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Effect of dietary supplementation of organic trace minerals on the performance of sows and their offsprings

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ABSTRACT

Trace minerals are essential for growth, reproduction and health of pigs. Organic form of trace minerals is found to be better available compared to inorganic form in animals. This study aimed to assess the effect of dietary supplementation of organic trace minerals at different levels on the performance of sows and their progeny. Control diet was prepared by supplementing inorganic trace minerals at 100% of requirement and test diets were prepared by supplementing organic trace minerals at 100% and 75% of requirement as per NRC (2012). Each diet was assigned to six sows from 90th day of gestation to farrowing (gestation diet, fixed diet allowance) and from farrowing to weaning (lactation diet, *ad libitum* feeding). The daily feed consumption, body weight, body weight changes and backfat thickness of sows remained similar among different groups during gestation and lactation phases. The number of total litters born, live litters born, stillbirths and piglets weaned including percentage survivability did not differ significantly among experimental groups. No significant effect was observed in duration of farrowing and wean to estrus interval. The body weight and average daily gain of piglets born to different experimental groups were similar to each other. The complete blood profile, serum enzymes (SGOT, SGPT, ALP, CRT) and protein fractions (total protein, albumin, globulin) of sows were comparable among different groups. It was concluded that that organic trace minerals can be incorporated at 75 % of the requirement without affecting productive and reproductive performance of sows.

Keywords: Organic form, Piglets, Reproductive performance, Sow, Trace minerals

Pig farming is one of the profitable and lucrative livestock enterprises. Feed accounts for 60–70% of the cost of pig production. Pig feed should contain required level of energy and protein including minerals and vitamins to achieve optimal production, reproduction and health. However, inclusion of minerals is often neglected in pig feeds since it constitutes less than 5% in diets. Although the minerals are required in less quantity, they play a pivotal role in animal body. Among various minerals, the micro minerals or trace elements such as copper (Cu), zinc (Zn), manganese (Mn), iron (Fe), selenium (Se) and iodine (I) have important role to play in overall health and reproductive performance of sows (McDowell 2003). Under small scale pig production, farmers tend to overlook the supplementation of minerals. The deficiency of trace minerals in the diet can reduce animal production by 20–30% (Overton and Yasui 2014). Thus, the common practice under commercial conditions is to include trace minerals above standard recommendations in the diets. The use of organic trace minerals has slowly gained acceptance over last 15 years as scientific evidence shows the advantages of this form of trace minerals. Dietary supplementation with organic trace minerals has been reported to enhance sow reproductive performance (Peters and Mahan 2008, Byrne and Murphy 2022), trace mineral content in milk, amount of trace minerals transferred across the placenta to the foetus (Peters *et al.* 2010), and reduce fecal mineral excretion (Burkett *et al*. 2009, Zhang *et al.* 2021). The aforementioned studies indicated that dietary supplementation of organic trace minerals improved the reproductive performance of sows and their litters. However, the level of inclusion of organic trace minerals needs to established for optimal reproductive performance of pigs and their litters under Indian context. Hence, a study to investigate the effect of dietary supplementation of organic trace minerals at different levels on the reproductive performance of Large White Yorkshire sows and their litters under tropical conditions was attempted.

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MATERIALS AND METHODS

The protocols used in the experiment were approved by the Institutional Animal Ethics Committee of Veterinary College, Bengaluru, India as per the guidelines of the Committee for Control and Supervision of Experimentation on Animals (CCSEA), New Delhi. This trial was conducted at the Department of Livestock Farm Complex, Veterinary College, Bengaluru located at latitude 13º04' N, longitude 77º61' E and altitude 916 m MSL.

Experimental diets: The organic trace minerals (OTM) employed in this experiment were proteinate in nature and was supplied by M/s Zeus Biotech Pvt. Ltd., Mysuru, India. The basal diets for gestation and lactation phases were formulated as per NRC (2012). Further, the control diet was prepared by incorporating inorganic trace minerals to the basal diet @ 2Kg/tonne to meet 100 per cent requirement (OTM 100) and test diets were prepared by incorporating organic trace minerals to the basal diet @ 2 Kg/tonne and 1.5 Kg/tonne to meet 100 % (OTM 100) and 75 % (OTM 75) of requirement, respectively as specified by NRC (2012). The ingredient and nutrient composition of control diet prepared for gestation and lactation phase is given in Table 1.

