sciendo DOI: 10.2478/ats-2023-0024 AGRICULTURA TROPICA ET SUBTROPICA, 56 OV, 217–224, 2023

Original Research Article

Influence of dietary manipulation on coping with stress in pig production

Olufemi Adebukola **Adebiyi**[1], Isaac Oluseun **Adejumo**[1,2], Elizabeth Abiola **Ajayi**[1], Emmanuel Ikemefuna **Okiwelu**[1]

[1]*Department of Animal Science, University of Ibadan, Nigeria*
[2]*Helix Biogen Institute, Nigeria*

Correspondence to:
I.O. Adejumo, Department of Animal Science, University of Ibadan, Nigeria;
e-mail: isaac.ade@helixbiogeninstitute.org; oa.adebiyi@ui.edu.ng; +2348066446246; +2348108149676

Abstract

Pigs for commercial production are often housed intensively because of its benefits, such as proper management of the animals, record-keeping, feed and water provision and management. However, intensive systems of production may also produce stress in animals, arising from operations such as weaning, feed reduction or manipulation, and vaccination. In Africa, pig farmers feed cassava peels to pigs to reduce the cost of production despite its low protein content and anti-nutritional factor (hydrocyanide). However, little is known about the effect of this feed change in terms of stress on weaners. In this study, we replaced maize with cassava peels and supplemented the diets with a fixed amount of tryptophan (Trp) to investigate its effect on performance, haematology, behavioural response of pigs to weaning, and their response to metabolic stress. Crossbred weaner pigs were used and randomly assigned to three treatments in a completely randomised design. Each treatment had three replicates and each replicate had three animals. The feeding trial lasted for four weeks. Dietary manipulations did not influence the growth performance characteristics and behavioural response of the animals. Packed cell volume, haemoglobin, red blood cell counts, and neutrophils were significantly ($p < 0.05$) higher for 20% cassava peel as a replacement for maize but lower for a 40% cassava peel-based diet when compared with the control group. Feeding cassava peels as a replacement for maize in weaner pigs may be carefully considered, although further studies in this direction are recommended.

Keywords: cassava; corticosterone; cost; diets; haematology; peels; performance; pigs; stress; tryptophan

INTRODUCTION

In commercial pig production, intensive system of production is mostly adopted because of some of its benefits, such as proper management of the animals, record-keeping, feed and water provision and management. However, intensive system of production may also produce stress in animals (Barnett et al., 2001). Stress is a term that could mean different things in different fields of human endeavors. Simply put, stress could mean any social imbalance or disequilibrium producing discomforts in the social structure within a society or population (Fink, 2009). Stress could be described as "the non-specific response of the body to any demand for change" (Selye, 1936). It may also mean the perception of threat with accompanying discomfort, anxiety, difficulty in adjusting to it and emotional tension or trauma (Fink, 2009). Stress may further be described as any stimulus or response provoking the release of adrenal secretions (adrenal glucocorticoids and adrenocorticotropic hormone) (Martínez-Miró et al., 2016). However, a supposedly universal definition may be any biological response or stimulus brought about when an individual (humans

© AUTHORS 2023.
This work is licensed under the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 License (https://creativecommons.org/licenses/by-nc-nd/4.0/)

or animals) perceives a threat to its homeostasis (Moberg, 2000).

The impact of dietary supplementation of neuromediators on reducing the negative impacts of the stress response has been documented. Inclusion of neuromediators in pig diets might reduce the adverse effect of the stress response and reduce production losses associated with weaning (Sterndale et al., 2020). Having a molecular weight of 204.22 g/mol and a molecular formula of $C_{11}H_{12}N_2O_2$ tryptophan (Trp) is the largest proteinogenic amino acid in the cell. Being an essential amino acid, it is not synthesised in animals and must thus be provided in the diets. Trp is hydrophobic and aromatic. Phenylalanine, tyrosine and Trp are the three aromatic amino acids that minimally contain a six-membered benzene ring in their side chains. The side chain of Trp is indole, which is complex. It is a six-membered benzene ring fused to a five-membered pyrrole ring with an integrated NH group. Trp can also be viewed as a derivative of alanine, having an indole substituent on the β carbon (Barik et al., 2020). Trp is required for normal growth and it serves as an *in vivo* precursor for bioactive compounds such as serotonin, nicotinamide (vitamin B6), melatonin, tryptamine, kynurenine, 3-hydroxykynurenine, and quinolinic and xanthurenic acids (Li et al., 2006; Le Floc'h and Seve, 2007; Poletto et al., 2010; Valros et al., 2015; Friedman, 2018).

