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Research Paper

EFFECT OF FEEDING GERMINATED SORGHUM AND METHIONINE SUPPLEMENTATION ON PERFORMANCE OF BROILER CHICKENS

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The study investigated the effects of germination on chemical composition and tannin content of Gadam and Serena sorghum varieties. In the second experiment, germinated and ungerminated Serena sorghum based diets were fed to broiler chickens for a period of six weeks. Grains from the 2 varieties were soaked in water for 12 h and then germinated for 48 h. Broiler chickens were allocated to four isocaloric and isonitrogenous diets containing : ungerminated sorghum (var serena) + 0.46% Methionine (Met) (UG46), germinated sorghum + 0.46% Met (G46), ungerminated sorghum + 0.69% Met (UG69) and ungerminated sorghum + 0.92% methionine (UG92). Germination slightly increased the crude protein content of both Gadam (10 to 11.6%) and Serena sorghum (9.9 to 10.3%). Germination increased (p>0.05) tannin content of Gadam sorghum (0.11 to 0.23% TA) and reduced (p>0.05) for the Serena variety from 0.47 to 0.32% TA. Birds fed the G46 diet had lower (P<0.05) feed intake (1264 g) during starter phase. Germination had no effect on weight gain, but improved (P<0.05) Feed Conversion Ratio (FCR) for the entire growth phase (2.16). The birds fed UG69 diet had the highest (P<0.05) weight gain. Increased methionine in the diet UG92 decreased feed intake in finisher and whole growth phases (2854, 4156). Birds fed the diets UG69 and UG92 had lower (p<0.05) FCR. Germination of the Serena sorghum had no effect on performance of broiler chickens. Supplementation of Serena sorghum based diets with 50% methionine above the recommended improved the performance of broilers with no beneficial effect beyond level.

Keywords: Sorghum, Tannin, Germination, Methionine, Broiler chickens

INTRODUCTION

Poultry production plays a key role, either for income generation or as food security in Kenya. The main problem facing this industry is the high cost of feed which has been attributed to the competition for maize between animal feed and human food especially during times of shortage. There is therefore need for alternative cereal

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based energy sources. Approximately 80% of the Kenyan land mass is either arid or semi-arid (ASAL) and is characterized by erratic rainfall (Mwadalu and Mwangi, 2013) and high ambient temperature for most part of the year. The conditions in these areas are suitable for sorghum production due to its high drought tolerance compared to maize. Use of sorghum in poultry diets is constrained by presence of tannins which affect its utilization. Effects of condensed tannins on chicken have been reported as reduction in feed intake due to reduced palatability, reduced weight gain, low digestibility and poor feed conversion efficiency (Mitaru *et al.,* 1983; Hassan *et al*., 2003; and Oke *et al*., 2015). Several processing techniques to reduce tannin content in sorghum based poultry rations to increase feed utilization efficiency have been reported. However, the use of a particular method will depend upon the cost involved and effectiveness to reduce the negative effects of tannin on poultry performance.

Germination of sorghum grain has been reported to be an effective treatment to reduce its tannin content. Osuntogun *et al.* (1989) reported that the tannin content of SRN484 (high tannin sorghum variety) decreased from 2.92% to about 1.3% Catechin Equivalent (CE) after 48 h germination. Elmaki *et al.* (1999) reported reduced tannin content from 0.34 to 0.20% for the Gadamelhamam (low tannin) and from 1.44 to 0.31% CE for the Cross 35:18 (high tannin variety) after 10 h soaking and 48 h germination. Ogbonna *et al.* (2012) observed that tannin content reduced by 8.45%, while Badi (2004) reported reduction by 73.69%. Germination of sorghum has been used as source of energy in poultry diets. Abbas and Musharaf (2008) did not observed significant effect of feeding 72 h germinated low tannin sorghum on performance of broiler chickens. Okoh *et al.* (1989) reported insignificant effect of 96 h germinated SK5912 sorghum on feed intake and FCR of broiler chicken compare to the control. Shem *et al.* (1990) reported that feeding 48 h germinated high tannin sorghum to the growing pigs had similar feed intake, weight gain and FCR as ungerminated sorghum based diet. Methionine, when used as dietary supplement, has alleviated the adverse effect of tannin in sorghum-soybean meal based diet (Elkin *et al.,* 1978) via being an essential nutrient, playing a big role as sulfur containing amino acid in methyl donor metabolism (Brosnan and Brosnan, 2006) and to alleviate the effect of methionine deficiency caused by presence of tannin. Chang and Fuller (1964) observed that birds fed on high tannin sorghum supplemented with methionine had similar growth performance and feed efficiency as low tannin sorghum. Sell and Rogler (1984) reported that supplementation of low and high tannin sorghum with 0.2% methionine had increased feed intake of laying hens. Therefore, this study aims to determine the impact of germination and methionine supplementation on unknown/untested local Kenyan sorghum variety.