Experimental animals: Eighteen Large White Yorkshire sows from the drove of 38 sows, as and when reaching 85–90th day of gestation were selected based on the records available at farm i.e., date of successful mating. Each group was randomly assigned with six sows totalling to 18 sows in the experiment. The selected sows were fed with respective gestation diet till farrowing followed by lactation diet till weaning. The weaning was done on 35th day of lactation phase.

Table 1. Ingredient and nutrient composition of control diets

Ingredient (kg)	Gestation diet	Lactation diet
Maize	66.0	63.5
Soybean meal	14.0	22.0
Wheat bran	18.0	10.0
Sunflower oil	0	2.5
Di–calcium phosphate	0.6	0.6
Calcite powder	1.2	1.1
L–Lysine	0.1	0.2
Vitamin premix	0.1	0.1
Common salt	0.5	0.5
Trace mineral premix*	0.2	0.2
Total	100.7	100.7
Calculated nutrients (%)		
Digestible energy (Kcal/kg)	3206	3419
Metabolizable energy (Kcal/kg)	3110	3289
Net energy (Kcal/kg)	2344	2479
Crude protein	14.20	16.28
Crude fiber	3.60	3.46
Calcium	0.68	0.66
Total phosphorus	0.54	0.51

*Inorganic trace minerals, each 200 g provided Cu: 5 (gestation diet) and 10 (lactation diet), Zn: 50, Mn: 12.5, Fe: 40, Se: 0.08 and I: 0.07 ppm

Performance of sows: Measured quantity of feed in gestation phase and *ad libitum* feeding in lactation phase was offered individually to all the animals and feed intake was calculated. Body weight of each sow was recorded at beginning of the experiment i.e. 90th day of gestation, on the day of farrowing and on the day of weaning (35th day after farrowing). Back fat thickness of individual sow was recorded during weighing. Number of live born and stillbirth were recorded after each farrowing. The weight of individual piglets was also taken immediately after birth to calculate litter weight. The time taken from birth of first piglet to last piglet was recorded. After weaning, the sows were also under close observation to detect the estrus symptoms. The duration from weaning to until it comes to first heat was recorded as wean to estrus interval. The symptoms like stand by reflex, estrous discharge and mounting behavior was considered to detect the heat.

Performance of piglets: Body weight of individual piglet was measured on the 1st day and cumulative weight of all piglets born was calculated. Body weight of individual piglet was also measured on 3rd, 5th, 21st day and at weaning (35th day) and cumulative weight of the all piglets was calculated. The average daily gain was calculated for different intervals. The ratio of total weaned to born litter size was calculated as percentage of survival rate of piglets.

Blood parameters: On 15th day of the experiment in gestation phase and on the 21st day after farrowing in lactation phase, four sows were randomly selected from each treatment and blood was collected by puncturing the ear vein of the sow into 5 mL test tubes with anti–coagulant. Similarly, four piglets were randomly selected from each treatment and blood was collected by puncturing the cranial vena cava of the piglets in 5 mL test tubes with anti–coagulant on 21st day. The blood samples for complete blood count were processed immediately to estimate total erythrocyte count (TEC), total leucocyte count (TLC), haemoglobin (Hb), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), MCH concertation (MCHC), platelet count, mean platelet volume (MPV), platelet distribution width (PDW) and platelet crit (PCT) using BC–2800 Vet Auto Haematology Analyzer. On same day (21st day of lactation phase or piglet age), another set of blood samples were collected in 5 ml test tubes without anti–coagulant and serum was separated as per the standard procedures (Calneck *et al.* 1992). The individual serum samples were analyzed for various biochemical parameters viz., serum glutamic oxoacetate transaminase (SGOT), serum glutamic pyruvate transaminase (SGPT), creatinine, alkaline phosphatase (ALP), total protein and albumin using biochemical semi–auto analyzer (Micro Lab, RX–50) and Erba analysis reagent kits as per the manufacturer's specification. The serum globulin content was obtained by subtracting albumin values from total protein content in serum (Sugiharto *et al.* 2018).

