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The impact of increased vitamin and mineral intake during early gestation on the reproductive performance of sows

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Abstract

This study investigated the effects of supplementing vitamins and minerals to sows during early gestation. A total of 36 primiparous sows were randomly assigned one day before mating to four dietary treatments that were applied from mating to day 30 of gestation. Treatment 1: low feed intake (1.5 kg/day) with standard vitamin and mineral provision (0.10% as fed); treatment 2: low feed intake (1.5 kg/day) with double the standard provision of vitamins and minerals (0.20% as fed); treatment 3: medium feed intake (2.0 kg/day) with standard vitamin and mineral provision (0.10% as fed); and treatment 4: high feed intake (3.0 kg/day) with standard vitamin and mineral provision (0.10% as fed). Results showed that sows in treatment 4 had the highest body weights at days 30 (179.17 kg) and 80 (211.97 kg) of gestation. Sows in treatments 2 and 4 also had numerically larger litters (12.50 and 12.74 piglets, respectively) than sows in treatments 1 and 3 (9.88 and 10.71 piglets, respectively), although this difference was not statistically significant. Additionally, treatment 2 and 4 sows tended to wean more piglets (11.00 and 11.20 piglets, respectively) than treatment 1 and 3 sows. Overall, both a high level of vitamin and mineral supplementation with a low feed intake (treatment 2), and a high feed intake with standard vitamin and mineral supplementation (treatment 4) during early gestation seemed to have the potential to increase litter size to a similar extent, although a high feed intake may be associated with non-significantly reduced piglet growth.

Keywords: feed intake, first parity, gestational nutrition, litter characteristics, micronutrient supplementation

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Introduction

A domestic sow typically produces 30–40 embryos during ovulation. After successful artificial insemination and conception, the number of embryos lost is around 20%–45% (Pope, 1988). A 20%–30% loss of embryos occurs during the early gestation stage, especially between 12 and 30 days after conception, which is known as the peri-implantation stage (Stroband *et al.*, 1990). The remaining embryo losses that occur in gestating sows happen between 50 and 90 days after conception, during mid-to-late gestation (Vallet *et al.*, 2011). It has been suggested that excessive feed should not be provided to

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animals during early gestation, as the resulting increase in body weight and metabolic rate increases progesterone clearance (Parr *et al.*, 1993). This leads to embryo losses and, consequently, a smaller litter size. The results of some studies have supported this theory (Dyck *et al.*, 1980; Peltoniemi *et al.*, 2000). However, recent studies have demonstrated that higher feed intakes during early gestation have no impact on embryo survival rates, despite changes in plasma progesterone concentrations (Athorn *et al.*, 2013). Furthermore, some studies have shown that increasing feed intake during early gestation benefits litter size performance (Leal *et al.*, 2019; Su *et al.*, 2025). Because of these conflicting results over the past 30 years, researchers have focused on the nutritional composition, including the energy, protein, and carbohydrate content, of early gestation sow diets. However, these nutritional components have not been shown to positively influence embryo survival rates (Chen *et al.*, 2012; Pedersen *et al.*, 2019).

An increase in feed intake not only increases the sow's protein and carbohydrate consumption, but also increases her vitamin and mineral intake, and this factor is often overlooked. The B-complex vitamins may affect a sow's early gestation, particularly as folic acid reduces embryo and foetal mortality rates (Fuchs *et al.*, 1996). Furthermore, additional vitamin B_{12} is essential because of its significant transfer to the uterus during early gestation (Guay *et al.*, 2002), suggesting that supplementation supports the physiological changes that takes place after conception. Cirillo *et al.* (2021) also proved that vitamins B_6, B_9, and B_{12} benefit fertility and conception rates in women. In addition, pregnant sows under oxidative stress need antioxidants such as vitamin A (Vince *et al.*, 1999), vitamin E (Wang *et al.*, 2017), and selenium (Chen *et al.*, 2016). Studies have reported positive associations between vitamin A and levels of progesterone (Panth *et al.*, 1991), which is vital for placental and maternal health. They have also shown that this vitamin enhances milk quality and blood parameters by protecting epithelial cells (Takahashi *et al.*, 2022). Dietary antioxidants may therefore reduce embryonic mortality and improve birth outcomes.

