# Dietary Influence of Beta-Glucanase and Enziblend Energy on Growth, Haematological and Serum Biochemical Indices of Weaner Pigs

**B. A. Makanjuola*[1], B. A. Boladuro[1], O. A. Adesehinwa[2], J. C. Moreki[3], A. O. Sorunke[1], A. A. Bolaji[1], and A. O. K. Adesehinwa[1]**

[1]Livestock Improvement Programme, Institute of Agricultural Research & Training, Obafemi Awolowo University, PMB 5029, Moor Plantation, Ibadan, Nigeria

[2]AK Research Farm, Eleyele, Ibadan, Nigeria.

[3]Department of Animal Science, Faculty of Animal and Veterinary Sciences, Botswana University of Agriculture and Natural Resources, P/Bag 0027, Gaborone, Botswana.

*Corresponding author: bamakanjuola@gmail.com

Received: 11 March 2025
Accepted: 01 June 2025

## Abstract

This study investigated the effects of commercial enzymes in the diet of weaner pigs on growth, haematological and serum biochemical indices of pigs. Total of 54 weaned pigs which were Largewhite × Landrace crosses with average weight of 11.87±2.36 kg were used. They were randomly allotted to three dietary treatments T1 (Control/Basal diet), T2 (Basal diet + β-Glucanase at 100g/tonne), and T3 (Basal diet + Enziblend Energy at 500g/tonne) with six replicates in each treatment in a completely randomized design. The results revealed that the feed intake and weight gain did not significantly (P>0.05) differ among the treatments. Weight gain was highest in T2 with 22.2 kg, 21.72 kg in T1 and 20.06 kg in T3. Similarly, the feed conversion ratio (FCR) was not significantly (P>0.05) influenced by the addition of the enzymes to the diets. The erythrocyte counts, leukocytes counts, haemoglobin concentration, packed cell volume (PCV) and other haematological indices assayed were not significantly (P>0.05) different among the treatments. The erythrocyte counts were 5.86, 5.55 and 5.91 x 106 μ/L in T1, T2 and T3 respectively. All serum indices showed no significant (P>0.05) difference across all treatments except in aspartate aminotransferase (AST), total cholesterol and high density lipoprotein cholesterol (HDL). The AST concentration was highest in T3 (57.88 IU/L). Cholesterol and HDL levels were significantly (P<0.05) highest in T1 (144.41 mg/dL and 93.18 mg/dL respectively). The addition of enzymes to the diet of the pigs in this study did not compromise the growth nor adversely affect the hepatic function and health of the animals.

**Keywords**: Beta-glucanase, Enziblend, Enzyme, Growth, weaned pigs.

## Introduction

Achieving optimal growth rates and feed efficiency in weaner pigs is a complex and multifaceted challenge which has significant implications on the welfare and economic sustainability within the swine industry. An essential aspect of this challenge is the formulation of efficient and cost-effective diets that can meet the nutritional needs of weaner pigs. The growth rates of weaner pigs are usually affected by the change in plane of nutrition from a liquid milk-based diet that is highly nutritious, soluble and easily absorbable into the body system to a solid feed diet that is not easily digestible. The process of this change in the plane of nutrition at weaning causes functional as well as morphological changes to the gastro-intestinal tracts (GIT) of the pigs leading to intestinal dysfunction and retarded growth. Dietary fibre and anti-nutritional factors in the diets of weaned pigs are part of the stressors that have been identified to contribute to post-weaning stress in pigs (Zheng et al., 2021). One promising avenue for addressing this challenge is the utilisation of additives such as enzymes which help to enhance nutrient absorption, reduce feed wastage and ultimately promote the growth and well-being of weaned pigs.

