerably higher than the rate observed in the remaining group (1.9%). The next node branch was based on colostrum intake. Piglets that consumed less than 172 g of colostrum presented a pre-weaning mortality rate of 22.7%, whereas this rate was reduced to

Table 1 - Database description[1]

Variable	Mean	SD	Percentile		
			25th	50th	75th
Gestation					
Parity order (n)	3.645	1.838	2.000	3.000	5.000
Backfat thickness (mm)	10.13	3.284	8.000	10.00	11.50
Inadequate body condition (%)	33.72	-	-	-	-
Weight gain (% of initial weight)	14.87	8.713	7.907	13.66	21.20
Duration (days)	115.0	0.920	115.0	115.0	115.0
Farrowing					
Duration (min)	332.3	162.2	242.0	302.0	368.0
Piglets born alive (n)	15.26	3.543	13.00	16.00	18.00
Mummified (n)	0.602	0.964	0.000	0.000	1.000
Stillborn (n)	0.862	1.097	0.000	1.000	1.000
Sow glucose (mg/dL)	94.87	18.14	83.00	93.00	102.0
Piglet					
Birth interval (min)	22.79	37.54	4.000	12.00	29.00
Birth order (n)	7.569	5.039	3.000	7.000	11.00
Birth weight (g)	1,343	355.5	1,116	1,355	1,595
Weaning weight (g, 20 days)	5,683	1,279	4,831	5,778	6,575
Mortality (%)	5.847	-	-	-	-
Vitality					
Colostrum intake (g)	331.6	183.2	224.9	320.2	415.1
Meconium presence (%)	24.92	-	-	-	-
Umbilical rupture (%)	68.73	-	-	-	-
Rectal temperature (°C)	38.93	16.01	37.60	38.40	39.00
Glucose (mg/dL)	52.08	18.15	41.00	48.00	59.00
Oxygenation (%)	98.32	3.712	99.00	99.00	99.00
Heart rate (bpm)	125.5	62.91	77.00	112.0	169.0

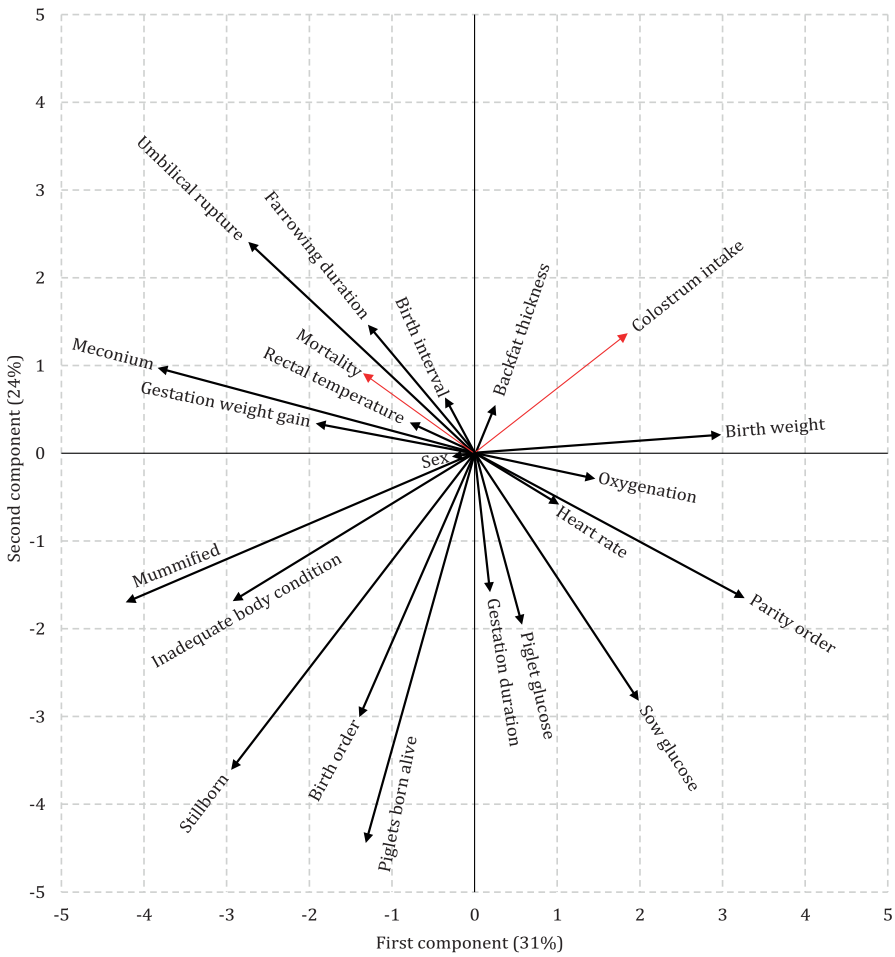
SD - standard deviation.
[1] A total of 2,050 piglets were considered.