During their lifetime, pigs encounter many stressors, including separation from the dam at weaning and changes in feed/feeding systems (Puppe et al., 1997; Martínez-Miró et al., 2016). Stress has been observed as "a process with multifactorial causes, producing an organic response that generates negative effects in the health and production of the animals affected" (Martínez-Miró et al., 2016). Pigs are highly productive. They are omnivores and compete with humans for food. They are fed varieties of food/feed but their performance depends to a large extent on the quality of their feed. Protein and energy sources are the most expensive feed ingredients for monogastric animals, considering the quantities required. Feed cost is increasingly rising, caused by several factors, which has made sourcing for alternative feed ingredients (less competed for by human beings) necessary, especially in areas where food security is currently a challenge.

In Africa, pig farmers feed cassava peels to pigs to reduce the cost of production despite its low protein content and anti-nutritional factor (hydrocyanide). It has recently been reported that the production of cassava in Nigeria stands at over 59 million tons per year (Garba et al., 2020). It has been documented that agro-waste could serve as a potential source of secondary raw material for energy and material recovery (Santos et al., 2022). Their suitability for energy and material recovery could be traced to their lignocellulosic content (Santos et al., 2022; Adeniyi et al., 2022). Cassava has been reported to contain anti-nutritional factors which may include cyanide, phytate, tannin and oxalate. The anti-nutritional factors in cassava are harmful to human health. Cyanogenic glycosides are the most important of them, which break down to release toxic hydrogen cyanide gas in a process known as cyanogenesis, which may lead to chronic health problems unless appropriately processed (Montagnac et al., 2009; Zekarias et al., 2019; Mariam and Woldeyes, 2020). However, little is known about the effect of this feed change in terms of stress to weaners. In this study, we replaced maize with cassava peels and supplemented the diets with Trp to investigate its effect on performance, haematology, behavioural response and corticosterone levels of pigs to weaning and metabolic stress.

MATERIALS AND METHODS

Management of experimental animals

The feeding trial was carried out at the Swine Unit of the University of Ibadan Teaching and Research Farm, Nigeria. The experiment was approved by the Animal Care and Ethics Committee of the Department of Animal Science, University of Ibadan, Nigeria (ANSUI/PS/09/21). Crossbred (Large White × Landrace) weaner pigs (4.5–4.7 kg) were used and randomly assigned into three treatments in a completely randomised design (CRD). The experimental animals were individually numbered, weighed and allotted to treatments in CRD in such a way that the difference in the average initial body weight within each treatment and across treatments was not significantly different (Adejumo et al., 2021). Each treatment had three replicates and each replicate had three animals. The feeding trial lasted for four weeks. The cassava peels used for the study were obtained from a reputable farm in Ogbomoso, Nigeria. The standard feed ingredients were procured from a reputable feed miller in Ibadan, Nigeria. The animals were injected with Ivomec® (Ivermectin) subcutaneously against endo-and ectoparasites and were properly housed and fed with a standard maize-based diet (T_1), 20% cassava peel inclusion (replacement for maize) (T_2) and 40% cassava peel-based diets (T_3). The animals had unrestricted access to feed and water throughout the experiment.

