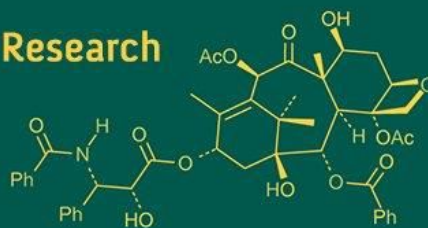
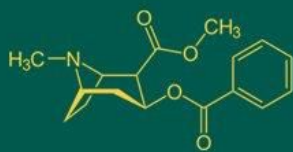


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2025; SP-9(1): 28-32
www.biochemjournal.com
Received: 29-10-2024
Accepted: 02-12-2024

Jianpui Pamei

Department of Physiology & Biochemistry, College of Veterinary Sciences & Animal Husbandry, Central Agricultural University, Selesih, Mizoram, India

Hemen Das

Assistant Professor, Department of Physiology & Biochemistry, College of Veterinary Sciences and A.H., Central Agricultural University (CAU), Selesih, Mizoram, India

M Ayub Ali

Department of Physiology & Biochemistry, College of Veterinary Sciences & Animal Husbandry, Central Agricultural University, Selesih, Mizoram, India

Probal Jyoti Doley

Department of Anatomy and Histology, College of Veterinary Sciences & Animal Husbandry, Central Agricultural University, Selesih, Mizoram, India

Biren Kumar Das

Department of Animal Nutrition, College of Veterinary Sciences & Animal Husbandry, Central Agricultural University, Selesih, Mizoram, India

MC Lallianchunga

Department of Physiology & Biochemistry, College of Veterinary Sciences & Animal Husbandry, Central Agricultural University, Selesih, Mizoram, India

Girin Kalita

Department of Livestock Production and Management, College of Veterinary Sciences & Animal Husbandry, Central Agricultural University, Selesih, Mizoram, India

Corresponding Author:**Hemen Das**

Assistant Professor, Department of Physiology & Biochemistry, College of Veterinary Sciences and A.H., Central Agricultural University (CAU), Selesih, Mizoram, India

Effect of dietary inclusion of *Moringa oleifera* leaf powder on metabolic enzymes, minerals and electrolyte profile of weaner piglets

Jianpui Pamei, Hemen Das, M Ayub Ali, Probal Jyoti Doley, Biren Kumar Das, MC Lallianchunga and Girin Kalita

DOI: <https://doi.org/10.33545/26174693.2025.v9.i1Sa.3414>

Abstract

Weaning stress severely impacts the post weaning health of piglets by effecting digestion and absorption of different nutrients. Enzymes, minerals and electrolytes are vital for optimum metabolism and maintenance of growth as well as health of piglets. Present study describes the effect of dietary inclusion of *Moringa oleifera* leaf powder (MOLP) on the status of metabolic enzymes, minerals and electrolytes of weaner piglets. Eighteen (18) piglets weaned at 28 days of age were grouped as control, treatment-I and treatment-II with six (6) piglets in each group. The control group was fed only basal feed; while, treatment-I and treatment-II were fed basal feed with inclusion of MOLP @ 1% and 2%, respectively. The feeding trial was conducted for six weeks. Blood samples were collected on day 28 (day of weaning), day 42 (two weeks post weaning), day 56 (four weeks post weaning) and day 70 (six weeks post weaning) from each piglet of all three groups for estimating the different parameters. Data generated through the study revealed that the activities of metabolic enzymes viz. alanine transaminase (ALT), aspartate transaminase (AST), creatine kinase- myocardial band (CK-MB) decreased significantly in the treatment groups, while the activity of gamma-glutamyl transferase (GGT) increased significantly. Nonetheless, lactate dehydrogenase (LDH) activity did not alter much amongst the experimental groups. The level of calcium (Ca) was slightly lower, but inorganic phosphorus (Pi) level was significantly higher in the treatment groups. However, the variation observed in magnesium (Mg) level was very minimal. Amongst the electrolytes, the concentration of sodium (Na) and potassium (K) in the treatment groups were comparable to those of control group; while concentration of chloride significantly hiked in the treatment groups during the period of study. Thus, it is evident that dietary inclusion of MOLP led to alteration of metabolic enzymes, mineral and electrolyte profile, which in turn signify potential role of MOLP in improving post-weaning health of piglets.

