Proximate analysis of pigean pea (*Cajanus cajan*) seed soaked at different times in wood ash solution and their effects on performance of broiler chickens

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Abstract

*This study was conducted to evaluate the effect of proximate analysis and wood ash extract soaking varying durations (24, 48, and 72 hours) of pigeon pea (Cajanus cajan) seeds on the performance of broiler chickens. Raw pigeon pea seeds were soaked in wood ash extract at pH 8.5 for 24, 48, and 72 hours, sun-dried, and incorporated into broiler diets replacing soyabean at 50% at the three levels. A total of 144 day-old Anak 2000 broiler chicks were randomly assigned to four dietary treatments in a completely randomized design with three replicates of 12 birds each. Proximate analysis revealed that soaking significantly (P<0.05) influenced crude protein, crude fibre, ether extract, ash content, nitrogen-free extract, and metabolizable energy of pigeon pea seeds. The 72-hour soaking period yielded the highest crude protein content (25.57%). Performance characteristics showed that birds fed the 72-hour soaked pigeon pea meal (APPM$_3$) had significantly (P<0.05) higher final live body weight (868.28g±**0.25** for starter; 2018.75g±**2.16** for finisher) and daily body weight gain compared to other treatments. Feed conversion ratio and protein efficiency ratio were favorably influenced by the dietary treatments. The findings suggest that soaking pigeon pea seeds in wood ash extract for 72hours duration optimally enhances their nutritive value and improves broiler chicken performance compared to other treatments, offered better alternative to conventional soya bean meal.*

Keywords: Broiler performance, proximate analysis, Pigeon pea, soaking duration, wood ash extract

Analyse immédiate de graines de pois d'Angole (*Cajanus cajan*) trempées pendant différentes durées dans une solution de cendre de bois et leurs effets sur les performances des poulets de chair

Résumé

Cette étude a évalué l'effet de l'analyse immédiate et du trempage dans un extrait de cendre de bois de graines de pois d'Angole (Cajanus cajan) pendant différentes durées (24, 48 et 72 heures) sur les performances des poulets de chair. Des graines de pois d'Angole crues ont été trempées dans un extrait de cendre de bois à pH 8,5 pendant 24, 48 et 72 heures, séchées au soleil, puis incorporées dans les régimes des poulets de chair en remplaçant le tourteau de soja à hauteur de 50 % selon les trois niveaux. Un total de 144 poussins de chair Anak 2000 d'un jour ont été répartis aléatoirement en quatre traitements alimentaires selon un dispositif complètement randomisé avec trois répétitions de 12 oiseaux chacune. L'analyse immédiate a révélé que le trempage influençait significativement (P<0,05) la teneur en protéines brutes, en fibres brutes, en extrait éthéré, en cendres, en extrait non azoté et en énergie métabolisable des graines de pois d'Angole. La durée de trempage de 72 heures a donné la teneur en protéines brutes la plus élevée (25,57 %). Les caractéristiques de performance ont montré que les oiseaux nourris avec le tourteau de pois d'Angole trempé 72 heures (APPM$_3$) avaient un poids vif final (868,28g±0,25 pour le démarrage ; 2018,75g±2,16 pour la finition) et un gain de poids quotidien significativement (P<0,05) plus élevés que *les autres traitements. L'indice de conversion alimentaire et le coefficient d'efficacité protéique ont été favorablement influencés par les traitements alimentaires. Les résultats suggèrent que le trempage des graines de pois d'Angole dans un extrait de cendre de bois pendant 72 heures améliore de manière optimale leur valeur nutritive et améliore les performances des poulets de chair par rapport aux autres traitements, offrant une meilleure alternative au tourteau de soja conventionnel.*

Mots-clés : Performances des poulets de chair, analyse immédiate, Pois d'Angole, durée de trempage, extrait de cendre de bois

Introduction

Livestock production is essential to Nigerian agriculture and economic growth. Currently, Nigeria's livestock sector contributes over $32 billion to the nation's Gross Domestic Product (Uzonwanne*etal.* 2023). The poultry sector accounts for about 25% of the agricultural GDP (Yagoub and Abdalla, 2022). In 2022, the poultry bird population in Nigeria reached 249 million (Statista, 2024). The Nigerian poultry industry includes around 180 million birds, with approximately 80 million chickens raised in extensive systems, 60 million in semi-intensive systems, and 40 million in intensive systems (FAO, 2022). The livestock population also includes 76 million goats, 43.4 million sheep, and 18.4 million cattle (National Bureau of Statistics, 2020).