7.5% when adequate colostrum intake (>172 g) was observed. Birth weight was the next node in the predictive model. Piglets born heavier than 897.5 g had a pre-weaning mortality rate of 4.9%, whereas 25.3% of those born lighter than 897.5 g did not survive until weaning. The final node corresponded to farrowing duration. A mortality rate of 7.4% was observed when farrowing duration exceeded 301 min, whereas the mortality rate of the remaining group was 2%.

The variable with the highest improvement score in this predictive model was piglet birth weight. Relative to the contribution of the top predictor variable (i.e., piglet birth weight = 100%), rectal temperature contributed 71.5%, followed by colostrum intake (38.8%), farrowing duration (38.1%), parity (29.0%), heart rate (9.8%), number of piglets born alive in the litter (9.8%), piglet glucose (9.8%), weight gain during gestation (9.2%), and birth order (8.4%).

3.3. Understanding the drivers of lower colostrum intake

The cutoff point of 172 g found in the previous analysis was applied to the dataset to classify the colostrum intake of each piglet as ‘low’ or ‘adequate’ (Table 3). Piglets with low colostrum intake had longer farrowing duration (7%; P = 0.044) and birth intervals (32%; P = 0.013). The birth order was higher in piglets with inadequate colostrum intake (12%; P = 0.015). At birth, these piglets had 5% lower body weight (P = 0.005), 11% lower frequency of umbilical rupture (P = 0.049), and 1% lower rectal temperature (P = 0.046). If marginal significance levels were considered, piglets with low colostrum intake also showed 28% lower meconium presence (P = 0.102) and 6% lower heart rate (P = 0.082). The glucose levels (sows or piglets) and oxygenation levels were similar between the groups.



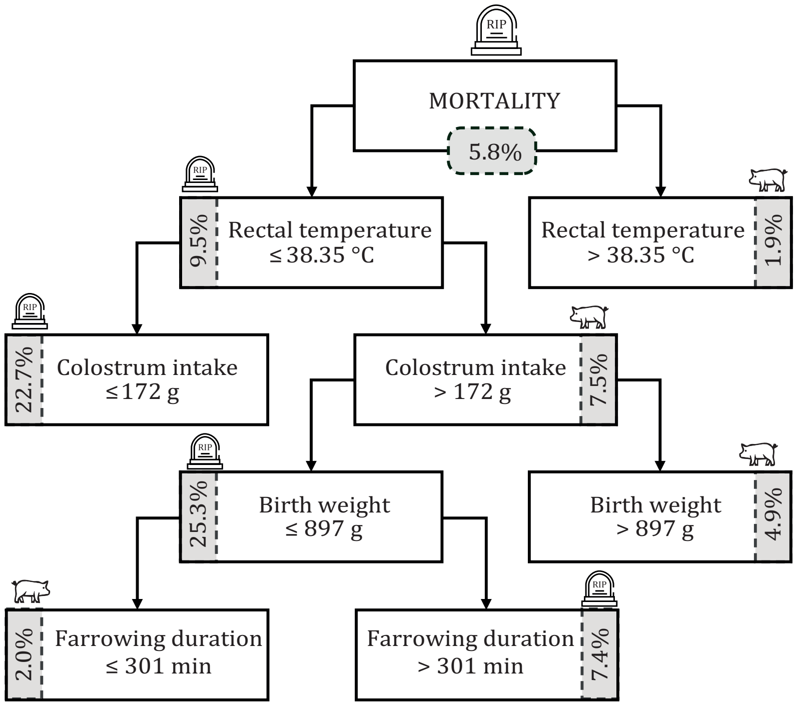
[1] Principal component (PC) analysis biplot of sow characteristics, farrowing process, neonatal vitality traits, and pre-weaning mortality (n = 2,050 piglets).
Arrows represent the original variables: the direction indicates the variable's orientation relative to the principal components (PC1 and PC2), and the length reflects the magnitude of its contribution (loading) to the variance explained by the two axes. All measured variables were included in the analysis.