Keywords: Piglets, weaning, blood, *Moringa*, enzyme, mineral, electrolyte

Introduction

Weaning is the most critical stage in the life of pigs. It leads to stress and considerably affects the health of piglets causing high mortality and thus, incurs huge economic losses to the farmers (Cao *et al.*, 2018; Tang *et al.*, 2022) [6, 31]. In modern systems of intensive farming, early weaning practices are often followed to increase the reproductive efficiency of sows, which in turn lead to more financial benefits for the breeders as well as the breeding enterprises (Campbell *et al.*, 2013; Moraes *et al.*, 2016) [5, 22]. However, due to abrupt separation of the piglets from sow and the sudden changes in the feeds, social and physical environments, the piglets suffer from weaning stress that eventually leads to morphological and functional changes of the small intestine of piglets (Su *et al.*, 2022) [30]. It also effects the mucosal lining of intestine and alters immune function, digestive ability and absorption capacity resulting in drop in feed intake, higher incidence of post-weaning diarrhoea leading to retardation of growth (Upadhaya and Kim, 2021; Su *et al.*, 2022) [32, 30].

Therefore, alleviating post weaning stress is major challenge for profitable pig production. It is univocal that enzymes, minerals and electrolyte play a key role in overcoming stress (Ortega *et al.*, 2022) [25]. Hence, a better understanding of metabolic enzymes, mineral and electrolyte profile of weaned piglets may be handy to formulate strategies to overcome weaning stress.

Dietary intervention is considered to be the logical approach in this aspect (Lipinski *et al.*, 2017) [20]. Accordingly, attempts are being made to modulate gut microflora to exert beneficial effects on the host by using dietary enzymes, natural herbs/ plants or probiotics (Upadhaya and Kim, 2021) [32]. One such important plant is *Moringa oleifera*, commonly called "Moringa". The therapeutic potential of *M. oleifera* leaf powder (MOLP) has been well documented by previous studies (Leone *et al.*, 2015; Kashyap *et al.*, 2022) [18, 16]. The anti-inflammatory, anti-parasitic, anti-diabetic, anti-oxidant, immune-modulatory and anti-microbial properties exhibited by MOLP are attributed to the richness of the leaves in various phyto-chemicals such as phenolic acids, flavonoids, carotenoids etc. (Amaglo *et al.*, 2010; El-Sayed and Fathy, 2019) [3, 9]. Nonetheless, no study is carried out till now to evaluate the efficacy of MOLP in improving the status of metabolic enzyme, minerals and electrolytes, which are pivotal in improving post-weaning health by reducing weaning stress.

Accordingly, present study attempted to evaluate the effect of dietary inclusion of MOLP on major metabolic enzymes and certain important minerals and electrolytes of early weaned Large White Yorkshire piglets.

Materials and Methods

The experiment was conducted on early weaned piglets reared in Instructional Livestock Farm Complex (ILFC), College of Veterinary Sciences and A.H., Central Agricultural University, Aizawl, Mizoram, India. The city of Aizawl is located at 1020 m altitude and 23°44'12 N latitude. The temperature of the study area was in the range of 20-30 °C with a relative humidity of 45-95% during the period of research. For the study, eighteen (18) clinically healthy Large White Yorkshire (LWY) piglets of same age were randomly selected from the piggery unit of ILFC of the college. All the piglets were weaned at 28 days of age and kept in the weaner pens throughout the period of study. Considering the parity, birth weight and apparent health, all the selected piglets were categorized as Control (C), Treatment-I (T₁), Treatment-II (T₂) comprising of 6 piglets each group. Routine management practices like iron injection, deworming, etc. were carried out as per standard procedure. All the piglets utilized were fed with standard rations prepared as per NRC (2012) [23] specification by using conventional feed ingredients with the inclusion of *Moringa oleifera* leaf powder (MOLP). The control group was fed the only basal feed; whereas T₁ and T₂ groups were fed the basal feed with inclusion of MOLP @ 1% and 2%, respectively. The feeding trial was carried out for a period of 42 days. Piglets of all the experimental groups were provided with similar care and management throughout the study period. Clean and fresh water for drinking were provided round the clock. Feed were provided *ad libitum*, twice daily at 9:00 AM and at 3:00 PM and proper record of feeding were maintained. Four (4) ml of blood was collected aseptically by Venipuncture of anterior vena cava in heparinized vacutainers from each animal of experimental groups at fortnightly interval during the study period i.e on the day of weaning (day 28), 14 days post weaning (day 42), 28 days post weaning (day 56) and 42 days post weaning (day 70). The collected blood samples were immediately subjected to centrifugation at 3,500 rpm for 15 minutes to separate out the plasma, which were used for estimation of

major metabolic enzymes, important minerals and electrolytes. All the parameters were estimated using ready to use commercially available kits with the help of automated clinical chemistry analyzer (Fuji Dry Chem 4000i, Fujifilm, Tokyo, Japan).