The use of enzymes such as β-Glucanase and Enziblend Energy have shown potential in breaking down fibrous components of non-ruminants diets and improving its nutrient utilisation (Fan et al., 2009; Amaefule et al., 2020). Usually, piglets are transitioned from milk to solid feed abruptly at weaning. This frequently leads to a decrease in feed intake, growth, increased susceptibility to diseases and diarrhoea (Spreeuwenberg et al., 2001; Bruininx et al., 2002; O'Doherty et al., 2023). Therefore, optimising nutrition during the weaner phase of pig life is crucial for swine producers in order to improve their health, productivity and overall profitability. β-Glucanase is an enzyme capable of degrading complex β-glucans found in many plant-based ingredients commonly used in swine diets. Enziblend Energy is a blend of enzymes designed to optimise the digestion of various dietary components particularly fibre and starches. Also, the use of agro-industrial by-products (AIBPs) such as maize offal, palm kernel cake, brewers' dried grains and rice milling waste has been limited due to the high levels of crude fibre and non-starch polysaccharides (NSPs) which may not be digested by the endogenous enzymes of monogastric animals (Dalolio et al., 2016; Amaefule et al., 2020). Nutritionists have carried out studies to investigate the effect of specific enzymes on fibrous feedstuff in pig diet (Mavromichalis et al., 2000; Duarte et al., 2021; Aderibigbe et al., 2024). However, there is need to keep investigating the effects of addition of various enzyme compositions to pig diets on the performance of different classes of pigs. Therefore, the objective of this study is to assess the effect of β-Glucanase, a single enzyme and Enziblend Energy which is a multi-enzyme complex on the performance, heamatological and serum biochemical indices of weaned pigs.

## Materials and methods

*Experimental site and Animal management*

This research was conducted at the Piggery Unit, AK Research Farms, Eleyele, Ibadan, Oyo State, Nigeria. The study lasted 70 days. Fifty-four (54) weaned piglets (Large White x Landrace crosses) with mean weight of 11.87±2.36kg (±SE) were used in this study. The animals were housed in an open-sided cross-ventilated pen with a concrete floor. The animals were fed ad libitum and were allowed free access to cool clean water throughout the experimental period

*Experimental Design*

The weaner pigs (54) were randomly allotted to 3 dietary treatments labeled T1, T2 and T3 in a completely randomized design (CRD). Each treatment was replicated 6 times with 3 animals per replicate. The diets were formulated as shown in Table 1 to meet the nutrient requirements for weaner pigs as recommended by the National Research Council (2012). Pigs in T1 (which was the control group) were fed a basal diet without enzyme addition. Pigs in T2 were fed basal diet with 100g/tonne of β-Glucanase while pigs in T3 contained the basal diet with 500g/tonne of Enziblend Energy®. β-Glucanase and Enziblend Energy® were included in the diets in this study at rates recommended by the producers.

Table 1: Composition of experimental diets

| Ingredients | T1 | T2 | T3 |
|---|---|---|---|
| Maize | 450.00 | 450.00 | 450.00 |
| Corn bran | 100.00 | 100.00 | 100.00 |
| Rice bran plus | 100.00 | 100.00 | 100.00 |
| Groundnut cake | 240.00 | 240.00 | 240.00 |
| β-Glucanase | 0 | 0.10 | 0 |
| Enziblend Energy | 0 | 0 | 0.50 |
| Bone | 16.00 | 16.00 | 16.50 |
| Oyster shell | 8.00 | 8.00 | 8.00 |
| PKC (local) | 80.00 | 80.00 | 80.00 |
| Methionine | 0.30 | 0.30 | 0.30 |
| Lysine | 0.40 | 0.40 | 0.40 |
| Salt | 2.50 | 2.50 | 2.50 |
| Threonine | 0.30 | 0.30 | 0.30 |
| Premix | 2.50 | 2.50 | 2.50 |
| **Total** | **1000.00** | **1000.10** | **1000.50** |
| **Calculated Analysis** | | | |
| Crude Protein (%) | 17.69 | 17.69 | 17.69 |
| Crude Fibre (%) | 5.50 | 5.50 | 5.50 |
| Energy (Kcal/kg ME) | 2883.90 | 2883.90 | 2883.90 |

*Data Collection*

The feed intake was estimated daily by subtracting the weight of the left-over feed from that of the feed given. A walk-through digital measuring scale was used to determine the weights of the pigs on a weekly basis. The weight gain was estimated as the difference between the initial and the final body weights. The feed conversion ratio (FCR) was calculated as the ratio of feed intake to weight gain. At the end of the study, blood samples were collected from the animals through the jugular veins using hypodermic needles and syringes. The blood was collected into 5ml sample bottles containing ethylenediamine tetra-acetate (EDTA) as anti-coagulant for the assessment of haematological indices while blood sampled for serum analysis were collected into plain (anti-coagulant-free) sample bottles.