MATERIALS AND METHODS

Germination

Two sorghum varieties namely Serena (brown) and Gadam (white) were purchased and hand sorted to remove foreign materials, soaked in fresh water for 12 hours at a ratio of 1:3 w/v, with the soak water changed after 6 hours. After soaking, the sorghum was germinated for 48 hours by spreading the grains thinly on trays, under room temperature. Water was sprinkled twice a day to keep the grains moist. Thereafter, the germinated sorghum was sun-dried to a moisture content of about 9-10%. Samples of the germinated and ungerminated sorghum were stored in airtight glass bottles for chemical analysis.

Feeding Trial

Four isocaloric and isonitrogenous diets were formulated to include germinated and ungerminated Serena sorghum and varying levels of methionine (Table 1). The diets were: UG46 ungerminated sorghum with the recommended methionine content (0.46%), G46 germinated sorghum with the recommended methionine, UG69 ungerminated sorghum with addition of methionine at 0.69% while UG92 contained ungerminated sorghum with addition of methionine at 0.92%.

A total of a hundred and sixty day old Abor acres chicks were weighed in groups of ten and randomly allocated to the 4 diets (each replicated 4 times) housed in 16 metal pens each 1 × 1 m in size (length and width) and 1m height. The birds were reared in deep litter pens for six weeks post hatch. Water and feed were provided *ad libitum* and chicks were vaccinated against Newcastle disease on 10th day and Gumboro disease at 14th day of age. The birds were fed starter diet upto 3

Table 1: Composition of Experimental Diets (%)

Treatment / Ingredient	UG46	G46 Starter	UG69 Phase	UG92	UG46	G46 Finisher	UG69 Phase	UG92
Sorghum	50	50	50	50	50	50	50	50
Pollard	12.4	12.4	12.4	12.8	23.8	23.8	24.2	24.4
Oil	1.25	1.25	1.44	1.6	3.31	3.31	3.56	3.74
Soya bean meal	30.39	30.39	30	29.03	16.18	16.18	15.2	14.49
Fish meal (Omena)[1]	2.91	2.91	2.75	3.01	3.37	3.37	3.44	3.48
Dicalcium phospate	0.5	0.5	0.53	0.5	0.5	0.5	0.5	0.5
Limestone	1.51	1.51	1.51	1.5	1.51	1.51	1.51	1.51
HCL-lysine	0.01	0.01	0.02	0.05	0.22	0.22	0.26	0.3
DL-methionine	0.06	0.06	0.3	0.51	0.06	0.06	0.37	0.6
Vitamin-mineral Premix[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Enzyme	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Biomos (toxin binder)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	100	100	100	100	100	100	100	100

Note: UG46 = ungerminated sorghum based diet; G46 = germinated sorghum based diet; UG69 = ungerminated sorghum supplemented with 0.69% methionine based diet; UG92 = ungerminated sorghum supplemented with 0.92% methionine based diet. [1] Fish called Rastrineobola argentea was whole dried, ground and incorporated in broiler chickens diet; [2] Vitamin mineral premix- The composition of the premix was: vitamin A, 10,000,000 IU; vitamin D3 2,000,000 IU; vitamin E, 24,000 IU; vitamin K3, 3,200 mg; choline chloride, 350,000 mg; thiamine, 1,600 mg; riboflavin, 5,600 mg; Nicotinic acid, 32,000 mg; panthothenic acid, 8,000 mg; pyridoxine, 4,000 mg; Biotin, 96 mg; folic acid, 960 mg; vitamin B12, 24 mg; Copper, 5,000 mg; Iron, 40,000 mg; Manganese, 150,000 mg; Zinc, 45,000 mg; Cobalt, 200 mg; Iodine, 1,400 mg; and Selenium, 120 mg.