Data generated in the study were analysed by one way ANOVA using SPSS version 25.0 and the significant values in ANOVA were further tested for Tukey and Tukey's b multiple range test. Results are presented as Mean ± SE. The difference were considered significant when P<0.05.

Results

Table-1 depicts the activity of different metabolic enzymes recorded in the present study.

It was observed that ALT activity ranged from 24.05±0.04 to 26.13±0.04 (U/L) amongst the experimental groups. It decreased significantly (P=0.00) in both the treatment groups as compared to control group. The activity of AST ranged from 64.29±0.01 to 66.27±0.009 (U/L). The drop in AST activity in the treatment groups was highly significant only on 42 days and 56 days, but the alteration was relatively less significant (p<0.05) on 70 days. The ALP activity recorded in the experimental groups ranged from 170.56±0.01 to 297.01±0.02 (U/L) with highly significantly low activity in the treatment groups on 56 and 70 day unlike 42 days. Similarly, the activity of CK-MB was also found to be reduced significantly (P=0.00) in the treatment groups with the values ranging from 176.81±0.014 to 194.56 ±0.76 (U/L) across the different experimental groups. The recorded values of GGT were in the range 45.01±0.40 to 48.03±0.009 (U/L). It increased significantly (P=0.000) in the treatment groups than those of control group on 42 days and 70 days. However, the hike was relatively less significant (p<0.05) on 56 days. Conversely, LDH activity value did not vary significantly between the experimental groups although the activity ranged from 326.45±0.01 to 330.01±0.01 (U/L).

Table-2 depicts the concentration of minerals and electrolyte recorded in the present study.

The concentration of calcium ranged from 10.02±0.01 to 10.93±0.008 mg/dL, while that of inorganic phosphorus ranged from 5.97±0.008 to 8.31±0.010 mg/dL amongst the experimental groups. The level of calcium was found to be slightly in lower side in the treatment groups than that of control group. However, the difference observed between the groups was non-significant. On the contrary, inorganic phosphorus level was found to be highly significantly (P=0.00) increased in the treatment groups as compared to control group. The range of magnesium was recorded to be 1.3±0.05 to 2.28±0.11 mg/dL, but the variation was non-significant between the control and treatment groups. Amongst the

Electrolyte profile revealed that there was only numerical variation in sodium concentration amongst the experimental group although the range was from 130.83±1.10 to 134.33±4.33 mEq/L. Similarly, potassium concentration was recorded to be in the range of 4.45±0.08 to 5.55±0.15 mEq/L. However, variation observed in potassium level between control and the treatment groups was non-significant. Whereas, The chloride level ranged from 91.33±0.81 to 103.33±1.33 mEq/L and was found to be significantly higher in the treatment groups than those of control group.