Haematological parameters such as packed cell volume (PCV), haemoglobin concentration, erythrocyte count, leucocyte count, platelet, neutrophils, monocytes and eosinophils were determined. Serum biochemical indices assayed were liver enzymes (aspertate aminotransferase and alanine aminotransferase), total protein, albumin, glucose, cholesterol, creatinine, blood urea nitrogen (BUN) and high density lipo-protein (HDL).

*Data analysis*

Data were subjected to analysis of variance (ANOVA) procedures using the General Linear Model (GLM) procedures of SAS (2002) version 9.0. The means among variables that were significant were separated using the Duncan's Multiple Range Test (1955). The data were presented as means and standard deviations. The level of significance was defined as $P < 0.05$.

## Results and discussion

*Growth indices of weaner pigs fed β-Glucanase and Enziblend Energy in the diet*

Results of the influence of supplementation of weaner pig diets with β-Glucanase and Enziblend Energy are as highlighted in Table 2. The results obtained in this study revealed that there were no significant ($P>0.05$) differences in the feed intake among the pigs in the different treatments {T1 (76.86kg), T2 (81.61kg) and T3 (76.07 kg)}. The weight gain of pigs in T2 (22.20 kg) and T3 (20.06 kg) were not significantly ($P>0.05$) different from those fed the basal diet (21.72 kg). This implied that pigs in T2 and T3 demonstrated weight gains comparable to those fed the basal diet but not better than them. The weight gain in the supplemented groups implied that these enzymes did not compromise the nutritional value or digestibility of the diets, reinforcing their potential as viable additives in pig nutrition. The results obtained were similar to what was reported by Munezero and Kim (2022) where the supplementation of the diets of weanling pigs with protease did not significantly influence feed intake and weight gain when fed up to 5 weeks. There was no significant ($P>0.05$) difference in the feed conversion ratio (FCR) of pigs across all the treatments {T1 (3.53), T2 (3.67) and T3 (3.86)}. It could be deduced that the incorporation of β-Glucanase and Enziblend Energy in the diets of the pigs did not substantially impact the conversion of feed into flesh. This corroborated the findings of Agyekum et al. (2015) who reported that β-Glucanase supplementation showed no significant improvement on the performance of pigs. In contrast, Dritz et al. (1995) and Fan et al. (2009) reported beneficial effects of β-Glucanase in the diet of weaned pigs.

Table 2. Effect of β-Glucanase and Enziblend Energy in the diet of weaner pigs on growth performance

| Parameters | T1 | T2 | T3 |
|---|---|---|---|
| Initial weight (Kg) | 12.03±1.80 | 11.78±2.51 | 11.81±4.59 |
| Final weight | 33.75±5.48 | 33.97±3.83 | 31.87±10.66 |
| Feed intake (Kg) | 76.86±14.17 | 81.61±8.76 | 76.07±17.60 |
| ADFI (Kg) | 1.10±0.20 | 1.17±0.13 | 1.09±0.25 |
| Weight gain (Kg) | 21.72±3.73 | 22.20±1.55 | 20.06±6.08 |
| ADWG (g) | 310.29±53.29 | 317.10±22.15 | 286.60±86.80 |
| FCR | 3.53±0.10 | 3.67±0.17 | 3.86±0.36 |

Means along the same row with the same superscript are not significantly different (P>0.05)

T1 - Control/Basal diet; T2 - Basal diet + β-Glucanase (100g/tonnes); T3 - Basal diet + Enziblend Energy (500g/tonnes); ADFI - Average daily feed intake; ADWG - Average daily weight gain; FCR - Feed conversion ratio.