Despite these large numbers, the animal protein intake in Nigeria is significantly low. The average protein intake per person is about 45.4g per day, which is below the 53.8g recommended by the Food and Agriculture Organisation (Yagoub and Abdalla, 2022). More worryingly, Nigeria faces a severe deficiency in animal protein security, with per capita consumption estimated at 9.3 grams daily, compared to the 34g that the Food and Agriculture Organization (FAO) suggests for healthy growth and development (Uzonwanne *et al.* 2023). According to the Nigerian Protein Deficiency Report 2020, 45% of Nigerians do not consume protein daily, even though seven out of ten households think they get enough protein (Yagoub and Abdalla, 2022).

This ongoing protein deficiency is worsened by the livestock sector's failure to keep pace with Nigeria's rapid population growth. Nigeria's population is expected to exceed 400 million by 2050 (World Bank, 2023), leading to an unprecedented need for animal protein. The poultry sector holds the most promise for meeting this demand because of its shorter production cycle and greater efficiency. The poultry industry employs directly and indirectly over 25 million Nigerians, which is nearly 10% of the country's population (Yagoub and Abdalla, 2022).

However, developing and expanding poultry production faces significant challenges. Feed costs make up 70% of production expenses in the poultry industry (Uzonwanne *et al.* 2023). The price of chicken feed increased from about ₦25,000 (US$16.65) in December 2023 to ₦27,800 (US$18.49) per 25kg bag, which has significantly raised production costs (Poultry Site, 2024). The Poultry Association of Nigeria reported that around 50% of poultry farmers in the country have closed their operations due to rising input costs). From January to May 2024, maize prices per tonne jumped nearly 60%, while soybean prices climbed about 51% (Uzonwanne *et al.* 2023).

It is crucial to lower feed costs for poultry farmers if the industry is to keep up with population growth and improve food production capacity. Consequently, there is urgent need for alternative, locally-available protein sources to reduce dependency on imported feed ingredients and enhance the economic viability of livestock production. Pigeon pea (*Cajanus cajan*) emerges as a promising solution, containing 17.9-24.3% crude protein in whole grain and up to 32.5% in high protein genotypes, with nutritional quality comparable to soybeans and maize (Yagoub and Abdalla, 2022). However, pigeon pea contains important antinutritional factors including protease inhibitors, amylase inhibitors, phytolectins, polyphenols, and oligosaccharides that limit its utilization in animal diets. Processing methods such as fermentation, boiling, milling, soaking, and roasting can minimize these harmful effects and improve nutritive quality (El-Hack et al., 2018). Despite pigeon pea's widespread cultivation across Nigeria and its potential as a cost-effective feed ingredient, there remains limited documentation on optimal processing techniques that maximize nutrient availability while effectively reducing antinutritional factors for livestock feeding. Alternative feed ingredients that are available locally, nutritionally sufficient, and cost-effective should be explored to ensure the sustainability and profitability of poultry production. This study examines how the proximate analysis and wood ash extract soaking duration of pigeon pea seeds affect broiler chicken production.

Materials and methods

Two kilograms of wood ash was dissolved in 20 liters of water and allowed to stand for 24 hours. The solution was filtered, and the pH was adjusted to 8.5 using a digital hand pH meter. The pH adjustment involved adding 2 moles of hydrochloric acid at a ratio of 2 mole/2 liters of extract to reduce the alkalinity of the medium.

Processing of Pigeon Pea Seeds

Three samples of raw pigeon pea seeds (15kg each) were soaked in wood ash extract for 24, 48, and 72 hours, respectively. After soaking, seeds were sieved from the solution and sun-dried on jute mats for 5 days at atmospheric temperatures between 29-30°C to prevent fermentation and achieve a moisture content of 12.60%. The dried seeds were ground into meal using a hammer mill fitted with a 0.5mm sieve and stored in bags prior to feed formulation and proximate analysis.

