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PERFORMANCE OF BROILERS FED ON EXTRUDED SORGHUM (*Sorghum bicolor* (L.) Moench) MEAL AND EXOGENOUS PHYTASE-BASED DIET

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ABSTRACT

Sorghum (*Sorghum bicolor* (L.) Moench) is more drought-resilient and adapted to varying soil types, and its grain has a similar nutrient composition to maize. However, some varieties contain high levels of tannins, kafirins, and phytates which adversely affect broiler performance. This study investigated the effect of extruded sorghum meal (ESM) and exogenous phytase on the performance of broilers. In total, 108, mixed-sex, Cobb 500, day-old broiler chicks were used. The chicks were weighed in groups of six and randomly assigned to cages and each one of the six dietary treatments comprising; T1 (0% ESM + 0% phytase), T2 (0 % ESM + 0.035 % phytase), T3 (50 % ESM + 0% phytase, T4 (50 % ESM + 0.035 % phytase), T5 (100 % ESM + 0 % phytase), and T6 (100 % ESM + 0.035 % phytase). The grower diets were offered 1-21 d and finisher diets 22-42 d. The average daily feed intake, average daily gain and feed efficiency were recorded weekly. ESM at a 50% inclusion did not affect the feed efficiency at the grower phase. The exogenous phytase enzyme improved ($p<0.05$) the average daily feed intake and average daily gain in the grower phase. In conclusion, ESM adversely affected broiler performance while the incorporation of exogenous phytase enzyme in the feed enhanced the performance of broilers in the grower phase.

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Keywords- Extrusion Cooking, Feed Efficiency, High-Tannin Sorghum, Kafirin, Phytates

INTRODUCTION

The demand for affordable animal protein sources such as broiler meat in developing countries is high [1]. The sustainability of the poultry sub-sector is dependent on the supply of costly primary feed ingredients. Maize grain is commonly used as the main energy source in broiler diets, yet it is the staple food, creating severe competition between livestock feed and human food. Maize is also used for biofuel production in developed countries, which increases its global market price [2,3]. The overreliance on maize grain makes commercial broiler feeds very costly and sometimes unavailable, which limits broiler production in Kenya [3]. This has stimulated interest in improving the utilisation of some underutilised, high-value, and drought-resilient crops for food, feed, and industrial use.

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important food and feed cereal crop globally, after maize, wheat, rice, and barley [4]. The crop is more drought resilient and adapted to varying soil types, and its nutrient composition is similar to maize grain [5]. Therefore, sorghum is a potential alternative cereal energy source in poultry diets. However, some sorghum varieties (those with a pigmented Testa, classified as type II and III sorghum) contain anti-nutritional factors (tannins, kafirins, and phytates) [5,4,6], which compromise protein, carbohydrate, and mineral metabolism in poultry [7,8,9]. Therefore, when included in commercial broiler diets as an energy source, they decrease feed intake, weight gain, and feed conversion efficiency. As a result, tannin-sorghum varieties are not commonly included in broiler diets or are used at smaller levels [10,11,6].

The feed efficiency of broilers fed on high-tannin sorghum is increased through feed processing. The use of a particular feed processing method depends on its effectiveness to reduce the anti-nutritional factors and increase digestibility. Extrusion cooking is used to enhance the nutritional value and feed efficiency of poultry feeds. Some advantages of extrusion cooking on the feed product include the inactivation of anti-nutritional factors (trypsin inhibitors, tannins, and phytates), starch gelatinisation, formation of soluble dietary fibre and reduction of lipid oxidation [12]. Based on *in vitro* studies, extrusion cooking of grain sorghum holds promise in broiler chicken diets. Some studies have suggested that improvements in nutrient digestibility through extrusion cooking may not always result in improved performance in animals [13,14]. The effect of extruded sorghum meal and exogenous phytase-based diets on broiler performance is unclear. Therefore, this study investigated the effect of including ESM partially or completely as an energy source with or without exogenous phytase enzyme in diets on the performance of broilers.

MATERIALS AND METHODS

Animal care and use

This study was approved by the Egerton University Research Ethics Committee with approval number EUISERC/APP/224/2023 and the National Commission of Science and Technology of Kenya, with license number NACOSTI/P/23/25493.