Table 2. Feed consumption, body weight, body weight changes and backfat thickness of experimental sows (n=6) at different phases

Physiological stage	T1 100% ITM	T2 100% OTM	T3 75% OTM	SEM	*p* value
Feed consumption (kg/d, as fed basis)					
Gestation phase	2.59	2.59	2.60	0.014	0.971
Lactation phase	5.60	5.54	5.86	0.146	0.672
Body weight (kg)					
At gestation (90^{th} day)	171.67	180.17	181.50	2.264	0.270
At farrowing (before)	182.04	190.14	191.62	2.341	0.318
At farrowing (after)*	168.01	176.64	177.93	2.259	0.261
At weaning (35^{th} day)	161.33	171.33	173.33	2.765	0.272
Body weight change (Kg)					
Gestation phase (gain)	10.38	9.98	10.12	0.467	0.955
Lactation phase (lost)*	6.67	5.31	4.59	1.375	0.864
Backfat thickness (mm)					
At gestation	17.50	16.17	17.00	0.529	0.589
At farrowing	16.50	16.00	16.00	0.406	0.883
At weaning	15.83	15.17	15.33	0.459	0.841

n: Number of animals, ITM: Inorganic trace minerals, OTM: Organic trace minerals, *Excluding conceptus weight

Statistical analysis: Data collected during the trial were analysed by analysis of variance (ANOVA) method as described by Snedecor and Cochran (1995). Tukey's post hoc test was applied if differences were found to be significant at $p<0.05$.

RESULTS AND DISCUSSION

Performance of sows: The feed intake, body weight, body weight changes and backfat thickness of sows during gestation and lactation phase are represented in Table **2**. There was no significant difference ($p>0.05$) in feed intake during gestation and lactation phases among the experimental groups. Acda and Chae (2002a) and Peters and Mahan (2008) also found no significant difference with daily feed intake of sows fed organic trace minerals at different levels. Feed intake during gestation is often restricted in pigs to prevent excessive weight gain, which can lead to complications during farrowing and reduce the sow's productivity. Feeding sows *ad libitum* during lactation is a common practice to ensure that the sow receives enough feed to support milk production and maintain her body weight and condition.

The absolute body weight and body weight changes of sows during gestation and lactation phases were not significantly different ($p>0.05$) among the experimental groups. Lima *et al.* (2006) also found insignificant difference in sow body weight, at the 100^{th} day of gestation, farrowing and weaning. The mean sow body weight increased from gestation to farrowing but the weight loss occurred during lactation because of high demands of energy associated with milk production. Additionally, after farrowing the sow experience a significant loss of body fluid due to birth process. This can result in temporary drop in body weight. To compensate for the energy deficit during the lactation, sows mobilize their body fat reserve to provide energy for milk production. This results in a loss of body weight during early lactation period.

The mean back fat thickness of sows among the experimental groups were non–significant during gestation, farrowing and weaning phases. The back fat thickness of sows at weaning was lower than the values at farrowing. This is essentially due to compensate for the energy deficit during the lactation, sows mobilize their body fat reserve to provide energy for milk production. This results in a loss of body weight during lactation period and back fat too. Lima *et al.* (2006) also found no significant treatment effect ($p>0.05$) on back fat thickness at 100^{th} day of gestation, farrowing and weaning. However, the present values were not comparable with Martineau (2017), this might be due to longer duration of experiment.

The number of live offspring born and number of stillbirth (Table 3) were non–significant ($p>0.05$) among different groups. Lima *et al.* (2006) also found no significant difference with average total litter born (10.43 to 11.22) and number of live litters born (9.45 to 10.29). The comparability of stillbirth rates between the present study and Martineau (2017) may be limited due to differences in sow feeding duration. Specifically, in Martineau (2017) study, sows were fed with organic trace minerals during the first two parities, resulting in increased bioaccumulation of trace minerals due to better availability. The number of litters weaned for different groups were similar to each other. Contrarily, Fehse and Close (2000) reported that sows fed a proportion of their mineral allowance in organic form (Zn, Mn, Fe, Cu, Se, Cr) showed better overall productivity than those fed only the inorganic sources. This meant 0.3 extra piglets weaned per litter, or 0.7 more piglets per sow per year. The value expressed in terms of percentage survivability from birth to weaning was also comparable among the experimental groups.