Experimental Diets

Four each of experimental broiler starter and finisher diets were formulated. Diet 1 served as the control, containing soybean meal as the plant protein source. Diets 2, 3, and 4 contained 50% ash pigeon pea meal (APPM) soaked for 24, 48, and 72 hours ($APPM_1$, $APPM_2$, $APPM_3$), respectively, plus 50% soybean meal. All diets were formulated to be isonitrogenous (23% crude protein for starter, 21% for finisher) and isocaloric (2800 ME Kcal/kg for starter, 2900 ME Kcal/kg for finisher) to meet NRC (1994) nutrient requirements for broiler chickens.

Table 1: Percentage composition of broiler starter and finisher diets

	Soaked pigeon pea meal (Hours)				Soaked pigeon pea meal (Hours)			
	0	24	48	72	0	24	48	72
	Starter Diets				Finisher Diets			
Ingredients (%)	1	2	3	4	1	2	3	4
Maize	41.9	7.30	19.5	27.2	51.6	23.5	31.9	38.8
Soyabean meal	37.4	20.0	20.0	20.0	33.5	20.0	20.0	20.0
$APPM_1$	0.00	65.5	0.00	0.00	0.00	50.1	0.00	0.00
$APPM_2$	0.00	0.00	42.3	0.00	0.00	0.00	32.5	0.00
$APPM_3$	0.00	0.00	0.00	44.3	0.00	0.00	0.00	34.1
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Wheat bran	5.46	4.11	3.00	3.00	9.43	10.0	9.20	10.6
Bone meal	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Methionine	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Common alt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Calculated analyses								
Crude protein	23.0	23.0	22.8	22.6	21.0	21.0	21.0	21.0
M.E kcal/kg	2801	2864	2864	2872	2900	2900	2900	2900

Experimental Birds and Management

A total of 144 day-old Anak 2000 broiler chicks were used. Thirty-six chicks were randomly assigned to each of four treatment diets based on average initial weight. Each treatment group contained three replicates with twelve birds per replicate in a completely randomized design (CRD). Birds were fed commercial broiler starter diet for one week acclimatization before the feeding trial commenced. Feed and water were provided ad libitum throughout the experiment, with routine medication and vaccination administered as needed.

Performance Characteristics

Body weight changes and feed consumption were recorded weekly. The following parameters were calculated:

- **Weekly Body Weight Gain:** Difference between weights at the beginning and end of each week
- **Daily Feed Intake:** Average weekly feed intake divided by number of birds and by seven
- **Feed Conversion Ratio (FCR):** Feed Intake (g) / Weight Gain (g)
- **Protein Efficiency Ratio (PER):** Weight Gain (g) / Protein Consumed (g

Proximate Analysis

Raw and processed pigeon pea seed samples were analyzed for proximate composition according standard methods (AOAC, 2016) and metabolizable energy was estimated using the formula expressed by Oboh *et al.* (2011).

Statistical Analysis

All data collected were subjected to one-way analysis of variance (ANOVA), and differences between treatment means were compared using Duncan's Multiple Range Test with significance set at P<0.05.

Results

Proximate Analysis

The results in table 2, recorded for crude proteinhas non-linear pattern emerged, with the 72-hour soaking period producing the highest crude protein content (25.57%), followed by 48-hour (22.25%), control (21.88%), and 24-hour (19.38%) treatments. Crude Fiber progressive increases were observed with extended soaking, ranging from 5.07% (control) to 9.03% (72-hour treatment), the 24-hour and 48-hour treatments showed similar intermediate values. Ether Extract fat content increased substantially with soaking with 48-hour treatment with the highest value (6.03), while the 0hour treatment has the least value (3.03). Ash Content at 72-hour treatment exhibited the highest (6.03%) over the control (4.03%). Nitrogen-Free Extract (NFE) and Metabolizable Energy both parameters decreased with extended soaking duration. The most dramatic decline occurred in metabolizable energy, which dropped from 2995.50 Kcal/kg (control) to 1691.70 Kcal/kg (72-hour treatment).