Study site

The study was undertaken at Egerton University in the Department of Dairy and Food Science and Technology (extrusion cooking processing), Department of Animal Sciences (laboratory analyses) and Tatton Agriculture Park (feeding experiment). The University is located in Njoro Sub-County, Nakuru County, at 0° 23' S, 35° 55' N. The altitude of the area is 2,238 m above sea level. The temperature of the area averages 21ºC and annual rainfall ranges between 900 to 1,020 mm [15].

Experimental Design

A (3x2) factorial arrangement was used in a completely randomized design to determine the effect of extruded sorghum meal as an energy source at three inclusion levels (0, 50, and 100%) and exogenous phytase at two levels (with or without). There were six dietary treatments: T1 (0% ESM + 0% phytase), T2 (0 % ESM + 0.035 % phytase), T3 (50 % ESM + 0% phytase, T4 (50 % ESM + 0.035 % phytase), T5 (100 % ESM + 0 % phytase), and

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T6 (100 % ESM + 0.035 % phytase). Each treatment was replicated three times with six mixed-sex, Cobb 500, day-old chicks per replicate. The model used was as follows;

$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + \varepsilon_{ijk}$ *i=1,2,3; j=1,2;*

where;

Y_{ijk} is observation k in level i of extruded sorghum meal and level j of phytase;

μ is the overall mean;

A_i is the effect of level i of extruded sorghum meal;

B_j is the effect of level j of phytase;

$(AB)_{ij}$ is the effect of the interaction of level i of the extruded sorghum meal with level j of phytase;

ε_{ijk} is a random error with mean 0 and variance σ^2.

Diet preparation

One indigenous variety of grain sorghum, containing 4.83% tannic acid (TA) equivalent tannin, and 455 mg/100g phytate content, was sourced from the Solai ward in Rongai sub-county, Nakuru County. The grain was cleaned to remove glumes before milling. The flour was extruded using a co-rotating twin-screw extruder (PSHJ-20, Jiangsu Xinda Tech Limited, China), at 40% feed moisture content, 300 rpm (screw speed) and 90ºC barrel temperature. The feed moisture content was achieved by adding a calculated amount of distilled water before the extrusion cooking process. The temperature of the four heating zones were 60, 70, 80 and 90ºC. Extrudate was collected after the process stabilized and cooled at room temperature (21±4°C) and then dried in a hot air oven at 60ºC for 24 h. The extrudate was then ground using a hammer mill fitted with a 2 mm sieve (9FC-22A, Shandong Gongyou Group Limited, China) for use in the formulation of the experimental broiler diets. The tannin and phytate content was reduced to 4.23% TA equivalent, and 375.6 mg/100g, respectively upon extrusion cooking.
The experimental diets were formulated to be isocaloric and iso-nitrogenous and meet or exceed broiler chicken requirements, according to NRC [16]. Tables 1 and 2 show the calculated composition of the experimental diets while Table 3 shows the analyzed proximate composition of the diets. Natuzyme®, a commercially available multienzyme, was used. The multienzyme contains 1,500 units/g of phytase, 12,000 units/g of xylanase, 6,000 units/g of cellulase, 700 units/g of beta-glucanase, 700 units/g protease, 400 units/g of alpha-amylases. The enzyme was added at 350mg/kg and mixed thoroughly according to the manufacturer's instructions and recommendations.

Table 1. Composition of experimental grower diet

	Dietary treatments					
Ingredient (% in the diet)	T1	T2	T3	T4	T5	T6
Maize meal	56.4	56.4	28.2	28.2	0.0	0.0
Extruded sorghum meal	0.0	0.0	28.2	28.2	56.4	56.4
Soybean meal	33.8	33.8	33.5	33.5	32.8	32.8
Fish meal (*Omena*)[1]	3.8	3.8	3.8	3.8	4.2	4.2
Vegetable oil	3.5	3.5	3.8	3.8	4.1	4.1
Dicalcium phosphate	1.2	1.2	1.2	1.2	1.2	1.2