This study takes a novel approach by examining the effects of high vitamin and mineral supplementation levels at different feed intake levels in early gestation sows. To our knowledge, no prior research has directly addressed this topic; therefore, the present experiment serves as an initial step towards understanding the role of overall micronutrient dosage, rather than that of individual nutrient dosage. It was hypothesised that increased vitamin and mineral supplementation would improve litter size, independently of a high feed intake.

Materials and methods

All the animals used in this study were under the supervision of the International Animal Care and Use Committee of the National Pingtung University of Science and Technology (NPUST112-089). A total of 36 gilts (Landrace × Yorkshire × Duroc) from the same batch on a commercial farm were chosen (Zhong Yang pig farm, Pingtung, Taiwan). All the animals were raised in a fully temperature-controlled chamber. The gilts received 5 mL of Regumate® Porcine (0.4 w/v oral solutions; MSD Animal Health) at 18:00 daily, mixed with their diet, for at least 18 days after their second heat to control the synchronisation of oestrus. After discontinuing Regumate® for five days, the sows exhibited standing heat behaviour and underwent artificial insemination at 05:00 and 17:00 for three consecutive days.

Before mating, the 36 gilts (average body weight: 143.76 ± 0.58 kg) were randomly assigned to four treatment groups based on their body weight, with nine gilts per group and one gilt per pen. Each pen was equipped with a feeder and a nipple drinker. The composition of the experimental diets is shown in Table 1, and Table 2 presents the daily nutrient intake for each treatment group.

During early gestation (days 0–30 of pregnancy), the dietary treatments were as follows:

- Treatment 1: Low feed intake (1.5 kg/day) of a diet with a standard vitamin and mineral content (0.10% as fed), serving as the baseline and representing the commercial standard.
- Treatment 2: Low feed intake (1.5 kg/day) of a diet with double the standard vitamin and mineral content (0.20% as fed). The energy, carbohydrate, and protein intake is thus the same as in treatment 1, but the vitamin and mineral intake levels are comparable to those in treatment 4.
- Treatment 3: Medium feed intake (2.0 kg/day) of a diet with a standard vitamin and mineral content (0.10% as fed), corresponding to a medium nutrient intake.
- Treatment 4: High feed intake (3.0 kg/day) of a diet with a standard vitamin and mineral content (0.10% as fed), corresponding to a high nutrient intake.

The sows' feed intake was determined by the amount of feed offered, as all the sows consumed their daily ration completely. Consequently, because the vitamin and mineral premixes were provided at fixed inclusion rates (0.10% or 0.20%), the total daily intake of micronutrients increased proportionally with the feed allowance. Thus, treatment 3 and 4 sows had higher absolute vitamin and mineral intakes because of their greater feed consumption, whereas treatment 2 was designed to isolate the effect of an increased micronutrient concentration at a low feed intake level relative to the other treatments. Additionally, treatments 2 and 4 provided similar total micronutrient intakes with different total feed intakes, allowing the assessment of whether the feed intake level modifies the response to equivalent micronutrient intake levels (Table 2).

Table 1 Composition and calculated nutrient content of the dietary treatments (% on an as-fed basis)

Ingredients %	Gestation feed A[1]	Gestation feed B[2]	Lactation feed[3]
Maize	68.90	68.90	63.60
Soybeans	17.10	17.10	22.10
Wheat bran	8.00	8.00	8.00
Soybean oil	3.00	3.00	3.00
Dicalcium phosphate	1.40	1.40	1.70
Calcium carbonate	1.10	1.10	0.90
Salt	0.30	0.30	0.50
Mineral premix[4]	0.10	0.20	0.10
Vitamin premix[5]	0.10	0.20	0.10
Calculated nutrient content			
Digestible energy (kcal/kg)	3486.00	3486.00	3484.00
Crude protein (%)	14.40	14.40	16.40
Calcium (%)	0.80	0.80	0.86
Phosphorus (%)	0.38	0.38	0.46
Lysine (%)	0.74	0.74	0.88
Methionine + cysteine (%)	0.38	0.38	0.44