Table 1: Mean ($\pm$ SE) of activity (U/L) of metabolic enzymes of LWY piglets

Parameters	Days	Control	T ₁	T ₂	P-value
ALT (U/L)	28	26.10 $\pm$ 0.61	26.07 $\pm$ 0.01	25.99 $\pm$ 0.02	0.054 ^{NS}
	42	26.13 ^a $\pm$ 0.04	24.05 ^b $\pm$ 0.04	24.29 ^b $\pm$ 0.005	0.000**
	56	26.05 ^a $\pm$ 0.03	24.75 ^b $\pm$ 0.03	24.65 ^b $\pm$ 0.02	0.001**
	70	25.87 $\pm$ 0.14 ^a	24.68 ^b $\pm$ 0.02	24.79 ^b $\pm$ 0.008	0.000**
ALT (U/L)	28	66.20 $\pm$ 0.04	66.27 $\pm$ 0.009	65.99 $\pm$ 0.18	0.684 ^{NS}
	42	66.13 ^a $\pm$ 0.03	64.81 ^b $\pm$ 0.42	64.29 ^b $\pm$ 0.01	0.000**
	56	66.05 ^a $\pm$ 0.01	64.79 ^b $\pm$ 0.04	64.75 ^b $\pm$ 0.01	0.003**
	70	65.87 ^a $\pm$ 0.16	64.73 ^b $\pm$ 0.008	64.69 ^b $\pm$ 0.01	0.011*
ALP (U/L)	28	296.12 $\pm$ 0.02	295.71 $\pm$ 0.01	295.92 $\pm$ 0.01	0.09 ^{NS}
	42	294.14 ^a $\pm$ 0.009	184.29 ^b $\pm$ 0.08	183.79 ^b $\pm$ 0.008	0.01*
	56	297.01 ^a $\pm$ 0.02	183.76 ^b $\pm$ 0.008	182.88 ^b $\pm$ 0.005	0.000**
	70	296.98 ^a $\pm$ 0.005	168.57 ^c $\pm$ 0.009	170.56 ^b $\pm$ 0.01	0.000**
CK-MB (U/L)	28	177.11 $\pm$ 0.02	176.92 $\pm$ 0.009	176.81 $\pm$ 0.014	0.065 ^{NS}
	42	181.45 ^a $\pm$ 0.008	178.50 ^b $\pm$ 0.019	178.11 ^c $\pm$ 0.012	0.000**
	56	192.31 ^a $\pm$ 0.01	185.45 ^b $\pm$ 0.01	180.49 ^c $\pm$ 0.018	0.000**
	70	194.56 ^a $\pm$ 0.76	190.01 ^b $\pm$ 0.006	184.79 ^c $\pm$ 0.011	0.000**
GGT (U/L)	28	329.16 $\pm$ 0.01	328.43 $\pm$ 0.01	329.04 $\pm$ 0.01	0.075 ^{NS}
	42	327.94 $\pm$ 0.17	326.45 $\pm$ 0.01	327.04 $\pm$ 0.01	0.056 ^{NS}
	56	330.01 $\pm$ 0.01	329.67 $\pm$ 0.01	328.79 $\pm$ 0.005	0.051 ^{NS}
	70	329.78 $\pm$ 0.01	328.92 $\pm$ 0.009	328.00 $\pm$ 0.01	0.06 ^{NS}
LDH (U/L)	28	329.16 $\pm$ 0.01	328.43 $\pm$ 0.01	329.04 $\pm$ 0.01	0.075 ^{NS}
	42	327.94 $\pm$ 0.17	326.45 $\pm$ 0.01	327.04 $\pm$ 0.01	0.056 ^{NS}
	56	330.01 $\pm$ 0.01	329.67 $\pm$ 0.01	328.79 $\pm$ 0.005	0.051 ^{NS}
	70	329.78 $\pm$ 0.01	328.92 $\pm$ 0.009	328.00 $\pm$ 0.01	0.06 ^{NS}

Mean $\pm$ SE bearing different superscript differs significantly.

(*/**) means significant and NS means Non-significant.