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Limestone	0.5	0.5	0.5	0.5	0.5	0.5
Vitamin and mineral premix	0.5	0.5	0.5	0.5	0.5	0.5
Common salt	0.3	0.3	0.3	0.3	0.3	0.3
Natuzyme®	0	0.035	0	0.035	0	0.035
Total	100.0	100.0	100.0	100.0	100.0	100.0
Calculated analysis						
CP	23.3	23.3	23.3	23.3	23.3	23.3
ME (kcal/kg)	3155.5	3154.6	3151.8	3150.9	3148.8	3147.9
CF	2.5	2.5	2.5	2.5	2.5	2.5

[1]Scientific name: *Rastrineobola argentea*, common name; silver cyprinid, and it's also called the Lake Victoria sardine or *Mukene*, [2]variety: 6213; The vitamin and mineral premix was similar to the one used in the per 2.5kg supplied: Vit A 10000000IU, Vit D3 2800000IU, Vit E 25000mg, Vit K_3 2800mg, Vit B_1 2000mg, Vit B_2 7000mg, niacin 40000mg, pantothenic acid 12000mg, Vit B_6 3500mg, folic acid 1000mg, Vit B_{12} 15mg, biotin 80mg, manganese 60000mg, zinc 60000mg, iron 30000mg

Table 2. Composition of experimental finisher diet

	Dietary treatments					
Ingredient (% in the diet)	T1	T2	T3	T4	T5	T6
Maize meal	65.0	65.0	32.5	32.5	0.0	0.0
Extruded sorghum meal	0.0	0.0	32.5	32.5	65.0	65.0
Soybean meal	24.8	24.8	24.3	24.3	23.7	23.7
Fish meal (*Omena*)[1]	4.5	4.5	4.6	4.6	4.8	4.8
Vegetable oil	3.2	3.2	3.6	3.6	4.0	4.0
Dicalcium phosphate	1.2	1.2	1.2	1.2	1.2	1.2
Limestone	0.5	0.5	0.5	0.5	0.5	0.5
Vitamin and mineral premix	0.5	0.5	0.5	0.5	0.5	0.5
Common salt	0.3	0.3	0.3	0.3	0.3	0.3
Natuzyme®	0	0.035	0	0.035	0	0.035
Total	100.0	100.0	100.0	100.0	100.0	100.0
Calculated analysis						
CP	20.1	20.1	20.1	20.1	20.1	20.1
ME (kcal/kg)	3204.2	3203.3	3203.6	3202.7	3203.1	3202.2
CF	2.4	2.4	2.5	2.5	2.5	2.5

[1]Scientific name: *Rastrineobola argentea*, common name; silver cyprinid, and it's also called the Lake Victoria sardine or *Mukene*; [2] Variety: 6213; The vitamin and mineral premix was similar as in the grower diets

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Table 3. Analysed proximate composition of the experimental diets (g/100g)

Treatment	Grower diets				
	Moisture	Ash	Crude protein	Crude fibre	Ether extracts
1	8.87± 0.34	5.97±0.37	23.27±0.13	4.39±0.33	11.85±0.29
2	8.56±0.13	5.68±0.26	23.48±0.53	3.82±0.47	12.07±0.61
3	7.81±0.03	6.82±0.48	23.58±0.12	3.44±0.19	9.92±0.29
4	7.79± 0.15	6.48±0.63	23.61±0.13	3.15±0.15	8.80±0.20
5	7.74± 0.14	5.63±1.10	23.07±0.24	2.43±0.39	9.39±0.06
6	7.91±0.12	7.00±0.25	23.54±0.24	3.05±0.67	9.53±0.12
	Finisher diets				
1	10.75±0.10	6.16±0.23	21.01±0.12	5.17±0.05	10.65±0.19
2	10.27±0.05	6.87±0.23	20.77±0.13	4.17±0.51	10.40±0.19
3	10.58±0.20	6.46±0.41	20.80±0.31	4.48±0.11	9.69±0.12
4	10.31±0.08	6.63±0.37	20.38±0.31	4.41±0.07	9.72±0.18
5	10.31±0.06	7.94±0.07	21.74±1.41	4.18±0.07	10.06±0.21
6	10.33±0.20	6.93±0.36	19.85±0.14	4.17±0.47	10.01±0.35