Figure 1 - Principal component analysis[1] considering sow characteristics, farrowing process, vitality traits in neonatal piglets, and pre-weaning mortality.

Table 2 - Farrowing and vitality traits of piglets[1] that survive or not until weaning[2]

Variable	Mortality		RSE	P-value
	Survived	Died		
Farrowing duration (min)	325.4	410.8	156.3	<0.001
Birth interval (min)	22.26	24.88	35.92	0.510
Sow glucose (mg/dL)	95.03	96.83	18.23	0.379
Birth order (n)	7.286	8.306	4.922	0.047
Birth weight (g)	1363	1072	347.2	<0.001
Meconium presence (%)	24.34	27.52	4.305	0.489
Umbilical rupture (%)	60.41	68.63	6.334	0.104
Rectal temperature (°C)	40.64	38.90	16.83	0.033
Glucose (mg/dL)	52.26	48.69	17.87	0.074
Oxygenation (%)	98.35	97.40	3.806	0.019
Heart rate (bpm)	125.7	120.21	60.39	0.086
Colostrum intake (g)	333.2	207.6	138.7	<0.001

RSE - residual standard error.
[1] A total of 2,050 piglets were considered.
[2] From birth to weaning, excluding natimortality.



[1] From birth to weaning, excluding stillbirths.
[2] A total of 2,050 piglets were considered.
Each node represents a decision point based on the most informative variables, as determined by the CART algorithm. The cutoff values reflect thresholds selected to best separate mortality outcomes. Percentages shown at each terminal node indicate the mortality rate within that subgroup.

Figure 2 - Tree-based model for identifying factors associated with pre-weaning[1] mortality in piglets[2].

The significance of colostrum intake and piglet performance is indisputable. Piglets that consumed insufficient colostrum were weaned 10% lighter (P<0.001) than those that consumed adequate colostrum. In addition, pre-weaning mortality was over four times higher (P<0.001) in piglets with low colostrum intake compared with those with adequate intake, highlighting the strong association between colostrum consumption and survival.

Table 3 - Farrowing and vitality traits of piglets[1] with adequate or low colostrum intake[2]

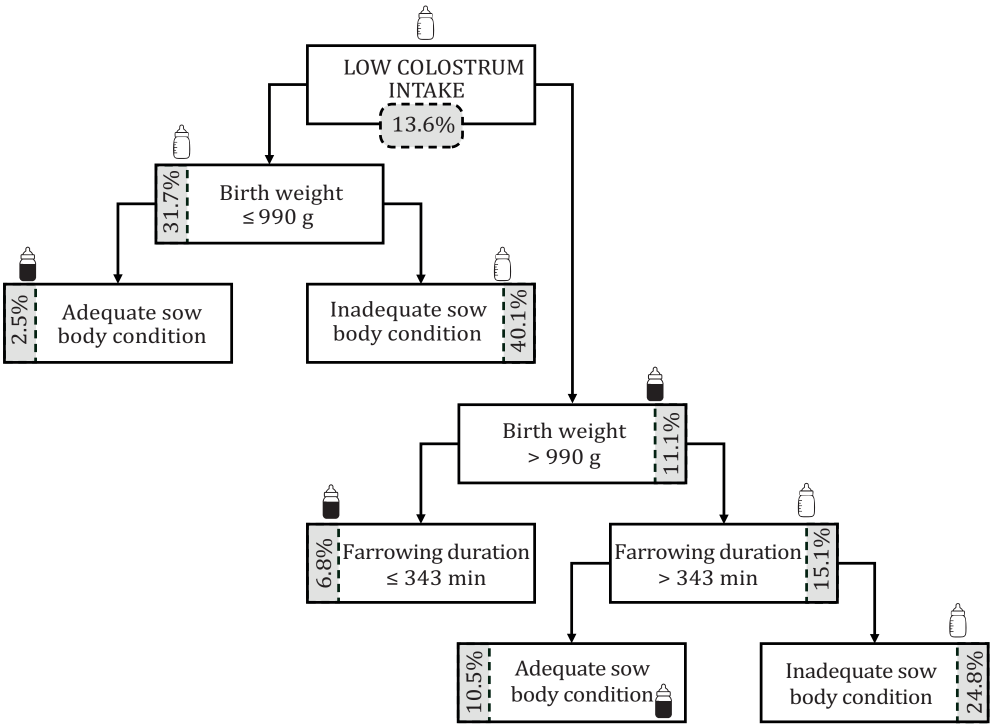
Variable	Colostrum intake		RSE	P-value
	Adequate	Low		
Farrowing duration (min)	328.4	351.7	154.5	0.044
Birth interval (min)	21.75	28.80	36.75	0.013
Sow glucose (mg/dL)	95.65	96.79	18.54	0.530
Birth order (n)	6.969	7.834	4.715	0.015
Birth weight (g)	1,392	1,324	324.3	0.005
Meconium presence (%)	18.41	23.62	4.204	0.102
Umbilical rupture (%)	64.32	71.20	4.573	0.049
Rectal temperature (°C)	39.64	39.06	17.83	0.046
Glucose (mg/dL)	52.09	52.72	17.77	0.657
Oxygenation (%)	98.34	98.26	3.718	0.757
Heart rate (bpm)	133.2	125.1	62.27	0.082
Weaning weight (g)	5800	5211	1267	<0.001
Mortality (%)	2.513	12.43	1.904	<0.001