The mean duration of farrowing was 179, 176 and 160 minutes and wean to estrous interval were 8.83, 7.73 and 6.67 days in T1, T2 and T3 groups, respectively. There was no significant difference in duration of farrowing among the experimental groups. The size of the litter can also impact farrowing duration. Sows with larger litters may take longer to farrow than those with smaller litters. Similarly, no significant difference was observed in wean to estrus interval of sows among the experimental groups. The results were similar to findings of Lima *et al.* (2006)

Table 3. Absolute body weight and average daily gain of piglets (n = 48 to 65)

Attribute	T1 100% ITM	T2 100% OTM	T3 75% OTM	SEM	*p* value
Litter performance					
No. of live born	10.33	10.83	10.83	0.719	0.961
No. of stillbirths	0.17	0.67	0.00	0.135	0.105
No. of piglets weaned	8.00	8.17	8.17	0.498	0.991
% survivability	77.44	75.43	75.43	3.319	0.914
Absolute body weight (kg) of piglets					
1st day	1.29	1.12	1.27	0.479	0.326
3rd day	1.56	1.47	1.55	0.055	0.819
5th day	1.95	1.90	1.94	0.086	0.970
21st day	5.10	5.19	5.25	0.322	0.981
35th day	7.46	8.15	8.01	0.579	0.887
Average daily gain (g) of piglets					
1–3 d	88.3	116.9	96.4	10.96	0.565
4–5 d	194.2	210.6	194.6	24.60	0.964
6–21 d	196.7	206.2	206.8	16.20	0.969
22–35 d	169.0	211.4	196.7	26.14	0.806
1–5 d	130.6	154.4	135.7	13.30	0.769
1–21 d	181.0	193.9	189.9	14.54	0.938
1–35 d	176.21	200.89	192.61	16.392	0.830

n: No. of animals, ITM: Inorganic trace minerals, OTM: Organic trace minerals

who noticed similar wean to estrous interval. Contrarily, Peters (2006) observed lesser wean to estrus interval in sows fed organic trace minerals for longer duration. The improved bioavailability of minerals in organic form can lead to increased follicle development and improved oocyte quality, and enhanced immune function, all of which can contribute to better reproductive performance. Zinc and copper are essential micronutrients that are involved in the synthesis of enzymes and proteins involved in follicle development and oocyte maturation. In addition, organic trace minerals can also improve immune function in sows. For example, selenium is an important micronutrient that is essential for optimal immune function. Selenium deficiency can lead to impaired immune function, increased susceptibility to infections, and reduced reproductive performance.

Performance of piglets: The mean absolute body weight and average daily body weight gain of piglets born to sows belongs to different groups are presented in Table 3. There was no significant difference (p>0.05) in absolute body weight of piglets among the experimental groups on 1st, 3rd, 5th, 21st and 35th day. Hence, average daily gain of piglets among the experimental groups were

Table 4. Complete blood profile of experimental sows (n=4) and piglets (n=4)

Attribute	T1 100% ITM	T2 100% OTM	T3 75% OTM	SEM	*p* value
No. of animals	6	6	6		
Sows at 105th day of gestation					
WBC (x10³/µL)	9.65	11.88	13.13	1.146	0.477
RBC (x10⁶/µL)	5.84	7.70	6.88	0.250	0.212
Hb g/dl	12.38	13.60	13.93	0.457	0.383
HCT %	39.70	43.78	44.15	1.430	0.446
MCV fL	68.10	65.45	64.40	0.921	0.249
MCH pg	21.15	20.25	20.23	0.265	0.345
MCHC g/dl	31.13	31.00	31.45	0.114	0.261
PLT (x10³/µL)	143.25	122.25	199.25	29.387	0.580
MPV (fL)	8.85	8.40	9.00	0.276	0.692
PDW	18.03	17.70	17.85	0.241	0.871
PCT %	0.13	0.10	0.18	0.027	0.533
Sows on 21st day of lactation					
WBC (x10³/µL)	14.53	16.13	15.93	0.839	0.754
RBC (x10⁶/µL)	5.60	6.88	6.18	0.380	0.397
Hb g/dl	12.00	14.70	12.85	0.784	0.376
HCT %	36.93	47.35	40.60	2.689	0.281
MCV fL	66.93	68.48	65.85	1.094	0.637
MCH pg	21.73	21.20	20.75	0.365	0.568
MCHC g/dl	32.50	31.08	31.60	0.286	0.099
PLT (x10³/µL)	212.25	330.25	204.75	37.462	0.383
MPV fL	8.63	8.75	9.25	0.230	0.552
PDW	17.08	16.98	17.08	0.103	0.930
PCT %	0.19	0.29	0.19	0.031	0.456
Piglets at 21st day of age					
WBC (x10³/µL)	14.83	14.90	16.73	0.761	0.605
RBC (x10⁶/µL)	6.40	6.67	6.48	0.178	0.830
Hb g/dl	9.80	9.98	10.80	0.613	0.815
HCT %	32.18	31.03	35.73	1.566	0.482
MCV fL	51.28	46.63	55.23	2.666	0.431
MCH pg	15.58	14.80	16.60	0.937	0.753
MCHC g/dl	30.25	31.88	30.10	0.810	0.684
PLT (x10³/µL)	492.00	341.50	450.50	43.997	0.380
MPV (fL)	7.60	8.00	8.08	0.335	0.857
PDW	15.43	15.13	15.58	0.133	0.392
PCT %	0.36	0.27	0.36	0.027	0.346