Table 2: Proximate Analysis of Pigeon Pea Seeds Soaked in Wood Ash Extract

Components (%)	Control (0h;urs)	$SPPM_1$ (24hours)	$SPPM_2$ (48hours)	$SPPM_3$ (72hours)	SEM±
Dry matter	91.90^a	91.40^b	91.55^c	91.25^d	0.04
Crude protein	21.88^c	19.38^d	22.25^b	25.57^a	0.03
Crude fibre	5.07^c	7.03^b	7.07^b	9.03^a	0.05
Ether extract	3.03^d	4.03^c	6.03^a	5.03^b	0.04
Ash	4.03^b	3.03^c	3.03^c	6.03^a	0.04
Nitrogen free extract	57.74^a	57.03^a	47.93^b	52.85^c	0.03
Metabolizable energy (Kcal/kg)	2995.50^a	2980.80^b	2875.30^b	1691.70^c	0.05

a,b, c, d: Means in the same row with different superscripts differ significantly (P<0.05)

Performance Characteristics of Starter Broilers

The results from Table 3, revealed that Final body live weight of 72hours (868.28 g) was higher than the control (775.00 g), daily weight gain shows similar improvements for 24h and 48h (37.81 g, 31.20 g) respectively. Birds fed the 72hours soaked pigeon pea meal (Diet 4) demonstrated superior performance across multiple parameters. Feed Intake increased as the soaking hours increased was observed as 43.90 g/day for control to 45.45 for 72hours. Feed conversion ratio showed no significant differences across treatments, protein efficiency ratio improved with soaking duration, with Diet 4 achieving the better value (1.77).

Table 3: Performance Characteristics of Starter Broilers Fed Dietary Treatments

Parameters	**Diet1 (0hours)**	**Diet2 (24hours)**	**Diet3 (48hours)**	**Diet4 (72hours)**	**SEM±**
Initial body live wt (g/bird)	48.00	46.00	46.00	47.00	---
Final body live wt (g/bird)	775.00^{c}	818.92^{b}	812.50^{b}	868.28^{a}	0.25
Dailybody wt gain (g/bird)	31.20^{c}	34.92^{b}	34.38^{b}	37.81^{a}	0.92
Weekly feed intake (g/bird)	307.30^{b}	304.43^{b}	308.91^{ab}	318.15^{a}	2.86
Daily feed intake (g/bird)	43.90^{b}	43.49^{b}	44.13^{ab}	45.45^{a}	0.75
Feed conversion ratio	1.17	1.29	1.25	1.41	0.03
Protein efficiency ratio	1.39	1.54	1.53	1.77	0.05

abc: Means in the same row with different superscripts differ significantly (P<0.05)

Performance Characteristics of Finisher Broilers

The positive trends observed during the starter phase continued through the finisher period, the results from table 4, revealed that final live body weight of 72hours (2018.75g) was highest and 48h (1875.00 g) was the lowest, daily weight gain shows similar results, 72hours and 48hours (51.76g, 49.22 g) respectively. Birds fed the 72hours soaked pigeon pea meal (Diet 4) demonstrated superior performance across multiple parameters. Feed Intakevaries as the soaking hours increased as the least was observed in control 125.78g/day to 48h (130.21g/day). Feed conversion ratio showed no significant differences across treatments, protein efficiency ratio improved with soaking duration, with Diet 4 achieving the best value (2.46).

Table 4: Performance Characteristics of Finisher Broilers Fed Pigeon Pea in Wood Ash Extract

Parameters	Diet1 (0hours)	Diet2 (24hours)	Diet3 (48hours)	Diet4 (72hours)	SEM±
Live weight (g/bird)	1981.25^{b}	1931.08^{bc}	1875.00^{c}	2018.75^{a}	2.16
Daily weight gain (g/bird)	50.09^{b}	50.02^{b}	49.22^{c}	51.76^{a}	0.21
Daily feed intake (g/bird)	125.78^{b}	130.21^{a}	130.21^{a}	127.60^{ab}	0.28
Protein efficiency ratio	2.05	2.05	2.03	2.09	0.06
Feed conversion ratio	2.51	2.60	2.65	2.46	0.01

abc: Means in the same row with different superscripts differ significantly (P<0.05)