weeks of age and thereafter a finisher diet upto 6 weeks. Data on feed intake and weight gain were collected on weekly basis and feed conversion ratio was obtained as the ratio of feed intake to body weight gain. Proximate analysis of the feeds was done according to procedures described by Association of Official Analytical Chemists AOAC (1998). Tannin content as tannic acid was determined by AOAC (1990) method.

Energy was calculated by the modified equation of Pauzenga (1985) ME = 37 x % CP + 81 x % EE + 35.5 x % NFE. All data were subjected to a one way analysis of variance (ANOVA) using Genstat software Discovery 13th edition, and differences between means were determined by a least significance method at significance level $p \leq 0.05$ using Tukey's multiple comparison procedure.

RESULTS AND DISCUSSION

The chemical composition of germinated and ungerminated Gadam and Serena sorghum is shown in Table 2. Crude Protein (CP) content of ungerminated sorghum was similar (P>0.05) for both sorghum varieties (10.0% for Gadam and 9.9% for Serena).

Table 2: Effect of Germination on Chemical Composition (% DM) and Tannin Content of White (var Gadam) and Brown (var Serena) Sorghum Grains

Sorghum	Gadam		Serena		SEM	p value
Ingredients	UG	G	UG	G		
Dry matter	91	90.6	90.6	90.1	0.254	0.234
Crude protein	10	11.6	9.9	10.3	0.55	0.268
Crude fiber	3.9^b	2.9^a	4.7^c	4.7^c	0.037	<.001
Ether extract	3.7^b	3.0^{ab}	2.6^a	2.5^a	0.147	0.016
Ash	1.7^c	1.3^a	1.4^b	1.3^a	0.022	<.001
Tannin (TA) %	0.11^a	0.23^{ab}	0.47^c	0.32^{bc}	0.032	0.006
Calculated analysis (DM basis)						
NFE %	71.6	71.5	71.8	71.1		
ME (Kcal/kg)	3227	3226	3142	3123		

Note: Means within a row with different superscripts differ significantly (p<0.05); UG = ungerminated; G = germinated.

The crude protein content of both sorghum varieties were within 7 to 15% and 9 to 18% range reported by Dicko *et al.* (2006) and Hamad (2007) for whole sorghum grain (white, brown, red sorghum). Kiprotich *et al.* (2014) reported crude protein of 6.5-10.9 % in white varieties, 5.8-12.6% in cream varieties, 4.8-12.1 % in brown varieties and 5.1-10.9% in red varieties. The CP content of 2 sorghum varieties increased (p>0.05) after germination from 10 to 11.6% (by 16%) for Gadam and from 9.9 to. 10.3% (by 4%) for the Serena sorghum variety.

The Crude Fibre (CF) content of brown sorghum (Serena) (4.7%) was higher (P<0.005) than that of white sorghum variety (Gadam) (3.9%). The CF decreased significantly (P<0.005) for the variety Gadam from 3.9 to 2.9% (by 25%) after germination. Similarly, Elmaki *et al.* (1999) reported that after 72 h germination the CF significantly decreased from 3.26 to 1% for Gadamelhamam cultivar (low tannin sorghum). This reduced CF could be explained by degradation of water-soluble dietary fiber by fiber degrading enzyme during germination (Hübner and Arendt, 2013). In contrast, Shem *et al.* (1990) and Nour *et al.* (2016) reported significant increase in CF of high tannin sorghum and Tabat variety (low tannin sorghum) from 2.74 to 3.01 and from 2.34 to 4.84% after overnight soaking and 48 h germination. However, Elkhier and Hamid (2008) and El-Beltagi *et al.* (2012) observed insignificant effect of 72 h germination on CF of white sorghum varieties (Feterita and Tabat and Dorado, Shandaweel and Giza-15 respectively). The length of soaking and germination period could affect the crude fiber content of the last product.