[1] Diet containing a standard vitamin and mineral content (0.1%), provided to sows in treatments 1, 3, and 4 during early gestation, and provided to all sows from day 31 of gestation until farrowing. [2] Diet containing double the standard dosage of vitamins and minerals (0.2%), provided to treatment 2 sows during early gestation. [3] Diet provided to all sows after farrowing and until weaning. [4] Mineral content per kg: ≥150 000 mg iron, 90 000–100 000 mg zinc, ≥60 000 mg manganese, 20 000–25 000 mg copper, ≥600 mg iodine, ≥300 mg selenium, and ≥300 mg cobalt. [5] Vitamin content per kg: 12 000 000 IU A, 1 500 000 IU D_3, 60 000 mg E, 2000 mg K_3, 2000 mg B_1, 10 000 mg B_2, 5000 mg B_6, 60 mg B_{12}, 30 000 mg pantothenic acid, 35 000 mg niacin, 3000 mg folic acid, and 300 mg biotin.

Table 2 Relative daily nutrient consumption of early gestation sows in four treatment groups

Nutrient levels	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Feed intake	Low (1×)	Low (1×)	Medium (1.3×)	High (2×)
Energy/protein/carbohydrate intake	Low (1×)	Low (1×)	Medium (1.3×)	High (2×)
Vitamin and mineral intake	Low (1×)	High (2×)	Medium (1.3×)	High (2×)

The gilts were housed in pens with partially slotted and solid concrete floors, with each pen equipped with a feeder and a nipple drinker. All the sows were housed in pens with the same design to minimise variation. Feed was provided on a restricted basis throughout the entire experimental period, while water was provided *ad libitum*. During early gestation, feed was provided in a mash form according to the treatments mentioned above.

The management practices applied during mid-gestation (days 31–79 of gestation), late gestation (day 80 of gestation to farrowing), and lactation (days 0–28 post-parturition) remained consistent in every group to avoid confounding variation. All the sows were fed gestation feed A during mid-gestation (2.2–2.6 kg/day) and late gestation (4.8 kg/day), and were fed lactation feed (4.8 kg/day) after farrowing. From gestation day 100 until farrowing, 500 g of feed was provided twice per day, and feed intake was gradually increased to 4.8 kg/day during the first week after farrowing. All sows farrowed naturally, without exogenous hormonal induction. Assistance was provided if a sow showed signs of distress during farrowing or if no progress was observed for 30 minutes after the birth of the last piglet.

Pregnancy diagnosis was performed on days 18, 25, and 35 of gestation, and the number of pregnant sows was 8, 7, 6, and 7 for treatments 1, 2, 3, and 4, respectively. The physical parameters recorded for the sows included the body weight, back-fat thickness, and body condition score, and these were measured one day before mating, as well as on days 30, 80, and 100 of gestation, and two and four weeks after farrowing. Back-fat thickness (mm) was measured using the Renco LEAN-MEATER®, while body condition score was assessed on a scale of 1 to 5, with 1: emaciated, 2: thin, 3: ideal, 4: fat, and 5: overly fat (Coffey *et al.*, 1999). Reproductive performance data were collected for the litter size (piglets per litter), number of stillbirths, farrowing period (time of day), farrowing duration (minutes), and the weaning-to-oestrus interval (days). The farrowing period was categorised based on the time of day at which farrowing occurred, with each day divided into four time slots: 1: early morning (00:00–06:00), 2: morning (06:00–12:00), 3: afternoon (12:00–18:00), and 4: night (18:00–24:00).

The average litter size was 11.38 piglets, and birthweight (kg) was recorded for a total of 318 piglets. The piglets were also weighed at two and four weeks of age, with weaning taking place at 28 days of age. The number of piglets weaned was also recorded for each treatment.

Data were collected and analysed using the Statistical Analysis System (SAS Institute, 2021). Differences between treatment means were evaluated using one-way analysis of variance (ANOVA), followed by Duncan's new multiple range test, with statistical significance set at $P<0.05$.

Results and discussion

Before 2010, the prevailing theory emphasised the importance of feed restriction during gestation to prevent embryonic losses. However, this view was challenged after 2010, as several studies suggested that increased feed intake could increase litter size. These represent two opposing perspectives. Notably, a higher feed intake also increases the daily intake of vitamins and minerals. Building upon this reasoning, the present experiment was designed to investigate whether vitamin and mineral supplementation during early gestation directly contributes to improving the reproductive performance of sows.

The sows' body weights during gestation are presented in Table 3.