RSE - residual standard error.
[1] A total of 2,050 piglets were considered.
[2] Lower than 172 g (defined based on the outcomes of the CART models).

The tree-based model used to identify the factors associated with this condition is shown in Figure 3. Birth weight was the initial node in this model. Piglets with inadequate colostrum intake represented 31.7% of the piglets among those born weighing less than 990 g. This proportion was considerably lower (11.1%) among piglets with adequate birth weight (>990 g).

For piglets with low birth weights, sow body condition during gestation was the next split criterion. Approximately 40% of piglets with low birth weight born to sows with inadequate body condition had low colostrum intake, whereas this proportion was reduced to 2.5% when sows presented adequate body condition during gestation. For piglets with adequate birth weight (>990 g), the farrowing duration was the next split criterion. Approximately 15% of piglets born with prolonged parturition (>343 min) had a low colostrum intake. Similarly, the final node was found in this group once again, based on the body condition of the sows during gestation. Low colostrum intake was observed in 24.8% of piglets born with prolonged parturition from sows with inadequate body condition, whereas this proportion was reduced to 10.5% when body condition was adequately maintained during the gestation.

According to previous assessments of mortality, the predictive model for colostrum intake showed the greatest improvement in piglet birth weights. The following variables were most important for the model: sow body condition during gestation (49.1%), farrowing duration (38.7%), parity order (20.4%), number of piglets born alive in the litter (18.7%), rectal temperature (16.0%), sow glucose level (15.1%), birth order (9.9%), heart rate (5.4%), and piglet glucose level (4.3%).

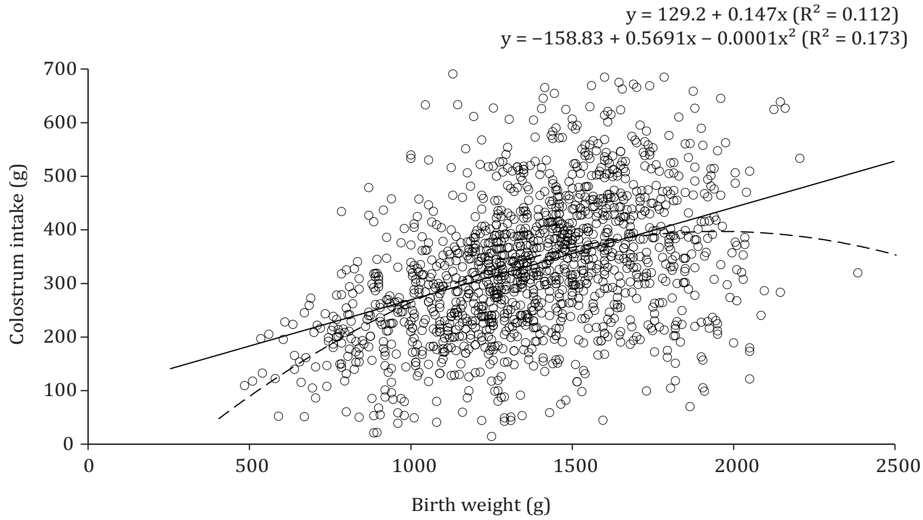


[1] Lower than 172 g (defined based on the outcomes of the previous CART model).
[2] A total of 2,050 piglets were considered.
Each node represents a decision point based on the most informative variables, as determined by the CART algorithm. The cutoff values reflect thresholds selected to best separate mortality outcomes. Percentages shown at each terminal node indicate proportion of piglets with low colostrum intake in that subgroup.