Ash content of ungerminated Gadam and Serena sorghum was 1.7 and 1.4% ($p<0.05$) respectively, which was within the range. In agreement, Hamid (2007) and Chung *et al.* (2011) reported that, the ash content in different varieties of sorghum varied from 1.51 to 2.06 (*var*. Edo, Engaz and safra) and from 1.43 to 1.92% (*var.* Hwanggeumchal, Heuin and Chal) respectively. The ash content was significantly reduced after germination for both varieties. The reduction in Gadam was higher (23.5%) than Serena variety (7.1%). Similarly, Shem *et al.* (1990); Phattanakulkeawmorie *et al.* (2011) and Baba *et al.* (2012) reported significant reduction in ash content after 48 and 72 h germination of red sorghum variety from 4.01 to 2.21%, 1.34 to 1.01% and 4 to 1% respectively. This declined in ash content could be ascribed to the leaching out during soaking and germination. Elmaki *et al.* (1999) Nour *et al.* (2016) did not observe any change in ash content of 48 h and 72 h germinated low and high tannin sorghum.

Fat (ether extract) content of Gadam and Serena sorghum was different ($p<0.05$) 3.7 and 2.6% respectively. The values of fat content of this study are within the range of 2.2 to 5.4% reported by Phattanakulkaewmorie *et al.* (2011). Medugu *et al.* (2010) reported fat content of 4.3% in low sorghum variety whereas 3.5% in high tannin variety. The observed levels are however lower than 7.1% reported by Mohamed *et al.* (2015). Germination insignificantly reduced the fat content of both Gadam and Serena sorghum varieties.

Tannin (tannic acid) content of Gadam and Serena sorghum varieties was significantly different (0.11 and 0.47%). Germination for 48 hours caused insignificant increase of tannin content from 0.11 to 0.23% in Gadam and decreased ($p>0.05$) that of Serena variety from 0.47 to 0.32%.

The chemical compositions of the experimental diets are shown in Table 3. All the starter and finisher diets were within the recommended standard for the phase.

The results of feeding trial are shown in Table 4. During starter phase the feed intake was lower ($p<0.05$) for chicks fed on G46 diet (1264 g/chick) compared to those on UG46 (1415 g/chick) with on significant change on those on diets UG69 and UG92 (1318 and 1302 g/chick). The reduction in intake of G46 diet could be due to accumulation of soluble/free sugar in germinated sorghum. Taylor *et al.* (2001) reported that germinated sorghum contained higher glucose compare to other reducing sugars due to enzyme α-glucosidase which degrades maltose and maltotriose to glucose. Glucose is a monosaccharide that is known to be readily absorbed into the bloodstream. Ferket and Gernat (2006) opined that blood sugar is one of the mechanisms that control feed intake (glucostatic theory) which ascribe to regulate the blood sugar and the quantity of glucose entering the liver after taking meal. Okoh *et al.* (1989), Kyarisiima *et al.* (2004) and Abbas and Musharaf (2008) did not observe any effect on feed intake when 28 h and 72 h germinated high tannin and low tannin sorghum were fed to broiler chickens compare to ungerminated sorghum. During the finisher and whole growth phases chickens fed on G46 and UG69 had similar feed intake compare to UG46, with those on diet UG92 being significantly lower.

This reduced feed intake could be due to excess amino acid (methionine) which led to its high concentration in bird's blood. Li and Anderson (1983) and Han and Baker (1993) reported that excessive individual amino acid in the blood and

Table 3: Chemical Composition and Tannin Content of Experimental Diets (DM %)