Table 3 The body weights (kg) of pregnant sows managed using different feeding strategies during early gestation

Treatments[1]	**1**	**2**	**3**	**4**	**SEM**	***P*-value**
Initial body weight	145.10^{b}	143.03^{ab}	143.23^{ab}	142.01^{a}	1.04	0.0083
Day 30 of gestation	164.36^{a}	163.17^{a}	167.66^{a}	179.17^{b}	1.61	0.0001
Day 80 of gestation[2]	201.26^{a}	199.80^{a}	203.59^{a}	211.97^{b}	2.73	0.0020
Day 100 of gestation[2]	248.60	250.70	249.10	241.30	7.05	0.7184
2 weeks after farrowing[2]	210.55	211.95	217.10	198.12	8.27	0.1786
4 weeks after farrowing[2]	250.92	195.58	208.13	190.16	10.73	0.3731

[1] Treatment 1: low intake (1.5 kg/day) of a diet with a standard vitamin and mineral content (0.10%); treatment 2: low intake (1.5 kg/day) of a diet with double the standard vitamin and mineral content (0.20%); treatment 3: medium intake (2.0 kg/day) of a diet with a standard vitamin and mineral content (0.10%); and treatment 4: high intake (3.0 kg/day) of a diet with a standard vitamin and mineral content (0.10%). [2] From day 31 of gestation onwards, all sows received identical feeding management. Data after this point are observational and do not reflect the experimental treatments. [ab] Means in the same row with different superscripts differ significantly. SEM: standard error of the mean.

The treatment 4 sows, which had high feed intakes during early gestation, had higher body weights at day 30 ($P<0.0001$) and day 80 ($P=0.0020$) after mating. Higher feed intake has been linked to increased sow weight gain (Noblet *et al.*, 1985). In contrast, the back-fat measurements did not differ between the treatments (Table 4), although the treatment 4 sows had consistently higher back-fat values throughout the experiment. Additionally, the body condition scores (Table 5) of the treatment 4 sows increased to day 30 of gestation, and were significantly higher than those of the other treatments at day 80 of gestation (P = 0.0205). However, after farrowing, the sows in treatment 4 lost more body weight than those in the other treatments, as heavier sows have a greater ability to mobilise energy reserves (Girardie *et al.*, 2024).

During lactation, all sows received 4.8 kg of lactation feed daily, and no significant differences were observed in physical parameters between treatments. Under these conditions, sows in treatment 4 had the highest average body weight, indicating that they experienced the greatest metabolic burden from pregnancy onward, which likely resulted in higher levels of oxidative stress compared to the other treatments. This condition may persist until weaning (Toy *et al.*, 2009; Berchieri-Ronchi *et al.*, 2011) and could potentially lead to reproductive disorders, decreased reproductive performance, and reduced milk production, which may, in turn, further affect piglet growth (Li *et al.*, 2021).

Table 4 The back-fat (mm) thickness of pregnant sows managed using different feeding strategies during early gestation

Treatments[1]	**1**	**2**	**3**	**4**	**SEM**	***P*-value**
Initial body weight	18.63	19.29	18.14	20.00	3.51	0.5849
Day 30 of gestation	21.75	22.14	21.14	23.43	3.60	0.5571
Day 80 of gestation[2]	22.13	22.57	21.71	23.86	4.29	0.3931
Day 100 of gestation[2]	25.20	28.00	27.00	29.33	3.24	0.5446
2 weeks after farrowing[2]	22.67	20.75	23.83	25.40	3.87	0.2813
4 weeks after farrowing[2]	23.67	19.50	22.67	24.60	1.66	0.2941

[1] Treatment 1: low intake (1.5 kg/day) of a diet with a standard vitamin and mineral content (0.10%); treatment 2: low intake (1.5 kg/day) of a diet with double the standard vitamin and mineral content (0.20%); treatment 3: medium intake (2.0 kg/day) of a diet with a standard vitamin and mineral content (0.10%); and treatment 4: high intake (3.0 kg/day) of a diet with a standard vitamin and mineral content (0.10%). [2] From day 31 of gestation onwards, all sows received identical feeding management. Data after this point are observational and do not reflect the experimental treatments. SEM: standard error of the mean.