n: No. of animals, ITM: Inorganic trace minerals, OTM: Organic trace minerals

Table 5. Serum profile of sows (n=4) and their piglets (n=4)

Attribute	T1 100% ITM	T2 100% OTM	T3 75% OTM	SEM	*p* value
Sows on 21st day of lactation					
SGOT (IU/L)	50.61	51.42	51.58	4.046	0.996
SGPT (IU/L)	98.10	90.53	102.41	5.462	0.710
ALP (IU/L)	112.15	292.09	145.19	52.509	0.387
Creatinine (mg/dl)	1.00	1.00	1.07	0.104	0.972
Total protein (g/dl)	8.50	9.23	8.43	0.198	0.225
Albumin (g/dl)	2.67	2.37	2.27	0.178	0.692
Globulin (g/dl)	5.83	6.87	6.17	0.263	0.280
Piglets on 21st day of age					
SGOT (IU/L)	53.44	46.92	48.45	2.804	0.669
SGPT (IU/L)	35.92	31.55	41.87	2.073	0.137
ALP (IU/L)	555.61	552.53	494.78	36.896	0.780
Creatinine (mg/dl)	0.35	0.45	0.40	0.023	0.234
Total protein (g/dl)	7.75	12.88	9.97	0.983	0.108
Albumin (g/dl)	1.82	3.23	2.05	0.267	0.095
Globulin (g/dl)	5.93	9.65	7.92	0.733	0.121

n: No. of animals, ITM: Inorganic trace minerals, OTM: Organic trace minerals

also remained similar among different groups at different intervals. Similar observation was made by Acda and Chae (2002b). McClellan *et al.* (2025) had indicated that enhancing maternal iron transfer through organic dietary sources can be a practical strategy to improve neonatal iron status and support early piglet development. However, the present study indicated that supplementation of organic trace minerals in sow diets has no significant effect on the body weight and daily body weight gain of piglets.

Blood parameters: The haematological parameters of sows under different groups during gestation and lactation phases are presented in Table 4 and the serum biochemistry of sows in lactation phase and their litters is presented in Table 5. There was no significant difference (p>0.05) in TEC, TLC, Hb, HCT, MCV, MCH, MCHC, platelet count, MPV, PDW and PCT among the experimental groups in both gestation and lactation phases. There was no significant difference (p>0.05) among the experimental groups for SGOT, SGPT, ALP, creatinine, total protein, albumin and globulin during lactation phase. Similarly, there was no significant difference in blood and serum parameters of piglets born to different experimental groups of sows. Although non–significant, Hb concentration in sows supplemented with organic minerals are higher than that of control which might be due to more efficiently absorbed and utilized organic iron by the sow's body. The values were comparable with Bertechini *et al*. (2012) for TEC, TLC and MCHC, but not for haematocrit value. Organic trace minerals can affect haematocrit through their involvement in the production and maintenance of healthy red blood cells. McClellan *et al.* (2025) reported that offspring from sows supplemented with organic iron had a markedly lower prevalence of anaemia at birth.

Dietary supplementation of organic trace minerals at 100 and 75% of requirement had no significant (p>0.05) effect on feed consumption, body weight, back fat thickness, reproductive performance and hematology of sows including their litter performance when compared to 100% inorganic trace minerals. Organic trace minerals at 100% inclusion have no beneficial effects on the performance of sows than that of 75% organic trace minerals. Hence, it was concluded that organic trace minerals can be incorporated at 75% of the requirement without affecting productive and reproductive performance of sows.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest, including any financial, personal or other relationships with other people or organizations that could inappropriately influence, or to be perceived to influence the present work.

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