Chemical determination and collection of data

The proximate analysis of the diet was determined using AOAC (1990). The composition of the diet is shown in Table 1. Weekly feed intake (FI) and body weight gain (BWG) were measured and feed efficiency (g/kg) was calculated from the values of FI and BWG. At the end of the feeding trial, blood samples were collected according to treatments early in the morning to minimise stress on the animals. The blood was collected into a serum tube through the jugular vein puncture method into two sample bottles using a sterilised needle and syringe. The blood samples (n = 27) for haematology were analysed for packed cell volume (PCV), haemoglobin (Hb), red blood cell counts (RBC), white blood cell counts (WBC), etc. The blood samples for serum analysis (corticosterone) were allowed to clot before centrifuging to obtain the serum. The blood was centrifuged at 1008 × *g* for 10 min to separate the serum. The serum samples were collected into micro tubes and stored at –20 °C until the determination of corticosterone concentration by chemiluminescent microparticle immunoassay using IMMULITE 1000 automated immunoassay system (Cinquanta et al., 2017).

The behaviours of the weaned pigs in the groups were video-recorded continuously for one hour per day for two consecutive days a week and it was done for four weeks. All behavioural data were obtained from video images that were digitally recorded. The behavioural time values presented are the means and standard errors of the relative frequencies of each behavior, calculated from the results obtained from each observation of each group (Rhim, 2012; Rhim et al., 2015). The feeding, manipulative, sleeping and lying, agonistic, and other behaviours were observed. The frequency and duration of these pig behaviours were recorded by video. Behavioural ethnology is presented in Table 2. Agonistic behaviour was defined as the encounter between two pigs involved in physical contact, and started with the first physical contact and ended with submissive behaviour (escape) being shown by one

Table 1. Gross composition of experimental weaned pig diet (g/kg DM)

Feed ingredients	Treatments		
	Treatment 1 (T_1)	Treatment 2 (T_2)	Treatment 3 (T_3)
Maize	40.00	20.00	0.00
Soybean meal	10.00	10.00	10.00
Cassava peels	0.00	20.00	40.00
Wheat	15.00	15.00	15.00
Groundnut cake	15.00	15.00	15.00
Bone	01.00	1.00	1.00
Palm kernel cake	13.00	13.00	13.00
Lysine	0.25	0.25	0.25
Methionine	0.25	0.25	0.25
Salt	0.25	0.25	0.25
Palm oil	5.00	5.00	5.00
Tryptophan	0.25	0.25	0.25
Total	**100.00**	**100.00**	**100.00**

Treatment 1 = 40% maize + 0%cassava peels + 60% fixed ingredients
Treatment 2 = 20% maize + 20% cassava peels + 60% fixed ingredients
Treatment 3 = 0% maize + 40% cassava peels + 60% fixed ingredients
Source: Self (obtained in this study)

Table 2. Behavioural ethnology

Behavior	Description
Ingestive behaviour	Feeding and drinking
Aggressive behaviour	Head thrusting, biting, chasing or fighting with another pen or littermate
Manipulative behaviour	Belly nosing, nosing and mounting other pen or littermates
Exploratory behaviour	Investigating the surroundings such as nosing the floor, scrapping the floor with one of the forelegs, nosing or nibbling of pen fixtures
Lying behaviour	Lying on the side or belly with eyes open, not performing any other described behaviour
Sleeping behaviour	Lying on the side or belly with eyes closed, not performing any other described behaviour

Source: Adapted from Bolhuis et al. (2005); Middelkoop et al. (2019)

of the opponents or when they both move away or separate from each other (Borberg and Hoy, 2009; Samarakone and Gonyou, 2009; Krauss and Hoy, 2011; Rhim, 2012).

Experimental design and statistical analysis

The experimental design of the study was completely randomised. Data obtained were analysed using the one-way analysis of variance and significant means were separated using Duncan's Multiple Range test, and the general linear model of the SAS package.

RESULTS

The proximate composition of the feed samples is shown in Table 3. The diets were isonitrogenous and isocaloric. The dry matter was similar with T_1 obtaining the highest numerical value while T_3 obtained the least value. The ash content ranged between 5.45 and 6.65 mg/g. T_2 obtained the highest numerical crude protein content while T_3 had the least value. Values for crude fat were also similar. Table 4 shows the effect of the varying levels of dried cassava peels on the growth performance of weaned pigs. There were no significant ($p > 0.05$) differences among the treatments for growth