Table 5 The body condition scores[1] of pregnant sows managed using different feeding strategies during early gestation

Treatments[2]/ Items	**1**	**2**	**3**	**4**	**SEM**	***P*-value**
Initial body weight	3.13	3.00	3.00	3.00	8.43	0.1016
Day 30 of gestation	3.00	3.07	3.00	3.21	4.41	0.3718
Day 80 of gestation[3]	3.19^a	3.36^a	3.36^a	3.79^b	4.41	0.0205
Day 100 of gestation[3]	3.70	3.83	3.70	3.83	2.30	0.9729
2 weeks after farrowing[3]	3.00	3.13	3.00	2.70	3.84	0.2858
4 weeks after farrowing[3]	3.17	3.00	3.17	3.00	3.84	0.1034

[1] Body condition scores were assigned as 1: emaciated, 2: thin, 3: ideal, 4: fat, and 5: overly fat. [2] Treatment 1: low intake (1.5 kg/day) of a diet with a standard vitamin and mineral content (0.10%); treatment 2: low intake (1.5 kg/day) of a diet with double the standard vitamin and mineral content (0.20%); treatment 3: medium intake (2.0 kg/day) of a diet with a standard vitamin and mineral content (0.10%); and treatment 4: high intake (3.0 kg/day) of a diet with a standard vitamin and mineral content (0.10%). [3] From day 31 of gestation onwards, all sows received identical feeding management. Data after this point are observational and do not reflect the experimental treatments. [ab] Means in the same row with different superscripts differ significantly. SEM: standard error of the mean.

Table 6 shows that the different nutrient intakes in early gestation did not affect the pregnancy rate in this study. However, sows receiving high levels of vitamins and minerals at either low (treatment 2) or high (treatment 4) feed intakes had numerically higher litter sizes than the control (P = 0.1211), suggesting a potential biological trend. Both groups received the same daily amounts of vitamins and minerals, but the total feed intake differed. Notably, treatments 2 and 4 produced slightly more piglets than treatments 1 and 3, and this difference approached statistical significance. These results align with previous findings indicating that higher feed intake in early gestation can enhance litter size (Su *et al.*, 2025). The comparable reproductive performance of treatment 2 sows, despite their lower feed intakes, underscores the importance of vitamin and mineral supplementation during early gestation. Although the difference did not reach statistical significance (P = 0.1211), the observed numerical trend may still hold biological relevance and warrants further investigation with a larger sample size.

Table 6 Impact of early gestation feeding strategies on sow reproductive performance

Treatments[1]	1	2	3	4	SEM	*P*-value
Sow traits						
Pregnancy rate[2]	1.11	1.22	1.22	1.22	0.15	0.9332
Litter size (number of piglets)	9.88	12.50	10.71	12.74	1.00	0.1211
Stillbirths (number of piglets)	0.25	0.43	0.67	0.71	0.28	0.6104
Farrowing period[3]	3.33^b	1.67^a	1.80^a	3.33^b	0.41	0.0064
Farrowing duration (minutes)	94.50	106.00	116.20	111.17	17.90	0.8017
Progeny traits						
Birthweight (kg)	1.58	1.72	1.63	1.44	0.14	0.5326
2-week-old body weight (kg)	5.03	5.28	4.87	3.73	0.44	0.1076
Weaning weight (28 days, kg)	9.75	8.06	8.99	7.16	0.93	0.2052
Number of piglets weaned	7.67	11.00	7.33	11.20	1.16	0.0656
Weaning-to-oestrus interval (days)	3.50	4.25	3.33	4.00	0.40	0.4396

[1] Treatment 1: low intake (1.5 kg/day) of a diet with a standard vitamin and mineral content (0.10%); treatment 2: low intake (1.5 kg/day) of a diet with double the standard vitamin and mineral content (0.20%); treatment 3: medium intake (2.0 kg/day) of a diet with a standard vitamin and mineral content (0.10%); and treatment 4: high intake (3.0 kg/day) of a diet with a standard vitamin and mineral content (0.10%). [2] Pregnancy rate was coded as 1: pregnant, 2: not pregnant. The values presented are group means, with values close to 1 indicating high pregnancy rates. [3] Farrowing period was coded as 1: early morning (00:00–06:00), 2: morning (06:00–12:00), 3: afternoon (12:00–18:00), 4: night (18:00–24:00). [ab] Means in the same row with different superscripts differ significantly. SEM: standard error of the mean.