Figure 3 - Tree-based model for identifying factors associated with low colostrum intake[1] in piglets[2].

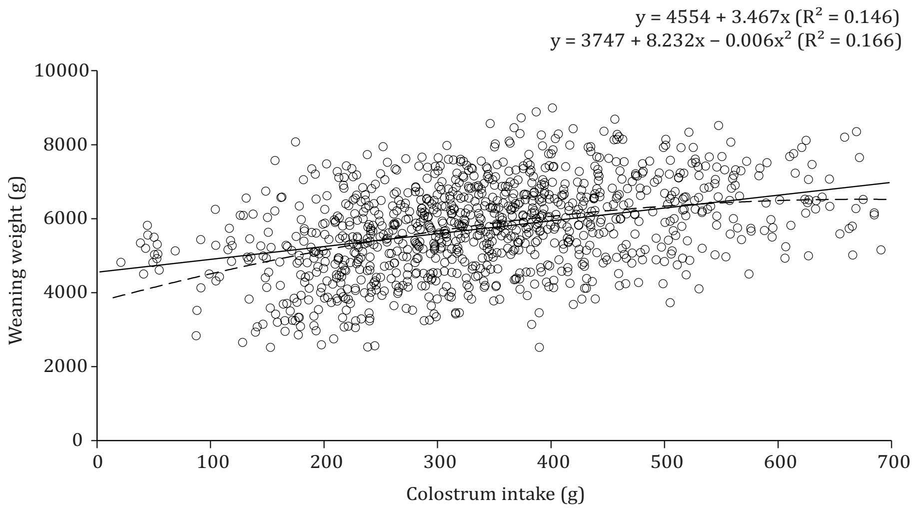
Significant linear and quadratic associations were identified when examining the relationship between birth weight and colostrum intake (P<0.05; Figure 4). Despite the crucial role of birth weight in the decision tree model and the significance of the previous equations, this variable (birth weight) accounted for only a limited proportion of the variance observed in the dataset (11.2% for the linear equation and 17.3% for the quadratic equation).

Linear and quadratic relationships (P<0.05) were also observed between colostrum intake and body weight at weaning (Figure 5). Once again, the proportion of variance explained by this factor was modest, at just 14.6% for the linear equation and 16.6% for the quadratic equation in the given dataset. The results of both modeling exercises underscore the significance of conducting exploratory studies. Colostrum intake and mortality rate are multifactorial and difficult to model. However, these responses are critical to the sustainability of swine production systems.



[1] A total of 2,050 piglets were considered.

Figure 4 - Colostrum intake according to piglet birth weight[1].



[1] A total of 2,050 piglets were considered.

Figure 5 - Piglet weaning weight according to colostrum intake[1].

4. Discussion

The present study reinforces the close association among birth weight, colostrum intake, and mortality from birth to weaning. In addition to mortality outcomes, the study provides practical thresholds for key biological indicators, such as colostrum intake and birth weight, which are highly relevant for on-farm risk assessment and management strategies. Piglets consuming less than 172 g of colostrum presented not only higher mortality, but also signs of impaired vigor and thermoregulation. These findings suggest that colostrum intake should be monitored as a performance indicator, not only as a survival factor. Moreover, sow body condition and birth order, which influenced birth weight and vitality, are important for management strategies aiming to enhance overall litter performance.

Low birth weight affects several vitality traits, thereby affecting colostrum intake (Theil et al., 2022). Milligan et al. (2002), Quiniou et al. (2002), Furtado et al. (2012), and Panzardi et al. (2013) have already reported higher mortality rates in low-birth-weight piglets. Among the driving factors for mortality, birth weight is the most crucial, with birth weight less than 897.5 g being a primary limiting factor (Theil et al., 2022).