Treatment / Ingredients	UG64	UG46 Starter	UG69 Phase	UG92	UG46	G46 Finisher	UG69 Phase	UG92
Dry matter	90.44	91.14	90.08	90.76	89.58	90.68	89. 78	89. 12
Crude protein	22.72	22.87	24	23.72	17.99	18.45	18.24	19.26
Crude fibre	7.66	7.31	7.13	7.35	7.1	6.08	6.76	6.31
Crude fat	6.25	6.68	6.65	6.93	6.44	6.43	6.54	6.86
Ash	6.82	7.43	6.47	6.35	6.26	6.34	6.59	6.8
Tannin (TA)	0.28	0.24	0.23	0.27	0.28	0.23	0.26	0.26
Calculated Analysis (DM Basis)								
NFE	47.99	46.85	45.83	46.41	51.79	53.38	51.65	49.89
ME (Kcal/kg)	3050	3050	3053	3086	3025	3098	3038	3039

Note: UG46 = ungerminated sorghum based diet; G46 = germinated sorghum based diet; UG69 = ungerminated sorghum supplemented with 0.69% methionine based diet; UG92 = ungerminated sorghum supplemented with 0.92% methionine based diet.

Table 4: Effects of Germination and Methionine Supplementation of Sorghum Based Diets on Performance of Broiler Chicken During Starter, Finisher and Entire Phase

Phase	Diets / Parameters	UG46	G46	UG69	UG92	SEM	p value
Starter	Feed intake/chick (g)	1415^{b}	1264^{a}	1318^{ab}	1302^{ab}	29.5	0.021
	Weight gain/chick (g)	707.3^{ab}	690.7^{a}	785.1^{c}	762.2^{bc}	16.76	0.005
	FCR	2.003^{b}	1.830^{ab}	1.681^{a}	1.709^{a}	0.0447	0.001
Finisher	Feed intake/chick (g)	3278^{b}	3300^{b}	3515^{b}	2854^{a}	88.3	0.001
	Weight gain/chick (g)	1299	1426	1473	1297	52	0.075
	FCR	2.526^{b}	2.323^{ab}	2.391^{ab}	2.203^{a}	0.0614	0.02
Starter and Finisher	Feed intake/chick (g)	4693^{b}	4563^{ab}	4833^{b}	4156^{a}	103	0.003
	Weight gain/chick (g)	2007^{a}	2116^{ab}	2258^{b}	2059^{ab}	52	0.027
	FCR	2.338^{b}	2.159^{a}	2.143^{a}	2.018^{a}	0.0374	<0.001

Note: Means within a row with different superscripts differ significantly ($p<0.05$): UG46 = ungerminated sorghum based diet; G46 = germinated sorghum based diet; UG69 = ungerminated sorghum supplemented with 0.69% methionine based diet; UG92 = ungerminated sorghum supplemented with 0.92% methionine based diet.

tissues causes homeostatic mechanisms to fail leading to reduction in feed intake. Similarly, Ferket and Gernat (2006) reported that circulation of specific amino acid imbalance in blood and gut distension and motility are part of the mechanisms that regulates feed intake. Another possible reason for the depressed feed intake could be related to methionine toxicity. Harter and Baker (1978) and Annongu *et al.* (2014) reported that chicks fed excess methionine caused toxicity which was associated with pancreatic damage. Pancreas plays a very important role in digestion, pancreatic damage can cause endocrine and exocrine system to fail which leads to reduce feed intake. In contrast, Houshmand *et al.* (2015) did not observe reduction in feed intake when oak acorn diet containing tannin was supplemented with 100% methionine more than NRC recommendation. This could be due to less amount of methionine supplemented (0.72%) compare to 0.92% in current study.

Birds fed on UG69 diet had the highest ($p<0.05$) weight gain compare to those on UG46 and G46 during starter phase. During the entire phase the weight gain of birds fed on UG69 was only significantly different from those on UG46 diet with no change in weight gain during finisher phase. This improved weight gain could be due to the role of methionine in skeletal muscle development which is a precursor of S-adenosylmethionine, which serves as methyl donor for DNA methylation. High methionine intake increases DNA methylation and changes gene expression which leads to increase in muscle development (Waterland, 2006; and Wen *et al.,* 2014). This could mean that supplementation of methionine upto 50% more than recommended (UG69) is beneficial with no increase beyond this. In agreement, Chang and Fuller (1964); Armstrong *et al.* (1973); Elkin *et al.* (1978) and Ahmed and Abass (2011) reported higher weight gain of broiler chickens fed on high or low tannin sorghum supplemented with less than 50% methionine compare to unsupplemented. Armanious *et al.* (1973) reported increase in weight gain of laying hens when low and high tannin sorghum (Pioneer 828 and DeKalb BR-64) were supplemented with 0.4% methionine and 0.4% choline compare to unsupplemented.