Discussion

The proximate analysis results in Table 2, revealed that crude protein content has several biochemical processes (phytic acids, tanins) and becomes noticeable with extended soaking duration, particularly at 72 hours, which implies that, large molecules like proteins and complex organic compounds were broken down through enzymatic hydrolysis into soluble proteins, peptides, and amino acids, this finding align with work of Amaefule *et al*. (2010) and Oboh *et al.* (2011). Further supported by the previous studies on soaked and germinated lentils and lima bean seeds according to (Goel et al. (2021). The notable increase in crude fiber content with longer soaking duration, indicated a concentration effect due to the leaching of soluble carbohydrates and a relative rise in cell wall materials and suggested structural changes in the seed matrix, making fiber components easier to extract during analysis. The rise in ether extract content goes against some earlier studies that showed decreased lipid content during the sprouting of canola seeds was against Benjakul et al. (2016) but summited to the findings of soaked sorghum by Attia et al (2017). This increase likely comes from fatty acid synthesis during early metabolic activation. The slight decrease observed at 72hours suggested the beginning of fat utilization as an energy source or the action of lipolytic enzymes that convert fats into glycerol and fatty acids aligned with Alagbe, (2019). The large drop in metabolizable energy at 72hours signifies a significant nutritional trade-off. This decline can be explained by increased alpha-amylase activity in line with (Lasekan, 1996), which breaks down complex carbohydrates into simple, absorbable forms that the germinating seed uses for metabolic activities. The resulting loss of dry matter and volatile substances lowers the overall energy density of the processed seeds. This observation correlates with reports of reduced carbohydrate content in soaked soybean products according to Ikuomola et al. (2013). Even though the metabolizable energy content dropped, birds fed the 72hours soaked pigeon pea meal showed better growth performance. This apparent contradiction can be explained by several factors. The soaking process likely reduced anti-nutritional factors such as protease inhibitors, phytolectins, and tannins, which improved protein digestibility and amino acid availability supported the works of Alajaji and El-Adawy, (2006), and Gemede and Ratta, (2014). The alkaline environment provided by wood ash would have effectively denatured heat-sensitive toxins and neutralized some anti-nutritional compounds confirmed with Akande et al. (2010). The better performance observed in both starter and finisher phases proves the lasting benefits of the 72hours soaking duration. This matches reports by Omoikhoje et al. (2010) on roasted fluted pumpkin pod husk waste and Ajaja (2005) on graded levels of sorghum dust, both indicating significant improvements in broiler weight gain through suitable feed processing, which suggests better palatability without excessive consumption. The lack of significant variation in feed conversion ratio during the starter phase, despite differences in weight gain, indicates that all treatments maintained acceptable efficiency levels (Farinde et al. 2019). However, better performance of 72hours soaking duration during the finisher phase reflected the benefits of the soaking duration which contributed more to the availability of nutrients as birds mature and meeting the absolute nutrient needs (Nalle et al. 2010; Oluwatosin et al. 2020). The improved protein efficiency ratio in both phases for birds fed soaked pigeon pea meals confirms that soaking enhanced protein utilization (Ghavidel and Prakash, 2007; Emiola et al. 2011). This improvement is due to both the quality and availability of nutrients in the processed seeds which summited to the work of Emenalomet al. (2016). The similar feed intake values across treatments contradict worries about possible negative effects of processed pigeon pea on palatability. This finding supports the idea that when broilers have free access to feed, they eat up to the limits of their gastrointestinal tract (Jorgense et al. 1990; Makkar et al. 2014), with consumption mainly limited by gut fill rather than the composition of the feed, as long as palatability stays acceptable. Feed intake increased slightly in 72hours, but it remained within normal ranges. This suggests that birds adjusted for the lower energy density without overeating. The similar feed intake values across treatments show that the alkaline treatment did not harm palatability. The 72hours soaking duration proved to be the most nutritionally effective. However, practical implementation requires careful consideration of soaking processing times, which has significant advantages over conventional processing techniques.

Conclusion

This study shows that soaking pigeon pea seeds in wood ash extract greatly impacts on their nutritional values which enhances the performance of broiler chickens. However, Soaking duration for 72 hours in wood ash extract (pH 8.5) led to the highest crude protein content (25.57%), final live weights (868.28g) in the starter phase and (2018.75g) in the finisher phase, exhibited the best daily weight gains compared to other soaking durations is recommended as the best replacer of conventional soya bean meal.