Table 3. Proximate analysis of the feed %

	Treatment 1	Treatment 2	Treatment 3	SEM
Moisture content	7.55	7.75	8.30	0.057
Dry matter	92.45	92.25	91.70	0.057
Ash content	6.65	5.45	6.20	1.517
Crude fat	13.85	14.15	13.55	0.258
Crude protein	18.46	19.25	17.14	0.390
Crude fibre	5.85	6.45	5.65	0.298

Treatment 1 = 40% maize + 0%cassava peels + 60% fixed ingredients
Treatment 2= 20% maize + 20% cassava peels + 60% fixed ingredients
Treatment 3 = 0% maize + 40% cassava peels + 60% fixed ingredients
Source: Self (obtained in this study)

Table 4. Growth performance contents of weaner pigs fed cassava peels as a replacement for maize

Parameters	Treatment 1(T_1)	Treatment 2(T_2)	Treatment 3(T_3)	SEM
Initial weight (kg)	4.69	4.65	4.54	0.05
Final weight (kg)	8.27	8.12	7.65	0.06
Weight gain (kg)	3.58	3.47	3.10	0.04
Feed intake (kg)	10.78	10.88	10.14	0.04
Feed efficiency (g/kg)	332.10	318.93	305.72	10.77

Treatment 1 = 40% maize + 0%cassava peels + 60% fixed ingredients
Treatment 2= 20% maize + 20% cassava peels + 60% fixed ingredients
Treatment 3 = 0% maize + 40% cassava peels + 60% fixed ingredients
Source: Self (obtained in this study)

Table 5. Haematology contents of weaner pigs fed cassava peels as a replacement for maize

	T_1	T_2	T_3	SEM
PCV%	35.67^b	38.67^a	30.33^c	0.11
Hb (g/dL)	11.43^b	12.47^a	9.90^c	0.05
RBC ($\times 10^6/mm^3$)	5.59^b	6.13^a	4.75^c	0.01
WBC ($\times 10^6/mm^3$)	3.48^c	4.82^a	3.78^b	0.32
Platelets ($\times 10^6/mm^3$)	79.33	79.67	79.33	11.03
Lymphocytes (%)	51.67^b	48.33^b	58.00^a	0.20
Monocytes (%)	3.67^a	2.67^b	4.00^a	0.05
Eosinophils (%)	4.00	4.00	3.33	0.07
Neutrophils (%)	40.67^b	44.00^a	34.67^c	0.14

T_1 = 40% maize + 0%cassava peels + 60% fixed ingredients
T_2= 20% maize + 20% cassava peels + 60% fixed ingredients
T_3 = 0% maize + 40% cassava peels + 60% fixed ingredients
Different superscripts within the same row indicate significant ($p < 0.05$) difference
PCV = packed cell volume; Hb = haemoglobin; RBC = red blood cell counts; WBC = white blood cell counts.
Source: Self (obtained in this study)