Table 2: Mean ($\pm$ SE) values of minerals and electrolyte of LWY piglets

Parameters	Days	Control	T ₁	T ₂	P-value
Calcium (mg/dL)	28	10.68 $\pm$ 0.009	10.50 $\pm$ 0.01	10.33 $\pm$ 0.13	0.353 ^{NS}
	42	10.51 $\pm$ 0.01	10.08 $\pm$ 0.007	10.00 $\pm$ 0.01	0.054 ^{NS}
	56	10.93 $\pm$ 0.008	10.52 $\pm$ 0.01	10.18 $\pm$ 0.01	0.061 ^{NS}
	70	10.54 $\pm$ 0.008	10.02 $\pm$ 0.01	10.15 $\pm$ 0.006	0.051 ^{NS}
Inorganic phosphorus (mg/dL)	28	6.25 $\pm$ 0.013	5.97 $\pm$ 0.012	6.05 $\pm$ 0.011	0.006 ^{NS}
	42	5.97 $\pm$ 0.008	7.67 ^b $\pm$ 0.010	7.89 ^a $\pm$ 0.011	0.001**
	56	7.04 $\pm$ 0.008	8.31 ^a $\pm$ 0.010	8.20 ^b $\pm$ 0.013	0.000**
	70	6.75 $\pm$ 0.01	97 ^b $\pm$ 0.008	8.14 ^a $\pm$ 0.015	0.000**
Magnesium (mg/dL)	28	2.23 $\pm$ 0.12	2.28 $\pm$ 0.11	2.26 $\pm$ 0.12	0.729 ^{NS}
	42	2.26 $\pm$ 0.59	2.0 $\pm$ 0.03	2.03 $\pm$ 0.08	0.881 ^{NS}
	56	1.98 $\pm$ 0.09	2.23 $\pm$ 0.12	2.20 $\pm$ 0.12	0.259 ^{NS}
	70	1.75 $\pm$ 0.19	1.3 $\pm$ 0.05	1.76 $\pm$ 0.08	0.066 ^{NS}
Sodium (mEq/L)	28	130.83 $\pm$ 3.44	132.60 $\pm$ 3.12	131.66 $\pm$ 1.02	0.053 ^{NS}
	42	131.66 $\pm$ 3.38	131.53 $\pm$ 1.20	133.01 $\pm$ 2.72	0.18 ^{NS}
	56	130.83 $\pm$ 1.10	131.16 $\pm$ 0.98	133.00 $\pm$ 1.2	0.066 ^{NS}
	70	134.00 $\pm$ 2.51	134.33 $\pm$ 4.33	133 $\pm$ 0.00	0.670 ^{NS}
Chloride (mEq/L)	28	92.50 $\pm$ 2.47	91.50 $\pm$ 2.64	91.33 $\pm$ 0.81	0.432 ^{NS}
	42	95.12 ^a $\pm$ 1.15	102 ^b $\pm$ 0.11	103.33 ^b $\pm$ 1.33	0.00**
	56	94.53 ^a $\pm$ 3.89	96.66 ^b $\pm$ 0.95	98.60 ^c $\pm$ 0.81	0.032*
	70	96.33 ^a $\pm$ 1.45	99.66 ^b $\pm$ 3.48	101.00 ^c $\pm$ 1.52	0.014*
Potassium (mEq/L)	28	5.55 $\pm$ 0.15	5.53 $\pm$ 0.27	5.45 $\pm$ 0.18	0.067 ^{NS}
	42	4.9 $\pm$ 0.32	4.69 $\pm$ 2.72	4.76 $\pm$ 0.06	0.845 ^{NS}
	56	4.71 $\pm$ 0.16	4.56 $\pm$ 0.16	4.68 $\pm$ 0.18	0.051 ^{NS}
	70	5.2 $\pm$ 0.41	5.4 $\pm$ 0.55	4.45 $\pm$ 0.08	0.381 ^{NS}

Mean $\pm$ SE bearing different superscript differs significantly.

(*/**) means significant and NS means Non-significant.

Discussion

Current study showed that the activities of enzyme ALT, AST and ALP, CK-MB significantly decreased in both treatment-I and treatment-II groups than that of control group. Similar type of observation was also recorded by Leitanthem *et al.* (2022) [17] in goats supplemented with *M. oleifera* leaves. On the contrary, Zaher *et al.* (2020) [34] observed a slightly higher level of SGPT and SGOT in moringa fed goats under climatic conditions of Abu Dhabi.

Nonetheless, a study carried out by Wankhede *et al.* (2022) [33] found no change in SGPT and ALP level in goat kids fed ration incorporated with moringa leaf powder. Some other previous reports stated that *M. oleifera* leaves have been found to exert reducing effect on AST, ALT, ALP and creatine kinase (Sharifudin *et al.*, 2013; Ouedraogo *et al.*, 2013) [29, 26]. They also observed that certain phytochemicals present in moringa leaves ameliorate liver and kidney damage induced by some drugs. Further, Das *et al.* (2012) [18]

documented the same effect in the activity of hepatic enzymes in rats fed with MOLP supplemented diet. It is well known fact that increase level of ALT, AST, ALP and CK-MB are indicators of hepatic diseases, inflammation and metabolic disorders (Giannini *et al.*, 2005) [11]. The observed lower level of these enzymes suggests hepato-protective effect of *M. oleifera* leaves (Melesse *et al.*, 2013) [21]. Likewise, Ganatra *et al.* (2012) [10] observed that methanolic extract of moringa leaves exhibited a protective effect on liver, which may be due to 'quercetin' present in *M. oleifera* leaves. Studies by other researchers (Oyagbemi *et al.*, 2013; Asiedu-Gyekye *et al.*, 2014) [27, 4] also proved that extract of moringa leaves when administered to mice resulted in a reduction of the level of serum enzymes viz. AST, ALT and AST. On the contrary, the current study demonstrated that GGT activities increased in the treatment groups, while there was no variation in LDH activity between control and experimental group. Our findings are in accordance with those of Melesse *et al.* (2013) [21]. Nevertheless, no report could be found to correlate the hike in GGT activity and feeding of moringa leaf powder.