*Haematology of weaner pigs fed β-Glucanase and Enziblend Energy in the diet*

Haematological assays are important indicators used for assessing the health status of an animal (Onasanya et al., 2015; Koomkrong et al., 2017; Zhang et al., 2022). The haematological indices of weaner pigs fed β-Glucanase and Enziblend Energy in the diet is as shown in Table 3. All haematological indices showed no significant (P>0.05) differences across the treatments. This may indicate that the packed cell volume (PCV) level was not influenced by inclusion of the enzymes. The erythrocyte counts did not differ significantly among the pigs on the different dietary treatments. This may imply that the animals were not anaemic during the experiment and erythrocyte count was not influenced by the inclusion of β-Glucanase and Enziblend Energy in the diet. The leucocyte count which is crucial for immune evaluation was highest in T1 (8570.00 x 103 µ/L) but not significantly (P<0.05) higher than those in T2 (8258.30 x 103 µ/L) and T1 (7350.00 x 103 µ/L). This is in contrast to the findings of Adesehinwa et al. (2011) and Irekhore et al. (2015) where PCV, haemoglobin, erythrocyte and leukocyte counts were significantly influenced by the addition of enzymes in the diet. The values obtained for the haematological indices examined in this study were within the normal physiological range for weaner pigs (Eze et al., 2010; Perri et al., 2017). This showed that the addition of the enzymes to the diet of the weaned pigs did not compromise the haematology of the animals.

*Serum biochemistry of weaner pigs fed β-Glucanase and Enziblend Energy in the diet*

One of the important factors that influences the concentration of different metabolites in the serum of animals is the nutritional status of the animals. Results of the serum biochemical indices of weaner pigs fed β-Glucanase and Enziblend Energy in the diet are as presented in Table 4. Pigs in T3 fed Enziblend Energy in the diet recorded the highest (P<0.05) concentration of Aspertate aminotransferase (AST) (57.88 IU/L) in comparison to values recorded for pigs in T1 (39.38 IU/L) and T2 (32.82 IU/L). Elevated AST and ALT (Alanine aminotransferase) levels in the blood are often indicative of liver damage or injury. However, the inclusion of enzyme in the diets of pigs in this study did not negatively affect hepatic function since the values were within the normal physiological range (Yu et al., 2019).

There were variations in the mean values of ALT (23.53 IU/L), albumin (2.93 g/dL), creatinine (1.84 mg/dL) and Blood Urea Nitrogen (BUN) (20.22 mg/dL) however, they were not significantly (P<0.05) different. Creatinine and blood urea nitrogen are general measures of renal function in animals because they are products of some metabolic activities which are eventually filtered from the body via the kidneys. Nevertheless, their levels in the serum increases when glomerular filteration decreases. The results obtained in this study was similar to reports of Wang et al. (2009) and Yin and Kim (2019). The authors reported that the addition of enzymes to the diets of pigs did not influence the creatinine and BUN concentration of pigs. The highest numerical concentration of cholesterol recorded in T1 (144.41 mg/dL) also was similar to that recorded in T2 (139.55 mg/dL) but significantly higher when compared to T3 (126.03 mg/dL). The significant (P<0.05) lower cholesterol level in T3 might be associated with changes in the pigs metabolic processes. High cholesterol levels are typically associated with a risk of cardiovascular disease.

Pigs in T1 (93.18 mg/dL) had the highest concentration of HDL which was similar to that recorded for pigs in T2 (83.26 mg/dL) but significantly (P<0.05) higher than those in T3 (71.98 mg/dL). Although the HDL level was significantly (P<0.05) lower in T3, having HDL levels across all treatments within the normal physiological range suggests that the enzymes did not have a significant impact on the pigs' ability to transport excess cholesterol. This can be seen as a positive outcome as maintaining healthy HDL levels is important for cardiovascular health (Navab et al., 2011). The serum biochemical indices measured in this study were within the normal physiological ranges for swine (Yu et al., 2019).