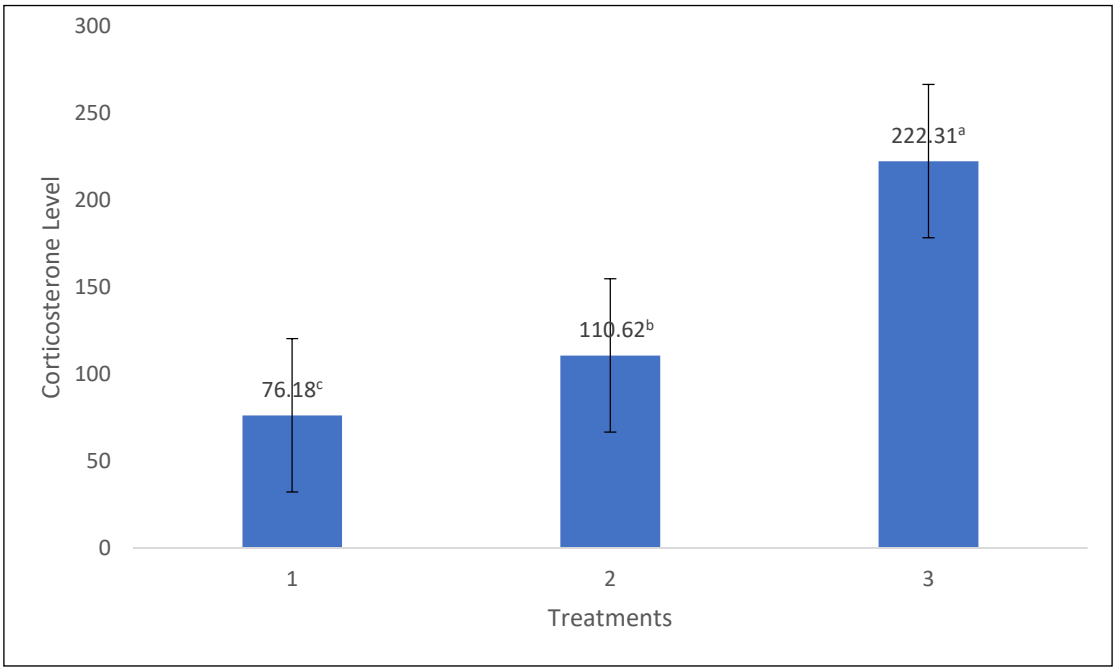

Figure 1. Corticosterone levels of weaner pigs fed cassava peels in replacement for maize
Treatment 1 = 40% maize + 0%cassava peels + 60% fixed ingredients
Treatment 2 = 20% maize + 20% cassava peels + 60% fixed ingredients
Treatment 3 = 0% maize + 40% cassava peels + 60% fixed ingredients
Source: Self (obtained in this study)

Table 6. Behavioural measurements (in minutes) of weaner pigs fed cassava peels as a replacement for maize (morning)

	T_1	T_2	T_3	SEM
Feeding	8.17	9.00	7.94	0.11
Sleeping/Lying	0.00	0.00	0.00	0.00
Manipulation	0.39	0.56	0.39	0.06
Aggression	0.11^{b}	0.61^{a}	0.55^{ab}	0.03
Explorative	2.89	3.11	2.00	0.25

Source: Self (obtained in this study)

Table 7. Behavioural measurements (in minutes) of weaner pigs fed cassava peels as a replacement for maize (afternoon)

	T_1	T_2	T_3	SEM
Feeding	5.72	6.00	5.83	0.11
Sleeping/Lying	3.72	3.44	3.56	0.12
Manipulation	2.00	1.39	1.11	0.07
Aggression	0.44	0.50	0.28	0.04
Explorative	1.39	1.00	1.67	0.16

T_1 = 40% maize + 0%cassava peels + 60% fixed ingredients
T_2 = 20% maize + 20% cassava peels + 60% fixed ingredients
T_3 = 0% maize + 40% cassava peels + 60% fixed ingredients
Source: Self (obtained in this study)

performance characteristics of the experimental animals. No mortality was recorded across the treatments for the experimental animals.

The haematological variables of weaner pigs fed cassava peels as a replacement for maize are shown in Table 5. Platelets and eosinophils were not significantly ($p > 0.05$) different across the treatments. Packed cell volume (PCV), haemoglobin (Hb), red blood cell counts (RBC), white blood cells counts (WBC) and neutrophils were significantly ($p < 0.05$) higher for T_2, but lower for T_3 when compared with the control group (T_1), except for WBC which was higher for T_3 than the control group. Monocytes were significantly ($p < 0.05$) lower for T_2 when compared with the control (T_1) group. However, the values for both T_1 and T_3 were similar. Lymphocytes were significantly ($p < 0.05$) higher for T_3

(58.00%) when compared with T_1 and T_2 groups, which were similar. Pigs fed on T_3 obtained the highest value of corticosterone followed by T_2, while T_1 obtained the least value (Figure 1). Behavioural measurements of weaner pigs fed cassava peels as a replacement for maize for morning and afternoon are presented in Tables 6 and 7, respectively. There were no significant ($p > 0.05$) differences observed across the treatments for both morning and afternoon measurements.

DISCUSSION

The present study shows that despite the variations in the cassava content of the various diets, there was relative adequacy of protein in all the diets. This is notwithstanding the very poor protein content of cassava meal (Gomez et al., 2018). The result of the present study for growth performance characteristics agrees with the findings of Adebiyi et al. (2017) who recorded no significant differences in the weight gain and average feed intake if weaner pigs were fed with cassava peels and plantain peels at levels 0, 60% cassava peels and 60% plantain peels.