Bird management

A total of one hundred and eight (108) healthy, mixed-sex, day-old commercial broiler chicks (Cobb 500 breed) were purchased from the local commercial hatchery (Kenchic® Limited). The chicks were vaccinated against Gumboro and Newcastle diseases at the hatchery. On the first day, the chicks were administered Lemycin® (a water-soluble chick booster containing an antibiotic, glucose, vitamins, and amino acids) and liquid paraffin (to soften and lubricate droppings). The chicks were fed on a standard maize-soybean diet for the first 48 h while acclimatizing to the experimental conditions. On the third day post-hatching, chicks were weighed in groups of six and randomly allocated into eighteen cages. Chicks in each cage were randomly assigned to one of the six diets with 3 replicates. The grower diets were offered in the first three weeks and the finisher diets from week four to six. Water and feed were provided *ad libitum*.

Data collection and calculations

Data on the following parameters were collected:

i. **Average daily feed intake**

Feed was provided *ad libitum* by giving a weighed amount of the respective diets (Tables 1 and 2) once daily at 0900 hours. Leftovers were collected and weighed before the next morning's feeding. Average daily feed intake (g) per broiler per day was calculated as the difference between the amount of each diet offered and that leftover daily divided by the number of broilers in the cage.

ii. **Average daily gain**

The body weights of broilers were measured at the end of each week at 0900 hours before feeding. The average daily gain per broiler was calculated by dividing the difference between the initial and final weight of the broilers by the number of days.

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iii. **Feed efficiency**

The feed efficiency was calculated by dividing the average weight gain by the average feed intake (g) by the broiler at the end of each growth phase.

Statistical Analysis

Data were subjected to a two-way analysis of variance in a completely randomized design using the general linear model (GLM) procedure of the SAS Institute Inc. (version 9.4; 2015). The mean separation was done using Tukey's HSD test at a level of significance of 0.05.

RESULTS AND DISCUSSION

The broiler performance responses as affected by ESM and exogenous phytase enzyme were summarised in Table 4.

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Table 4. Average daily gain, average daily feed intake, and feed efficiency of broiler chicken as influenced by the dietary treatments

Treatment	Average daily feed intake (g/bird)			Average daily gain (g/bird)			Feed efficiency (g:g)		
	1-21 d	22-42 d	1-42 d	1-21 d	22-42 d	1-42 d	1-21 d	22-42 d	1-42 d
ESM effect									
0%	25.54[a]	45.868[a]	36.90[a]	10.91[a]	15.88[a]	13.49[a]	0.42[a]	0.35[a]	0.36[a]
50%	17.94[b]	33.04[b]	25.33[b]	6.55[b]	8.23[b]	7.39[b]	0.35[a]	0.25[b]	0.29[b]
100%	13.22[c]	15.70[c]	14.85[c]	3.33[c]	4.21[c]	3.77[b]	0.25[c]	0.27[b]	0.25[b]
SEM	1.05	1.83	1.48	0.69	0.55	0.84	0.02	0.02	0.02
Significance	*	*	*	*	*	*	*	*	*
Phytase effect									
0%	17.42[b]	30.69[a]	25.11[a]	5.97[b]	9.03[a]	7.90[a]	0.32[a]	0.29[a]	0.29[a]
0.035%	20.38[a]	32.38[a]	26.28[a]	7.89[a]	9.85[a]	8.53[a]	0.36[a]	0.29[a]	0.31[a]
SEM	0.86	1.50	1.21	0.56	0.45	0.69	0.02	0.01	0.01
Significance	*	ns	ns	*	ns	ns	ns	ns	ns
ESM × phytase (significance)	ns	ns	ns	ns	*	ns	ns	*	ns

[a, b, c] Means bearing different superscripts in a column differ significantly; * is significant at $p < 0.05$; ns is not significant at $p < 0.05$; ESM is extruded sorghum meal; SEM is the standard error of the mean;