Present study showed that the plasma calcium level was slightly lower in the treatment groups than that of control group. Nonetheless, the difference observed between the groups was non-significant. Whereas, the level of inorganic phosphorus was significantly ($P=0.00$) higher in both the treatment groups than that of control group. Further no significant alteration was found in magnesium concentration amongst the different groups. Our findings are in concurrence with the report of Riaz *et al.* (2014) [28]. However, contrasting our observation, Abu-Hafsa *et al.* (2020) [1] reported that broilers fed ration with incorporation of MOLP resulted in significantly lowered blood calcium level. Similarly, analogous level of calcium and phosphorus was reported in goat kids fed with *Moringa oleifera* foliage by Wankhede *et al.* (2022) [33]. *M. oleifera* is reported to contain very high amount of phosphorus (Ogbe and Affiku, 2012) [24]. The significantly higher level of phosphorus recorded in our study may be ascribed to the high content of this macro-mineral in *M. oleifera* leaves (Dai *et al.*, 2020) [7]. It is reported that higher level of phosphorus up-regulate phosphorus regulating hormone that suppress renal α -1 hydroxylation of Vit-D₃ (Gutierrez *et al.*, 2005) [12]. This may, in turn, predispose the animals to secondary hyperparathyroidism and thus hamper release of bone calcium during resorption. This, in part, could be responsible for the lower level of calcium observed in the present study.

Data on electrolytes observed in the current study demonstrated that there were no significant changes in sodium and potassium levels between the control and treatment groups, while concentration of chloride was found to be significantly higher in the treatment groups during the study period. Similar type of observation was also recorded by Adinoyi *et al.* (2017) [2] pertaining to sodium and chloride, but they reported lower level of serum potassium in does fed *M. oleifera* leaves. Conflicting with our result, Idoko *et al.* (2018) [14] observed a non-significant alteration of chloride ion in all the test groups of Wistar rats throughout the duration of the study. Nonetheless, the plasma level of sodium, potassium and chloride found in our study was very much within the range set for pigs (Kaneko *et al.*, 2008) [15]. Electrolytes play a vital role in a number of body processes like regulating blood pressure, acid-base balance and fluid levels coagulation and muscle contraction

(Hasona and Elsbali, 2016) [13]. Electrolyte homeostasis is strictly controlled within a very narrow range for optimum physiological and biochemical functions (Kaneko *et al.*, 2008) [15]. Hence, electrolyte imbalance is considered to be an important pointer of general health of animals. The recorded values of electrolytes in our study signify that feeding of *M. oleifera* leaf powder has not any deleterious effect on the health of weaned piglets, rather it imparts a positive effect by maintaining the electrolyte balance within physiological limit even during the stress imposed by the process of weaning.

Conclusions

In view of the results of the current study, it is evident that dietary inclusion of *M. oleifera* leaf powder improved the status of metabolic enzyme, minerals and electrolytes of weaner piglets indicating beneficial impact of MOLP on health of piglets during post weaning. Dietary inclusion of both 1% and 2% resulted in positive result, but 2% level of inclusion was found to be more effective. Nonetheless, further study with large sample size and different level of dietary inclusion of MOLP is warranted to understand better and exploit fully the potential benefits of MOLP in improving post weaning health of piglets.

Acknowledgements

The authors are highly grateful to the Dean, College of Veterinary Sciences and A.H., CAU, Aizawl (Mizoram) for providing necessary financial support and facilities to carry out the research work.