In the present study values obtained for white blood corpuscles were lower than the values reported in the previous study by Etim et al. (2013), which might be a result of the breed, season, age, and fasting (Afolabi, 2010). Eheba et al. (2008) posited that a decrease in WBC count, however, reflected a fall in the production of defensive mechanisms to combat infection. The result showed that there were significant reductions in PCV, RBC counts, Hb concentration and neutrophils in T_3. Based on the findings in the present study, pigs in T_1 and T_2 could be said to have better haematological values than those in T_3. The values obtained were similar to earlier values reported by previous authors (Radostits et al., 2000). WBC values were higher for cassava peel-based diets, which may be an indication of stress. It is known that any form of stress can increase WBC. Etim et al. (2013) previously noted stated that low values in pig haematological parameters might be due to malnutrition. In a previous study by Adesehinwa et al. (2011) Hb and RBC of pigs were increased by the inclusion of enzyme, and replacement of the maize content of the basal diet with cassava peels significantly reduced both parameters. The authors, however, recommend further studies in this direction to unravel the subject matter presently being discussed, that is, the adverse effect of cassava peels on haematological and physiological parameters of pigs.

Pigs are very adaptable to their environment, but nutritional status may affect their response to environmental stimulus. Even though a fixed level of Trp was included in all diets, maize has a higher Trp content than cassava. However, in the present study pigs' behavioural displays were not significantly different between treatments. Previous studies reported a decreased aggressive behaviour among mice when their water was supplemented with Trp (Li et al., 2006; Janczak et al., 2001). Also, Martínez-Trejo et al. (2009) reported that Trp supplementation in the diets of piglets positively affected some of their behaviour, however, it did not affect their productive performance, which is similar to the growth performance of pigs in the present study.

CONCLUSION

Pigs are known to easily adapt to their environment but it is becoming clearer that their nutritional quality or status might influence their response to stimulus including stress. Cassava peels are fed to pigs mainly to reduce the cost of production. However, supplementing cassava peel-based diets with Trp might help reduce the effect of stress on the animals as a result of feed amendment. Therefore, it can be concluded from this study that:

1. Cassava peel-based diets supplemented with a fixed amount of Trp did not influence the growth performance of weaner pigs.
2. Haematological variables seem compromised for pigs fed a 40% cassava peel-based diet as a total replacement for maize, supplemented with Trp.
3. Cassava peel-based diets supplemented with a fixed amount of Trp did not affect pigs' behaviour when compared with a maize-based diet.
4. As a coping strategy for metabolic stress that diet manipulation might have brought on the pigs, a cassava peel-based diet as a total replacement for maize raised the corticosterone level of the experimental animals.
5. Based on the findings on corticosterone, the complete replacement of maize with cassava peel in the diets of piglets may be carefully considered, although this may be subjected to further studies.

CONFLICT OF INTEREST

The authors declared no conflicts of interest concerning the research, authorship, and publication of this article.

ETHICAL COMPLIANCE

This experiment was conducted in line with the approval of protocol by the Animal Ethics and Care Committee of the Department of Animal Science, University of Ibadan, Nigeria by the ethical standards of the Institutional and/or National Research Committee

and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

REFERENCES

Adebiyi O.A., Alaba O., Emeruwa C.H. (2017): Effect of palm oil slurry on haematology and serum profile of growing pigs. In: Sustainable Livestock Production for National Development. Proceedings of 6th Joint Annual Meeting of Animal Science Association of Nigeria and Nigerian Institute of Animal Science's Conference, 10–14 September.