The impact of low birth weight is well established in the literature. Additionally, low colostrum intake and low body temperature at birth are often associated with a greater predisposition to death due to crushing or anorexia, which may be related to energy and immunological deficiencies (Devillers et al., 2011). Moreover, piglets with low birth weight are susceptible to asphyxiation during the intrapartum period because they have a lower oxygen reserve capacity (Herpin et al., 2001). Despite being well established, these connections are often not well characterized quantitatively, as very few studies have included statistical assessments that allow the determination of critically low responses for both birth weight and colostrum intake. After assessing the database, these parameters were established at 897.5 g of birth weight, considering the impact on mortality, and 990 g when considering colostrum intake. On the other hand, the critical colostrum intake was established at 172 g when considering the mortality risk. Previous research has established similar values for colostrum intake (Devillers et al., 2011; Quesnel, 2011). However, in some studies, these values were not predefined using statistical analysis.

Tuchscherer et al. (2000) described disparities between piglets that did not survive within the initial 10 days of life and those that survived during this period. Survivors exhibited a higher birth weight, lower birth order, rapid colostrum intake following birth, and a smaller decline in rectal temperature after 1 hour, which is consistent with the results of the current study. Panzardi et al. (2013) observed elevated mortality rates in the first week in piglets with a higher birth order (>9), low birth weight (<1,275 g), elevated blood glucose concentrations (30–45 mg/dL) or lower temperatures (<38.1 °C) within 24 hours of life. Quiniou et al. (2002) found that piglets weighing less than 600 g at birth had a 25% chance of surviving until weaning. However, Furtado et al. (2012) observed that piglets weighing less than 900 g accounted for 25% of deaths before weaning. Smith et al. (2007) reviewed the effect of birth weight, quantifying that the lowest percentage of survival until weaning was found in piglets weighing less than 870 g. These findings provide compelling evidence that birth weight influences pre-weaning piglet survival.

Due to the high fertility rate and the consequent increase in the number of piglets born per litter, sows require high energy supply before the start of parturition during pregnancy, fetal growth, colostrum production, uterine contractions, and physical activities during childbirth (Theil et al., 2012). The low energetic state of females can delay uterine contractions and predispose them to an increased farrowing duration (Feyera et al., 2018). This negatively affects piglet vitality owing to oxygen deprivation and umbilical cord rupture (Edwards and Baxter, 2015). Consequently, the ability of piglets to suckle is reduced, resulting in delayed feeding, decreased colostrum intake, and mortality (Devillers et al., 2007). The first-born piglets have a lower risk of asphyxiation compared to later-born piglets (Devillers et al., 2011), which reduces oxygen levels and causes ischemia and hypoxia in tissues and organs (Hales et al., 2015), thereby compromising their performance and survival. Piglets born with respiratory difficulties were more likely to have low colostrum intake. These difficulties may be caused by the rupture of the umbilical cord or displacement of the membranes, which may ultimately cause mortality (Devillers et al., 2007). These findings were found in the current study, with the contribution of the piglet oxygenation variable as a significant factor for pre-weaning mortality, and the umbilical cord rupture variable as a significant factor for lower colostrum intake (<172 g).

The litter heterogeneity directly affects competition for the maternal udder during the first 24 hours of life. Thus, piglets with lower vitality may find it more difficult not only to meet the required colostrum intake but also to compete with other members of the litter throughout lactation (Milligan et al., 2002; Kobek-Kjeldager et al., 2020). As previously stated, Devillers et al. (2011) and Rooke and Bland (2002) suggested that 200 g of colostrum was sufficient to provide enough immunoglobulins in the intestinal mucosa, which is comparable to the value found in the present study (172 g). Thus, to ensure that piglets have a better chance of life, some strategies can be employed, such as improvements in farrowing housing and attempts to meet the nutritional needs of piglets (King et al., 2006; Bikker et al., 2010; Campbell et al., 2013; Costa et al., 2022) and sows (King et al., 2006).

The higher mortality rate of piglets born with rectal temperature below 38.35 °C in this study is consistent with the findings of Baxter et al. (2008) and Baxter et al. (2009), which reported higher body temperatures in surviving piglets. However, the accuracy of temperature measurements after birth is controversial. Panzardi et al. (2013) argued that the uterine environment may provide a more intense reflection than the external environment. Even so, thermoregulation capacity is a critical component for survival, and more information on this matter is certainly necessary (Tuchscherer et al., 2000; Casellas et al., 2004). In this study, birth order contributed to 29% of the predisposition for piglet mortality. This is particularly important in larger litters, as last-born piglets may face more difficulties in reaching an appropriate colostrum intake. In the present study, 40% of the sows with low body condition scores had light piglets (<990 g), and these piglets failed to ingest an adequate amount of colostrum. The importance of a proper feeding program for sows has been well established; however, surprisingly, few studies (Rehfeldt et al., 2004; Zou et al., 2017; Ferreira et al., 2021) have documented this quantitatively.