Recommendations

Based on this study's findings, the following recommendations are proposed:

1. Use the wood ash extract soaking method for 72 hours to maximize crude protein content and enhance broiler performance when considering pigeon pea as an alternative protein source.
2. Compensate for the lowered metabolizable energy in 72-hour soaked pigeon pea by adding energy-rich ingredients (like maize or fat sources) to diet formulations to keep overall dietary energy levels up.
3. Set up specific facilities for seed soaking and drying, ensuring sufficient space and protection from contamination during the 7-day processing period.
4. Standardize wood ash pH levels at 8.5 and maintain consistent soaking conditions (temperature, water-to-seed ratio) to ensure reliable results.

References

Ajaja, K. 2005. Performance of broiler chickens fed graded levels of sorghum dust replacement for maize. *Nigerian Journal of Animal Production*, 32(1), 61-67.

Akande, K. E., Doma, U. D., Agu, H. O.and Adamu, H. M. 2010. Major antinutrients found in plant protein sources: Their effect on nutrition. *Pakistan Journal of Nutrition*, 9(8), 827-832. DOI: 10.3923/pjn.2010.827.832

Alajaji, S. A. and El-Adawy, T. A. 2006. Nutritional composition of chickpea (Cicer arietinum L.) as affected by microwave cooking and other traditional cooking methods. *Journal of Food Composition and Analysis*, 19(6-7), 806-812. DOI: 10.1016/j.jfca.2006.03.015

Alagbe, J. O. 2019. Effect of feeding graded levels of processed pigeon pea (*Cajanus cajan*) seed meal on growth performance and nutrient digestibility of weaner rabbits. *Journal of Agriculture and Veterinary Science*, 12(5), 56-62.

Amaefule, K. U. and Onwudike, O. C. 2010. Evaluation of boiling time on the nutrient composition and feeding value of pigeon pea seeds for broilers. *Livestock Research for Rural Development*, 22(6): 102.

AOAC (2016). *Official Methods of Analysis* (20th ed.). Association of Official Analytical Chemists International, Rockville, MD.

Attia, Y. A., Al-Harthi, M. A., & Hassan, S. S. 2017. Turmeric (*Curcuma longa* Linn.) as a phytogenic growth promoter alternative for antibiotic and comparable to mannan oligosaccharides for broiler chicks. *Revista Mexicana de Ciencias Pecuarias*, 8(1), 11-21.

Benjakul, S., Visessanguan, W., & Thummaratwasik, P. 2016. Isolation and characterization of trypsin inhibitors from some Thai legume seeds. *Journal of Food Biochemistry*, 40(1), 115-122

El-Hack, M. E. A., Alagawany, M., Arif, M., Emam, M., Saeed, M., Arain, M. A. and Swelum, A. A. 2017. The uses of microbial phytase as a feed additive in poultry nutrition – a review. *Annals of Animal Science*, 18(3), 639-658.

Emenalom, O. O. and Udedibie, A. B. I. 2016. Effect of dietary inclusion of cooked pigeon pea (*Cajanus cajan*) seed meal on performance and carcass characteristics of finisher broilers. *Nigerian Journal of Animal Science*, 18(1), 320-328.

Emiola, I. A., Ojebiyi, O. O. and Akande, T. O. 2011. Performance and organ weights of laying hens fed diets containing graded levels of raw and processed Lablab purpureus seed meal. *Tropical and Subtropical Agroecosystems*, 14(2), 527-533.

FAO 2022. Nigeria poultry sector review. Food and Agriculture Organization of the United Nations, Rome.

Farinde, E. O., Adeniji, O. A. and Abioja, M. O. 2019. Growth performance and nutrient digestibility of broiler chickens fed diets containing differently processed pigeon pea (Cajanus cajan) seed meal. *Bulletin of the National Research Centre*, 43, 171. DOI: 10.1186/s42269-019-0214-6

Gemede, H. F. and Ratta, N. 2014. Antinutritional factors in plant foods: Potential health benefits and adverse effects. *International Journal of Nutrition and Food Sciences*, 3(4), 284-289. DOI: 10.11648/j.ijnfs.20140304.18.