Table 3: Haematological indices of weaner pigs fed β-Glucanase and Enziblend Energy in the diet.

| **Parameters** | **T1** | **T2** | **T3** | **P (ANOVA)** |
|---|---|---|---|---|
| PCV (%) | 35.67±1.89 | 34.17±1.61 | 35.83±0.58 | 0.699 |
| Haemogblobin (g/dl) | 11.85±0.71 | 11.27±0.55 | 11.77±0.15 | 0.669 |
| Erythrocyte Count (×$10^6$ μ/L) | 5.86±0.53 | 5.55±0.33 | 5.91±0.43 | 0.597 |
| Leucocyte Count (×$10^3$ μ/L) | 8370.00±1161 | 8258.30±1371 | 7350.00±1481 | 0.501 |
| Platelet (×$10^3$ μ/L) | 129.50±6.94 | 140.33±3.69 | 131.00±1.73 | 0.212 |
| Lymphocyte (%) | 65.33±2.02 | 64.33±0.29 | 66.00±2.65 | 0.699 |
| Neutrophils (%) | 31.33±0.76 | 32.17±0.76 | 29.83±4.25 | 0.583 |
| Monocytes (%) | 1.83±0.76 | 1.33±0.76 | 1.33±1.04 | 0.585 |
| Eosinophils (%) | 1.50±0.87 | 2.17±0.29 | 2.33±0.58 | 0.255 |

Means along the same row without superscript are not significantly (p<0.05) different
PCV - Packed cell volume

Table 4: Serum biochemistry of weaner pigs fed β-Glucanase and Enziblend Energy in the diet

| Parameters | T1 | T2 | T3 | P (ANOVA) |
|---|---|---|---|---|
| AST (IU/L) | 39.37±9.05$^b$ | 32.82±2.51$^b$ | 57.88±23.00$^a$ | 0.024 |
| ALT (IU/L) | 21.04±4.87 | 23.00±4.15 | 23.53±5.27 | 0.688 |
| Total Protein (g/dL) | 7.07±0.21 | 6.58±0.35 | 6.80±0.77 | 0.508 |
| Albumin (g/dL) | 2.87±0.19 | 2.43±0.37 | 2.93±0.36 | 0.201 |
| Globulin (g/dL) | 4.18±0.35 | 4.16±0.44 | 3.87±1.08 | 0.795 |
| Glucose (mg/dL) | 75.80±14.65 | 70.93±5.72 | 71.93±6.38 | 0.796 |
| Cholesterol (mg/dL) | 144.41±7.95$^a$ | 139.55±6.99$^a$ | 126.03±5.78$^b$ | 0.011 |
| Creatinine (mg/dL) | 1.56±0.64 | 1.79±0.10 | 1.84±0.20 | 0.478 |
| BUN (mg/dL) | 19.69±0.95 | 19.32±1.56 | 20.22±0.11 | 0.621 |
| HDL (mg/dL) | 93.18±1.88$^a$ | 83.26±4.49$^{ab}$ | 71.98±13.03$^b$ | 0.047 |

$^{a,b}$ Means along the same row without superscript are not significantly (p<0.05) different. Where AST - Aspartate aminotransferase, ALT - Alanine aminotransferase, BUN - Blood Urea Nitrogen, HDL – High density lipoprotein

## Conclusion

In conclusion, the addition of β-Glucanase and Enziblend Energy to the diets of weaner pigs in this study did not improve nor compromise the growth performance of the pigs. Also, the health status and liver function of the pigs were not adversely affected by the inclusion of the enzymes in the diets of the weaner pigs. Further studies involving increase in dietary fibres and the enzymes is suggested.

**Acknowledgements**

Authors of this paper wish to appreciate the management and staff of Mid-Century Nigeria Limited and AK Research Farm, Eleyele, Ibadan, Oyo State, Nigeria. They are appreciated for their support and contributions towards the successful execution of this project.

**Conflict of interests**

The authors declare that there were no competing interests.