Adejumo I.O., Bryson B., Olojede O.C., Bedford M.R., Adedokun S.A. (2021). Effect of sodium sources and exogenous phytase supplementation on growth performance, nutrient digestibility, and digesta pH of 21-day-old broilers. Poultry Science 100: 1–13, 101467 https://doi.org/10.1016/j.psj.2021.101467

Adeniyi A.G., Adeyanju C.A., Iwuozor K.O., Odeyemi S.O., Emenike E.C., Ogunniyi S., Te-Erebe D.K. (2022): Retort carbonization of bamboo (*Bambusa vulgaris*) waste for thermal energy recovery. Clean Technologies and Environmental Policy 25:1–11. DOI:10.1007/s10098-022-02415-w

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. African Journal of Biotechnology 10: 2791–2796.

Afolabi K.D., Akinsoyinu A.O., Olajide R., Akinleye S.B. (2010): Haematological parameters of the Nigerian local grower chickens fed varying dietary levels of palm kernel cake In: Proceedings of 35th Annual Conference of Nigerian Society for Animal Production (p. 247).

AOAC International (1990): Official Methods of Analysis. 15th Edition, Association of Official Analytical Chemists, Washington DC.

Barik S. (2020): The uniqueness of tryptophan in biology: properties, metabolism, interactions and localization in proteins. International Journal of Molecular Science 21: 8776

Barnett J.L., Hemsworth P.H., Cronin G.M., Jongman E., Hutson G.D. (2001): A review of the welfare issues for sows and piglets in relation to housing. Australian Journal of Agricultural Research 52: 1–28.

Bolhuis J.E., Schouten W.G.P., Schrama J.W., Wiegant V.M. (2005): Behavioural development of pigs with different coping characteristics in barren and substrate-enriched housing conditions. Applied Animal Behaviour Science 93: 213–28.

Borberg C., Hoy S. (2009): Mixing of sows with or without the presence of a boar. Livestock Science 125: 314–317.

Cinquanta L., Fontana D.E., Bizzaro N. (2017): Chemiluminescent immunoassay technology: what does it change in autoantibody detection? Autoimmunity Highlights 8: 9 https://doi.org/10.1007/s13317-017-0097-2

Eheba E.T.E., Omoikhojie S.O., Bangbose A.M., Druna M.B., Isidhahomen C.E. (2008): Haematology and serum biochemistry of weaner rabbits fed cooked Bambara groundnut meal as replacement for soybeans meal In: Proceedings of 33rd Annual Conference of Nigerian Society for Animal Production (pp. 192–196).

Etim N.N., Enyenihi G.E., Williams M.E., Udo M.D., Offiong E.E.A. (2013): Haematological parameters: indicators of the physiological status of farm animals. British Journal of Science 10: 33–45.

Fink G. (2009): Stress: definition and history. In: Squire L. R. (Eds): Encyclopedia of Neuroscience (pp. 549–455). Elsevier, London.

Friedman M. (2018): Analysis, nutrition, and health benefits of tryptophan. International Journal of Tryptophan Research 11: 1–12.

Garba B., Balogun R., Kalejaiye-Matti R., Maku B. (2020): Ensuring sustainable development in cassava value chain and value addition in Nigeria. International Journal of Economic Development Research and Investment 11: 50–68.

Gomes L.M., de Mello Miassi G., dos Santos L.S., Dib Saleh M.A., Sartori J.R., Panhoza Tse M.L., Berto D.A. (2018): Impact of two light programs and two levels of dietary tryptophan for weanling piglets. Livestock Science 216: 191–196.

Janczak A.M., Bakken M., Braastad B.O. (2001): A cautionary note regarding the use of nutritional L-tryptophan to alter aversion-related behavior in mice. Applied Animal Behaviour Science 72: 365–373.

Krauss V., Hoy S. (2011): Dry sows in dynamic groups: an investigation of social behavior when introducing new sows. Applied Animal Behaviour Science 130: 20–27.

Le Floc'h N., Seve B. (2007): Biological roles of tryptophan and its metabolism: potential implications for pig feeding. Livestock Science 112: 23–32.

Li Y.Z., Kerr B.J., Kidd M.T., Gonyou H.W. (2006): Use of supplementary tryptophan to modify the behavior of pigs. Journal of Animal Science 84: 212–220.

Mariam L. W., Woldeyes F. (2020): Review on effect of processing on cassava anti-nutritional factors and impacts on health. International Journal of Forensic Research 1: 23–33.