Reference

1. Abu-Hafsa SH, Ibrahim SA, Eid YZ, Hassan AA. Effect of dietary *Moringa oleifera* leaves on the performance, ileal microbiota and antioxidative status of broiler chickens. *Journal of Animal Physiology and Animal Nutrition*. 2020;104(2):529-538.
2. Adinoyi SS, Oluwagbamila OB, Ademola AO. Role of *Moringa oleifera* on electrolyte levels and cardiovascular function in humans. *Therapeutic Advances in Cardiology*. 2017;1:80-86.
3. Amaglo NK, Bennett RN, Curto RBL, Rosa EAS, Turco VL, Giuffrida A, *et al.* Profiling selected phytochemicals and nutrients in different tissues of the multipurpose tree *Moringa oleifera* L., grown in Ghana. *Food Chemistry*. 2010;122(4):1047-1054.
4. Asiedu-Gyekye II, Frimpong-Manso S, Awortwe C, Antwi DA, Nyarko AK. Micro- and macroelemental composition and safety evaluation of the nutraceutical *Moringa oleifera* leaves. *Journal of Toxicology*. 2014;2014:786979.
5. Campbell JM, Crenshaw JD, Polo J. The biological stress of early weaned piglets. *Journal of Animal Science and Biotechnology*. 2013;4(1):19.
6. Cao ST, Wang CC, Wu H, Zhang QH, Jiao LF, Hu CH. Weaning disrupts intestinal antioxidant status, impairs intestinal barrier and mitochondrial function, and triggers mitophagy in piglets. *Journal of Animal Science*. 2018;96(3):1073-1083.
7. Dai J, Tao L, Shi C, Yang S, Li D, Sheng J, *et al.* Fermentation improves calcium bioavailability in *Moringa oleifera* leaves and prevents bone loss in calcium-deficient rats. *Food Science & Nutrition*. 2020;8(7):3692-3703.