Whittemore *et al.* (2002) outlined the NRC mineral recommendations for breeding sows, emphasising their crucial role in reproductive success. Selenium, owing to its antioxidant properties, reduces the risk of foetal losses during early gestation. Hostetler *et al.* (2003) highlighted the importance of trace minerals in foetal development. Vitamin E has been shown to improve embryonic development and survival (Lindemann *et al.*, 2008), while vitamin A supports foetal growth. However, the efficacy of vitamin E is limited by its restricted placental transfer, unlike vitamin C, which crosses the placenta more efficiently (Pinelli-Saavedra *et al.*, 2005). This suggests that vitamin E primarily acts at the uterine level to protect embryo survival. The B-vitamins function as coenzymes in the tricarboxylic acid cycle, thereby enhancing metabolic efficiency. Matte *et al.* (2006) reported that folic acid supplementation during early gestation increases litter size and reduces embryo mortality. In addition, vitamin B_6 has been shown to lower blood oestrogen levels and increase progesterone levels in women (Abraham, 1983). Although vitamins B and C can enhance progesterone concentrations, their water-soluble nature may limit their long-term effectiveness.

Micronutrients – including vitamins A, B-complex, and E, as well as selenium – are known to contribute to antioxidant defence and epithelial integrity. While oxidative stress was not directly evaluated here, the improved litter outcomes could reflect a general enhancement in metabolic and cellular protection. Parr *et al.* (1993) demonstrated that a high feed intake may increase the progesterone clearance rate, potentially influencing reproductive performance. Although progesterone levels were not measured in the present study, the improved litter sizes of the sows in treatment 4 might be partly related to a better metabolic or hormonal balance supported by an adequate micronutrient supply. Razdan *et al.* (2004) indicated that feed deprivation in early gestation increases progesterone levels because of acute stress responses and reduced liver clearance. Similarly, Langendijk *et al.* (2017) noted that while low feed intake temporarily elevates plasma progesterone levels, it does not sustain them in the long term. Based on this concept, sows in treatment 1 (low intake of a diet with a standard vitamin and mineral content) may have experienced an initial rise in progesterone but failed to sustain elevated levels beyond implantation (around day 21), which could have compromised embryo survival. In contrast, sows in treatment 2 (low intake of a diet containing high levels of vitamins and minerals) may have exhibited improved reproductive performance through reduced progesterone clearance and enhanced micronutrient status, thereby indirectly supporting embryo survival. Nevertheless, since neither progesterone concentrations nor antioxidant markers were measured in this study, this interpretation remains speculative. Future research should investigate whether micronutrient supplementation is positively correlated with progesterone concentration. Sows in treatment 3, which received a relatively moderate intake of protein, carbohydrates, vitamins, and minerals, also had numerically larger litters than the control group.

Observations of the farrowing period revealed that sows preferred to farrow in the early morning and late afternoon. Phillips *et al.* (2000) indicated that sows prefer to choose cooler flooring when preparing to give birth, suggesting that they tend to farrow during cooler times of the day. In this study, the farrowing house maintained a routine temperature of 28 °C during the daytime (06:00–18:00) and 24 °C at night (18:00–06:00). Therefore, sows preferred to farrow before 06:00, when temperatures were lowest, and in the late afternoon, as the temperature began to decrease, ensuring a more comfortable environment.

Farrowing duration did not differ significantly between the treatments (P >0.100); however, in treatment 4, it was numerically higher, in association with both litter size and the number of stillborn piglets (Table 6). Prolonged farrowing in sows with larger litters may elevate stillbirth rates or reduce neonatal viability (van Dijk *et al.*, 2005; Oliviero *et al.*, 2010; Langendijk *et al.*, 2018), likely due to energy deficits and/or complications during the expulsion process (Manu *et al.*, 2019). Feyera *et al.* (2018) reported that increasing feeding frequency in transition sows reduced the time from the last feeding to farrowing, likely as a result of higher arterial blood glucose concentrations and shorter farrowing durations, since glucose is critical for uterine contractions and colostrum synthesis (Tucker *et al.*, 2022).