Martínez-Miró S., Tecles F., Ramón M., Escribano D., Hernández F., Madrid J., Orengo J., Martínez-Subiela S., Manteca X., Cerón J.J. (2016): Causes, consequences and biomarkers of stress in swine: an update. BMC Veterinary Research 12: 171, DOI 10.1186/s12917-016-0791-8

Martínez-Trejo G., Ortega-Cerrilla M.E., Rodarte-Covarrubias L.F., Herrera-Haro J.G., Figueroa-Velasco J.L. Galindo-Maldonado F., Sanchez-Martinez O., Lara-Bueno A. (2009): Aggressiveness and productive performance of piglets supplemented with tryptophan. Journal of Animal and Veterinary Advances 8: 608–611.

Middelkoop A., van Marwijk M.A., Kemp B., Bolhuis J.E. (2019): Pigs like it varied; feeding behavior and pre- and post-weaning performance of piglets exposed to dietary diversity and feed hidden in substrate during lactation. Frontiers in Veterinary Science 6: 408.

Moberg G. P. (2000): Biological response to stress: implications for animal welfare. In: Moberg G. P., Mench J. A. (Eds). The biology of animal stress: basic principles and implications for animal welfare (pp. 1–22). CABI Publishing USA.

Montagnac J.A., Davis C. R., Tanumihardjo S.A. (2009): Processing techniques to reduce toxicity and anti-nutrients of cassava for use as a staple food. Comprehensive Reviews in Food Science and Food Safety 8: 17–27.

Poletto R., Meisel R.L., Richert B.T., Cheng H.W., Marchant-Forde J.N. (2010): Aggression in replacement grower and finisher gilts fed a short-term high-tryptophan diet and the effect of long-term human-animal interaction. Applied Animal Behaviour Science 122: 98–110.

Puppe B., Tuchscherer M., Tuchscherer A. (1997): The effect of housing conditions and social environment immediately after weaning on the agonistic behaviour, neutrophil/ lymphocyte ratio, and plasma glucose level in pigs. Livestock Production Science 48: 157–164.

Radostits O.M., Gay C.C., Blood D.C., Hinchcliff K.W. (2000): Veterinary Medicine, 9th edn, W.B. Saunders, London, pp. 1819–1822.

Rhim S.J. (2012): Effects of group size on agonistic behaviors of commercially housed growing pigs. Revista Colombiana de Ciencias Pecuarias 25: 353–359.

Rhim S.J., Son S.H., Hwang H.S., Lee J.K., Hong J.K. (2015): Effects of mixing on the aggressive behavior of commercially housed pigs. Asian-Australasian Journal of Animal Sciences 28: 1038–1043.

Santos A.L.M., Castro A.L.S., Salomon K.R., Souza T.S.O., Vich D.V. (2022): Global research trends on anaerobic digestion and biogas production from cassava wastewater: a bibliometric analysis. Journal of Chemical Technology & Biotechnology 97: 1379–1389.

Sterndale S.O., Miller D.W., Mansfield J.P., Kim J.C., Pluske J.R. (2020): Increasing dietary tryptophan in conjunction with decreasing other large neutral amino acids increases weight gain and feed intake in weaner pigs regardless of experimental infection with enterotoxigenic *Escherichia coli*. Journal of Animal Science 98: 1–10.

Samarakone T.S., Gonyou H.W. (2009): Domestic pigs alter their social strategy in response to social group size. Applied Animal Behaviour Science 121: 8–15.

Selye H. (1936): A syndrome produced by diverse nocuous agents. Nature 138: 32

Valros A., Palander P., Heinonen M., Munsterhjelm C., Brunberg E., Keeling L., Piepponen P. (2015): Evidence for a link between tail biting and central monoamine metabolism in pigs (*Sus scrofa domestica*). Physiology & Behaviour 143: 151–157.

Zekarias T., Basa B., Herago T. (2019): Medicinal, nutritional and anti-nutritional properties of cassava (*Manihot esculenta*): a review. Academic Journal of Nutrition 8: 34–46.

Received: July 5, 2023
Accepted after revisions: November 27, 2023