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The average daily feed intake, average daily gain and feed efficiency of broilers were significantly affected by the ESM and the exogenous phytase. The adverse effect of ESM on broiler performance was attributed to the high levels of tannins and phytates tested. Tannins are considered detrimental to the utilization of sorghum in broiler diets because they limit the bioavailability of macromolecules such as proteins, carbohydrates, amino acids, and vitamins, and have a lower protein efficiency ratio [17]. According to Zarei et al. [17], tannins lower feed intake, weight gain, and feed efficiency. Phytate, on the other hand, comprises 28.2% phosphorus (phytate-phosphorus) which cannot be efficiently utilized by non-ruminant animals [18]. The ability of phytate to bind minerals lowers the digestibility of calcium (Ca), magnesium (Mg), trace minerals (zinc and iron), and protein and lowers energy utilization in chickens [19,9]. As the inclusion levels of ESM increased from 0 to 100%, there were more adverse effects on broiler performance. The inclusion of ESM reduced average daily feed intake by 31 to 60%. This is probably due to astringency and bitter taste caused by the coagulation of salivary proteins and mucous epithelium when in contact with tannins. High-tannin sorghum has been found to constrain feed intake in broilers [20,21.22]. Overall, the inclusion of ESM in broiler diets reduced average daily gain by 40 to 69%. This is probably due to the deleterious effects of tannins, which included a reduction in both total and protein digestibility and inhibition of amylase enzyme activity by tannins hence constraining energy utilization [17,23]. This confirms the results of other similar studies in broilers [24]. On the contrary, Kumar et al. [11] observed no negative effect of high-tannin sorghum on the body weights of broilers in the overall growth phase. This is probably due to different levels of dietary tannins. The tannin content of the sorghum used in the study by Kumar et al. [11] was lower compared to the current study (2.3% vs. 4.23% TA equivalent). During the grower phase, the inclusion level of 50% of ESM did not affect the feed efficiency of the broilers although in the overall phase, feed efficiency reduced by 11 to 19.4%. The mode of action is probably binding proteins, carbohydrates, and minerals, thus compromising their digestibility [25]. This constrained the utilization of energy, protein, and specific amino acids [26]. Ambula et al. [21] observed a 23-42.5% reduction in feed efficiency of broilers fed on high-tannin sorghum (2.71 to 3.54% catechin equivalent). Nyachoti et al. [27] also found that broilers fed on high-tannin sorghum (1.57% catechin equivalent) were 6.5% less efficient in feed utilization.

The exogenous phytase significantly improved average daily feed intake (17%) and average daily gain (32%) in the grower phases. There is a possibility that the phytase response was more pronounced in the grower phase than the finisher phase because of the difference in dietary crude protein levels; the grower and finisher diets contained approximately 23 and 20% crude protein, respectively. As reviewed by Moss et al. [19], apart from liberating phytate-bound phosphorus, the "extra-phosphoric effect", phytase may prevent the *de novo* formation of binary protein–phytate complexes in the crop, the "protein effect", thus increasing protein digestibility in broilers. Moreover, the phytase response may have been influenced by the age of the broilers. In young birds, the rate of feed passage in the digestive tract is relatively faster [28], thus the lack of adequate phytate hydrolysis in the gizzard may have increased the phytase response. This was consistent with the work of Li et al. [29], who found greater phytase responses in younger broilers (7 d) than in older broilers (21 d). The somewhat muted phytase response observed in the current study is probably because the enzyme does not address the deleterious effects of other factors (kafirins and tannins) which are notable in sorghum-based diets [30]. This concurs with another study in broilers fed on sorghum-based diets where the phytase responses were lower in comparison with those fed on maize or wheat-based diets [31].

There was a significant ESM-phytase interaction effect for average daily gain ($p<0.05$) and feed efficiency ($p<0.05$) of broilers in the finisher phase, where phytase responses were reduced as ESM inclusion levels increased.

CONCLUSION

ESM adversely affected broiler performance while incorporation of exogenous phytase enzyme in the diet enhanced the performance of broilers in the grower phase.

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CONFLICT OF INTEREST

The authors declare no conflict of interest for this article.

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