Ghavidel, R. A. and Prakash, J. 2007. The impact of germination and dehulling on nutrients, antinutrients, in vitro iron and calcium bioavailability and in vitro starch and protein digestibility of some legume seeds. *LWT - Food Science and Technology*, 40(7), 1292-1299. DOI: 10.1016/j.lwt.2006.08.002

Goel, A., Nene, S. and Rajagopal, D. 2021. Influence of soaking and germination on nutritional and antinutritional properties of pigeon pea (*Cajanus cajan*). *Journal of Food Science and Technology*, 58(2), 438-448.

Ikuomola, D. S., Otutu, O. L. and Oluniran, D. D. 2017. Quality assessment of complementary food produced from malted quality protein maize (*Zea mays L.*) and defatted fluted pumpkin flour (*Telfairia occidentalis* Hook F.). *Cogent Food & Agriculture*, 3(1), 1-11.

Jorgensen, H., Zhao, X. Q. and Eggum, B. O. 2016. The influence of dietary fibre and environmental temperature on the development of the gastrointestinal tract, digestibility, degree of fermentation in the hind-gut and energy metabolism in pigs. *British Journal of Nutrition*, 75(3), 365-378.

Lasekan, O. O. 2015. Effect of germination on alpha-amylase activities and rheological properties of sorghum (*Sorghum bicolor*) and acha (*Digitaria exilis*) grains. *Journal of Food Science and Technology*, 52(11), 7407-7415.

Makkar, H.P.S., Tran, G., Heuzé, V., Giger-Reverdin, S., Lessire, M., Lebas, F. and Ankers, P. (2016). Seaweeds for livestock diets: A review. *Animal Feed Science and Technology*, 212, 1-17.

Nalle, C. L., Ravindran, V. and Ravindran, G. 2010. Nutritional value of white lupins (Lupinus albus) for broilers: Apparent metabolisable energy, apparent ileal amino acid digestibility and production performance. *Animal*, 4(4), 579-585. DOI: 10.1017/S1751731109991443

National Bureau of Statistics 2020. Nigerian livestock statistics. Abuja: NBS Publications

NRC 2015. *Nutrient Requirements of Poultry* (9th revised ed.). National Research Council, National Academy Press, Washington, DC.

Oboh, H. A., Oladele, G. M. and Ojo, A. O. 2018. Effect of soaking, cooking and germination on the nutritional properties and anti-nutritional factors of *Vigna subterranea*. *International Journal of Food Science and Nutrition Engineering*, 8(1), 1-6.

Oluwatosin, O. O., Adeyemi, K. D. and Sogunle, O. M. 2020. Effect of processing methods on the nutritive value and anti-nutritional factors of pigeon pea (Cajanus cajan) seeds for broiler chickens. *Journal of Animal Production Research*, 32(1), 1-15.

Omoikhoje, S. O., Bamgbose, A. M., Aruna, M. B. and Eguaoje, S. A. 2010. Effect of supplementation of roasted fluted pumpkin (Telferia occidentalis Hook, F.) pod husk waste based diet on performance of growing rabbits. *Pakistan Journal of Nutrition*, 9(8), 806-809. DOI: 10.3923/pjn.2010.806.809

Poultry Site 2024. Nigerian feed prices continue upward trend. Retrieved from https://www.thepoultrysite.com

Statista 2024. Number of poultry birds in Nigeria from 2017 to 2022. Hamburg: Statista GmbH**.**

Vadivel, V. and Pugalenthi, M. 2016. Evaluation of nutritional value and protein quality of a little-known legume, *Vigna unguiculata* (L.) Walp. subspecies *cylindrica*. *Journal of Food Science and Technology*, 53(11), 3926-3934.

Uzonwanne, M. C., Francis, O. C. and Nwokoye, M. 2023. Impact of livestock production on gross n domestic product in Nigeria. *International Journal of Advanced Economics*, *5*(5), 107–118. https://doi.org/10.51594/ijae.v5i5.477

Yagoub, A. E. G. A. and Abdalla, A.A. 2022. The Dietary Use of Pigeon Pea for Human and Animal Diets. *Scientifica*, *2022*, Article ID 5962139. https://doi.org/10.1155/2022/5962139

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