The current results are consistent with those of previous research conducted by Milligan et al. (2002) and Devillers et al. (2011), indicating that weaning weight is significantly influenced by factors such as birth weight and colostrum intake. These findings highlight the significant production challenges posed by the hyperprolificity of sows, which, while resulting in an increase in the number of piglets born, also present challenges due to the greater likelihood of piglets with low vitality (Oliviero et al., 2019).

The results of this study are similar to those of Quesnel et al. (2023), confirming that colostrum intake influences piglet survival and growth until weaning. These results also identified physiological indicators associated with reduced colostrum intake, including lower birth weight, prolonged births, and inadequate sow body condition. To explain the mortality factors, reviews by Devillers et al. (2011) and Hasan et al. (2019) were used, which reported similar findings, reinforcing the idea that birth weight and colostrum intake are the determining factors for the survival of neonates. Quesnel et al. (2023) reinforced that rectal temperature is also related to the factors that predispose to mortality. Hasan et al. (2019) observed that prolonging the duration of parturition and body condition score of the sow negatively affect colostrum production, which differs from the present study, where prolonged parturition and inadequate sow body condition were associated with reduced piglet colostrum intake. Other parameters evaluated, such as heart rate, blood glucose, oxygenation, presence of meconium, and umbilical rupture, could not be completely confirmed as contributing factors, although they may negatively affect colostrum intake and pre-weaning mortality. The average comparison table isolates the factors, but these are not sufficient to allow a better explanation of colostrum intake and pre-weaning mortality due to the complexity of the issue and the multiple contributing factors present in production systems. However, some of these aspects are noteworthy for future studies.

Gestation and lactation are crucial stages in pig production and are influenced by a multitude of physiological and environmental factors. Colostrum production, intake, and survival rates are critical factors that need to be further understood (Feyera et al., 2018). Although some connections among these factors are well known, others remain unclear. Vitality traits may provide valuable insights into the mechanisms underlying colostrum intake and survivability. Although measuring these traits can be challenging due to limited labor resources in farms, these are important variables to be considered in genetic improvement programs and research projects.

5. Conclusions

Our results demonstrated that the individual characteristics of piglets and sows have considerable and dynamic effects on colostrum intake and pre-weaning mortality rates. For example, traits such as birth weight, rectal temperature, oxygenation, umbilical cord rupture, birth order, farrowing duration, and sow body condition directly and indirectly influence colostrum intake and pre-weaning piglet mortality. Under practical conditions, these results are useful for defining appropriate management strategies to improve the survival, growth, health, and vigor of piglets at weaning. Even so, genetic selection based on pig vitality traits can enhance the ability of lineages to respond to survival challenges (pre- and post-weaning). This knowledge can contribute significantly to the sustainability of swine production systems.

Data availability

The data supporting this study will be shared upon reasonable request to the corresponding author.

Author contributions

Conceptualization: Camargo, M. F.; Galli, G. M.; Fraga, A. Z. and Andretta, I. **Data curation:** Camargo, M. F.; Galli, G. M.; Fraga, A. Z.; Cony, B. S. L.; Franceschi, C. H.; Martins, G. B.; Silva, J. P.; Pereira, M. M. C. and Alves, A. M. **Formal analysis:** Kipper, M. and Andretta, I. **Methodology:** Galli, G. M.; Fraga, A. Z. and Andretta, I. **Supervision:** Andretta, I. **Visualization:** Galli, G. M.; Fraga, A. Z. and Kipper, M. **Writing – original draft:** Camargo M. F. and Andretta I. **Writing – review & editing:** Camargo, M. F.; Galli, G. M.; Fraga, A. Z.; Kipper, M.; Cony, B. S. L.; Franceschi, C. H.; Martins, G. B.; Silva, J. P.; Pereira, M. M. C.; Alves, A. M. and Andretta, I.

Conflict of interest

The authors declare no conflict of interest.

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