**References**

Aderibigbe, A. S., Park, C. S., Johnson, T., Velayudhan, D. E., Vinyeta, E., & Adeola, O. (2024). Efficacy of a novel multi-enzyme feed additive on growth performance, nutrient digestibility, and gut microbiome of weanling pigs fed corn–wheat or wheat–barley-based diet. J. Anim. Sci., 102, skae064. https://doi.org/10.1093/jas/skae064

Adesehinwa, A. O. K., Obi, O. O., Makanjuola, B. A., Oluwole, O. O. & Adesina, M. A. (2011). Growing pigs fed cassava peel-based diet supplemented with or without Farmazyme® 3000 proenx: Effect on growth, carcass and blood parameters. Afri J. Biotech., 10(14), 2791-2796. https://doi.org/10.5897/AJB10.967

Agyekum, A. K., Sands, J. S., Regassa, A., Kiarie, E., Weihrauch, D., Kim, W. K., & Nyachoti, C. M. (2015). Effect of supplementing a fibrous diet with a xylanase and β-glucanase blend on growth performance, intestinal glucose uptake, and transport-associated gene expression in growing pigs. J. Anim. Sci, 93(7), 3483-3493. https://doi.org/10.2527/jas.2015-9027

Amaefule, R. A., Iwuji, T. C., Ogbuewu, I. P., & Etuk, I. F. (2020). Blood chemistry of growing male pigs in response to low protein and energy diets with EnziBlend Plus supplementation. Comp. Clin. Pathol., 29, 1157-1164. https://doi.org/10.1007/s00580-020-03163-3.

Bruininx, E. M. A. M., Binnendijk, G. P., Peet-Schwering, C. M. C. van der, Schrama, J. W., Hartog, L. A., Everts, H. den & Beynen, A. C. (2002). Effect of creep feed consumption on individual feed intake characteristics and performance of group housed weanling pigs. *J. Anim. Sci.* 80, 1413-1418. https://doi.org/10.2527/2002.8061413x

Dalolio, F. S., Moreira, J., Vaz, D. P., Albino, L. F. T., Valadares, L. R., Pires, A. V., & Pinheiro, S. R. F. (2016). Exogenous enzymes in diets for broilers. *Rev. Bras Saúde Prod. Anim.*, 17, 149-161. https://doi.org/10.1590/S1519-99402016000200003

Dritz, S. S., Shi, J., Kielian, T. L., Goodband, R. D., Nelssen, J. L., Tokach, M. D., & Blecha, F. (1995). Influence of dietary β-glucan on growth performance, nonspecific immunity, and resistance to

Streptococcus suis infection in weanling pigs. *J. Anim. Sci*, 73(11), 3341- 3350. https://doi.org/10.2527/1995.7311334 1x

Duarte, M. E., Sparks, C., & Kim, S. W. (2021). Modulation of jejunal mucosa-associated microbiota in relation to intestinal health and nutrient digestibility in pigs by supplementation of β-glucanase to corn–soybean meal-based diets with xylanase. *J. Anim. Sci* 99(7), 1 - 13.. https://doi.org/10.1093/jas/skab190

Duncan, D.B. (1955) Multiple Range and Multiple F-Test. Biometrics, 11, 1-5.

Eze, J. I., Onunkwo, J. I., Shoyinka, S. V. O., Chah, F. K., Ngene, A. A., Okolinta, N., ... & Onyenwe, I. W. (2010). Haematological profiles of pigs raised under intensive management system in South-Eastern Nigeria. *Nig. Vet. J.*, 31(2), 115 - 123.

Fan, C. L., Han, X. Y., Xu, Z. R., Wang, L. J., & Shi, L. R. (2009). Effects of β-glucanase and xylanase supplementation on gastrointestinal digestive enzyme activities of weaned piglets fed a barley-based diet. *J. Anim. Physiol. Anim. Nutr.*, *93*(2), 271-276. https://doi.org/10.1111/j.1439-0396.2008.00816.x

Irekhore, O. T., Adeyemi, O. M., Idowu, O. M. O., Akinola, O. S., & Bello, K. O. (2015). Growth performance, haematological indices and cost benefits of growing pigs fed cassava peel meal diets supplemented with Allzyme® SSF. *Int. J. Apld Agri. Api. Res.,* 11(1&2), 51 - 59.