In the present study, all sows were managed using the same feeding strategy after the early gestation stage. Nevertheless, sows in treatment 2, who also produced larger litters, tended to exhibit shorter farrowing durations and have fewer stillbirths than those in treatment 4. Moreover, the piglets produced by the treatment 4 sows were lighter at two weeks of age (P = 0.1076), although the difference was not statistically significant. This suggests that heavier sows may be at a higher risk of prolonged farrowing and reduced piglet survival. The prolonged farrowing observed in the heavier sows of treatment 4 likely contributed to increased oxidative stress during this period. Oxidative stress has been reported to increase stillbirth rates, induce inflammation, and reduce the number of live-born piglets, litter size, and litter weight (Yang *et al.*, 2023). Weldon *et al.* (1991) suggested that excessive energy or feed intake may lead to the replacement of mammary tissue with fat before proper development. Both oxidative stress and fat accumulation in the mammary tissue could limit milk availability for piglets during the first two weeks post-partum, ultimately resulting in lower piglet body weights. Although no significant difference was observed in weaning weight (P = 0.2052), both of the treatments that produced large litters tended to have lighter piglets, particularly treatment 4. Alvarenga *et al.* (2013) reported that piglets with low birthweights have reduced mucosal height, which may result in impaired intestinal absorption.

The number of weaned piglets showed a trend towards higher values in treatments 2 and 4, which had the largest litter sizes (P = 0.0656), while the weaning weight in these groups was numerically lower; however, neither difference reached statistical significance. Although reproductive performance differences were not statistically significant, the observed numerical increases, together with the significant effects on sow body weight and body condition score measured in the same sows, suggest that these findings still provide biologically meaningful insights. These outcomes may be related to intrauterine growth restrictions, which often occur in larger litters and can reduce weaning weight. In addition, large litter sizes raise welfare concerns (Rutherford *et al.*, 2013), as sows experience increased production pressure, leading to severe oxidative stress, while piglets face a higher risk of stillbirth, low birthweight, and intense teat competition. Although high feed intake during early gestation can increase litter size, it may also exacerbate these issues. Therefore, low feed intake combined with high vitamin and mineral supplementation may help maintain a balanced uterine environment without inducing excessive oxidative stress. Micronutrients not only support uterine health but also help regulate oxidative stress, thereby promoting better reproductive outcomes. These findings suggest that optimised vitamin and mineral intakes, in combination with appropriate feeding strategies, may enhance reproductive performance while reducing oxidative stress-related complications.

This study provides preliminary evidence that vitamin and mineral supplementation may enhance reproductive performance in sows during early gestation. However, because of the deductive approach employed, the specific contributions of individual vitamins and minerals could not be determined. This study also has limitations related to the small sample size, the absence of mechanistic measurements (e.g. reproductive hormone and oxidative stress marker levels), and the use of only primiparous sows. Nonetheless, this work represents the first phase of a broader experimental series. Building on these findings, subsequent experiments will focus on mechanistic aspects by examining reproductive hormones, oxidative stress, and their relationships with reproductive and/or growth performance, as well as evaluating effects in multiparous sows. Future research should also aim to identify the key micronutrients responsible for these effects, optimise supplementation levels, and clarify the underlying physiological mechanisms to enhance reproductive outcomes and inform practical feeding strategies.

Conclusions

In conclusion, both a low feed intake with high levels of vitamin and mineral supplementation and a high feed intake with standard levels of vitamins and minerals were associated with higher litter sizes. These results suggest that increasing vitamin and mineral supplementation during early gestation was associated with a numerical improvement in sow reproductive performance, even under conditions of low feed intake. However, excessive feed intake may have a detrimental effect on piglet growth. Overall, these preliminary findings suggest a potential biological trend that warrants further investigation, while highlighting the possible advantage of combining low feed intake with high levels of vitamin and mineral supplementation as a strategy to maintain reproductive performance without negatively affecting piglet growth.

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Authors' contributions

S.S.P. conducted the experiments, collected the data, and drafted the manuscript. L.C.H. designed the experiment, performed the statistical analysis, provided funding support, approved the final manuscript, and supervised the research. W.J., J.W.L., and Y.D.H. contributed to research guidance and provided critical suggestions. All authors have read and approved the final manuscript.

Conflict of interest declaration

We certify that there is no conflict of interest with any financial organisation regarding the material discussed in the manuscript.

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