8. Das N, Sikder K, Ghosh S, Fromenty B, Dey S. *Moringa oleifera* Lam. leaf extract prevents early liver injury and restores antioxidant status in mice fed with high-fat diet. *Indian Journal of Experimental Biology*. 2012;50:404-412.
9. El-Sayed NM, Fathy GM. Prophylactic and therapeutic treatments' effect of *Moringa oleifera* methanol extract on cryptosporidium infection in immuno-suppressed mice. *Anti-Infective Agents*. 2019;17(2):130-137.
10. Ganatra T, Joshi U, Bhalodia P, Desai T, Tirgar P. A panoramic view on pharmacognostic, pharmacological, nutritional, therapeutic and prophylactic values of *Moringa oleifera* Lam. *International Research Journal of Pharmacy*. 2012;3(6):1-7.
11. Giannini EG, Testa R, Savarino V. Liver enzyme alteration: a guide for clinicians. *CMAJ*. 2005;172(3):367-379.
12. Gutierrez O, Isakova T, Rhee E. Fibroblast growth factor-23 mitigates hyperphosphatemia but accentuates calcitriol deficiency in chronic kidney disease. *Journal of the American Society of Nephrology*. 2005;16(7):2205-2215.
13. Hasona NA, Elaslali A. Evaluation of electrolytes imbalance and dyslipidemia in diabetic patients. *Medical Science*. 2016;4(7):1-4.
14. Idoko IS, Ugochukwu IC, Abalaka SE, Adamu AM, Columbus PK, Kwabugge YA, *et al.* Effects of experimental lead exposure and the therapeutic effect of defatted *Moringa oleifera* seed meal on serum electrolyte levels of Wistar rats. *Sokoto Journal of Veterinary Sciences*. 2018;16(1):45-54.
15. Kaneko JJ, Harvey JW, Bruss ML. *Clinical Biochemistry of Domestic Animals*. 6th ed. London: Academic Press; 2008. p. 117-138.
16. Kashyap P, Kumar S, Riar CS, Jindal N, Baniwal P, Guiné RPF, *et al.* Recent advances in Drumstick (*Moringa oleifera*) leaves bioactive compounds: composition, health benefits, bioaccessibility, and dietary applications. *Antioxidants*. 2022;11(2):402.
17. Leitanthem VK, Chaudhary P, Maiti S, Mohini M, Mondal G. Impact of *Moringa oleifera* leaves on nutrient utilization, enteric methane emissions, and performance of goat kids. *Animals*. 2022;13(1):97.
18. Leone A, Fiorillo G, Criscuoli F, Ravasenghi S, Santagostini L, Fico G, *et al.* Nutritional characterization and phenolic profiling of *Moringa oleifera* leaves grown in Chad, Sahrawi Refugee Camps, and Haiti. *International Journal of Molecular Sciences*. 2015;16(8):18923-18937.
19. Li Y, Zhao X, Jiang X, Chen L, Feng B, Xu S, *et al.* Effects of dietary supplementation with exogenous catalase on growth performance, oxidative stress, and hepatic apoptosis in weaned piglets challenged with lipopolysaccharide. *Journal of Animal Science*. 2020;98(3):skaa067. doi: 10.1093/jas/skaa067.
20. Lipiński K, Mazur M, Antoszkiewicz Z, Purwin C. Polyphenols in monogastric nutrition: A review. *Annals of Animal Science*. 2017;17(1):41-58.
21. Melesse A, Getye Y, Berihun K, Banerjee S. Effect of feeding graded levels of *Moringa stenopetala* leaf meal on growth performance, carcass traits and some serum biochemical parameters of Koekoek chickens. *Livestock Science*. 2013;157(2-3):498-505.
22. Moraes KAF, Moreira KMS, Drugowick RM, Bonanato K, Imparato JCP, Reis JB. Factors associated with early weaning. *Pesquisa Brasileira em Odontopediatria e Clínica Integrada*. 2016;16(1):491-497.
23. National Research Council (NRC). *Nutrient Requirements of Swine*. 11th Revised Edition. Washington, DC: National Academies Press; 2012.
24. Ogbe AO, Affiku JP. Proximate study, mineral and anti-nutrient composition of *Moringa oleifera* leaves harvested from Lafia, Nigeria: potential benefits in poultry nutrition and health. *Journal of Microbiology, Biotechnology and Food Sciences*. 2011;1(3):296-308.
25. Ortega AD, Babinszky L, Ozsváth XE, Oriado OH, Szabó C. The effect of heat stress and vitamin and micro-mineral supplementation on some mineral digestibility and electrolyte balance of pigs. *Animals*. 2022;12:386. doi:10.3390/ani12030386.
26. Ouedraogo M, Lamien-Sanou A, Ramde N, Ouedraogo AS, Ouedraogo M, Zongo SP, *et al.* Protective effect of *Moringa oleifera* leaves against gentamicin-induced nephrotoxicity in rabbits. *Experimental and Toxicologic Pathology*. 2013;65:335-339.
27. Oyagbemi AA, Omobowale TO, Azeez IO, Abiola JO, Adedokun RA, Nottidge HO. Toxicological evaluations of methanolic extract of *Moringa oleifera* leaves in liver and kidney of male Wistar rats. *Journal of Basic and Clinical Physiology and Pharmacology*. 2013;24(4):307-312.
28. Riaz MQ, Südekum KH, Clauss M, Jayanegara A. Voluntary feed intake and digestibility of four domestic ruminant species as influenced by dietary constituents: a meta-analysis. *Livestock Science*. 2014;162:76-85.
29. Sharifudin SA, Fakurazi S, Hidayat MT, Hairuszah I, Aris Mohd Moklas M, Arulselvan P. Therapeutic potential of *Moringa oleifera* extracts against acetaminophen-induced hepatotoxicity in rats. *Pharmaceutical Biology*. 2013;51(3):279-288.
30. Su W, Gong T, Jiang Z, Lu Z, Wang Y. The role of probiotics in alleviating post-weaning diarrhea in piglets from the perspective of intestinal barriers. *Frontiers in Cellular and Infection Microbiology*. 2022;12:883107. doi:10.3389/fcimb.2022.883107.
31. Tang X, Xiong K, Fang R, Li M. Weaning stress and intestinal health of piglets: A review. *Frontiers in Immunology*. 2022;13:1040123. doi:10.3389/fimmu.2022.1040123.
32. Upadhaya SD, Kim IH. The impact of weaning stress on gut health and the mechanistic aspects of several feed additives contributing to improved gut health function in weanling piglets-A review. *Animals*. 2021;11(8):2418. <https://doi.org/10.3390/ani11082418>.
33. Wankhede SD, Dutta N, Tambe MB, Kaur N, Jadhav SE, Pattanaik AK. Effect of dietary inclusion of *Moringa oleifera* foliage on nutrient metabolism, metabolic profile, immunity and growth performance of goat kids. *Emerging Animal Species*. 2022;3:100005.
34. Zaher HA, Alawaash SA, Tolba AM, Swelum AA, Abd El-Hack ME, Taha AE, Abdelnour SA. Impacts of *Moringa oleifera* foliage substituted for concentrate feed on growth, nutrient digestibility, hematological attributes, and blood minerals of growing goats under Abu Dhabi conditions. *Sustainability*. 2020;12(15):6096. <https://doi.org/10.3390/su12156096>.