Koomkrong, N., Boonkaewwan, C., Laenoi, W., & Kayan, A. (2017). Blood haematology, muscle pH and serum cortisol changes in pigs with different levels of drip loss. *Asian-Australas J. Anim. Sci.*, *30*(12), 1751. https://doi.org/10.5713/ajas.17.0037

Mavromichalis, I., Hancock, J. D., Senne, B. W., Gugle, T. L., Kennedy, G. A., Hines, R. H. & Wyatt, C. L. (2000). Enzyme supplementation and particle size of wheat in diets for nursery and finishing pigs. *J. Anim. Sci.* , 78, 3086 – 3095.

Munezero, O. & Kim, I. H. (2022). Effects of protease enzyme supplementation in weanling pigs' diet with different crude protein levels on growth performance and nutrient digestibility. *J. Anim. Sci. Technol.*, *64*(5), 854 https://doi.org/10.5187/jast.2022.e51

National Research Council. (2012). Nutrient requirements of swine, 11th edn. Washington, DC, USA: National Academies Press.

Navab, M., Reddy, S. T., Van Lenten, B. J., & Fogelman, A. M. (2011). HDL and cardiovascular disease: atherogenic and atheroprotective mechanisms. *Nat. Rev. Cardiol.*, *8*(4), 222-232. https://doi.org/10.1038/nrcardio.2010.222

O'Doherty, J., Dowley, A., Conway, E., & Sweeney, T. (2023). Nutritional Strategies to Mitigate Post-Weaning Challenges in Pigs: A Focus on Glucans, Vitamin D, and Selenium. *Animals*, *14*(1), 13. https://doi.org/10.3390/ani14010013

Onasanya, G. O., Oke, F. O., Sanni, T. M., & Muhammad, A. I. (2015). Parameters influencing haematological, serum and bio-chemical references in livestock animals under different management systems. *Open J. Vet. Med.*, *5*(08), 181. http://www.scirp.org/journal/PaperInformation.aspx?PaperID=59218&#abstract

Perri, A. M., O'Sullivan, T. L., Harding, J. C., Wood, R. D. & Friendship, R. M. (2017). Hematology and biochemistry reference intervals for Ontario commercial nursing pigs close to the time of weaning. *Can. Vet. J.*, *58*(4), 371-376. https://pmc.ncbi.nlm.nih.gov/articles/PMC5347327/

SAS (2002) Statistical Analysis System: Version 9.0. SAS Institute Inc., Cary.

Spreeuwenberg, M. A. M., Verdonk, J. M. A. J., Gaskins, H. R. & Verstegen, M. W. A. (2001). Small intestine epithelial barrier function is compromised in pigs with low feed intake at weaning. *J. Nutr.*, *131*(5), 1520-1527. https://doi.org/10.1093/jn/131.5.1520

Wang, J. P., Hong, S. M., Yan, L., Yoo, J. S., Lee, J. H., Jang, H.D., Kim, H. J. & Kim, I. H. (2009). Effects of single or carbohydrases cocktail in low-nutrient-density diets on growth performance, nutrient digestibility, blood characteristics, and carcass traits in growing-finishing pigs. *Livest. Sci.* 126, 215-220. https://doi.org/10.1016/j.livsci.2009.07.003

Yu, M., Li, Z., Chen, W., Rong, T., Wang, G. & Ma, X. (2019). Hermetia illucens larvae as a potential dietary protein source altered the microbiota and modulated mucosal immune status in the colon of finishing pigs. *J. Anim. Sci. Biotechnol.* 10, 50. https://doi.org/10.1186/s40104-019-0358-1

Zhang, S., Yu, B., Liu, Q., Zhang, Y., Zhu, M., Shi, L., & Chen, H. (2022). Assessment of hematologic and biochemical parameters for healthy commercial pigs in China. *Animals*, *12*(18), 2464. https://doi.org/10.3390/ani12182464

Zheng, L., Duarte, M. E., Sevarolli Loftus, A., & Kim, S. W. (2021). Intestinal health of pigs upon weaning: challenges and nutritional intervention. *Front. Vet. Sci.*, *8*, 628258. doi:10.3389/fvets.2021.628258