During the starter and finisher phases, birds fed on diet G46 had similar feed conversion ratio as other groups on UG46 and UG69 with those on diet UG92 being significantly lower. This improved FCR could be explained by the beneficial impact of the extra methionine on deleterious effect of tannin on methionine absorption/utilization although the feed intake was impaired in those fed on diet UG92. Birds fed on UG46 had significantly ($p<0.05$) higher feed conversion ratio. This is due to the anti-nutrient factor (condensed tannin) that affects the digestibility and absorption of nutrients and thereafter bioavailability of these nutrients to birds (Douglas *et al.,* 1990; and Elkin *et al.,* 1996). Similarly, Armstrong *et al.* (1973) and Elkin *et al.* (1978) reported poor feed conversion ratio with feeding sorghum containing high tannin compare to sorghum based diet supplemented with methionine. Ahmed and Abass (2011) and Hind *et al.* (2012) observed that feeding low tannin sorghum resulted in poor feed conversion efficiency of broiler chickens compare to diet supplemented 40% and 30% methionine above requirement. In contrast, Chang and Fuller (1964) and Jacob *et al.* (1996) observed insignificant effect of feeding high tannin sorghum on feed efficiency ratio of broiler chickens compare to sorghum supplemented with methionine.

CONCLUSION

Germination increased ($p>0.05$) the tannin content of Gadam sorghum variety from 0.11 to 0.23% Tannic Acid (TA) but reduced ($p>0.05$) that of Serena sorghum variety from 0.47 to 0.32% TA. Germination of brown sorghum had no beneficial effect on performance of broiler chickens. Supplementation of high tannin diets with methionine upto 50% more than recommended improved performance of broiler chickens with no improvement beyond this.

REFERENCES

1. Abbas T E and Musharaf N A (2008), "The Effects of Germination of Low-Tannin Sorghum Grains on its Nutrient Contents and Broiler Chicks Performance", *Pakistan Journal of Nutrition*, Vol. 7, No. 3, pp. 470-474.
2. Ahmed M E and Abbas T E (2011), "Effects of Dietary Levels of Methionine on Broiler Performance and Carcass Characteristics", *Int. J. Poult. Sci.*, Vol. 10, No. 2, pp. 147-151.
3. AOAC (1990), *Official Methods of Analysis,* 15th Edition, Association of Official Analytical Chemists, Washington DC, USA.
4. AOAC (1998), *Official Methods of Analysis of AOAC International*, 16th Edition, CD-ROM Third Revision.
5. Annongu A A, Karim O R, Sola-Ojo F E, Kayode R M O and Adeyemi K D (2014), "Investigation of the Toxicity Levels of Supplemental Dietary Dl-methionine for Poultry in a Tropical Environment", *Wayamba Journal of Animal Science*, Vol. 6, pp. 975-980.
6. Armanious M W, Britton W M and Fuller H L (1973), "Effect of Methionine and Choline on Tannic Acid and Tannin Toxicity in the Laying Hen", *Poultry Science*, Vol. 52, No. 6, pp. 2160-2168.
7. Armstrong W D, Featherston W R and Rogler J C (1973), "Effects of Bird Resistant Sorghum Grain and Various Commercial Tannins on Chick Performance", *Poultry Science*, Vol. 53, No. 6, pp. 2137-2142.
8. Baba G M, Modu S, Falmata A S, Hajjagana L and Ibrahim Z (2012), "Evaluation of the Nutritional Value of Sprouted Sorghum Fortified with Cowpea and Groundnut", *Scholarly Journal of Agricultural Science,* Vol. 2, No. 11, pp. 292-296.
9. Badi W H I (2015), "Effect of Processing on Anti-Nutritional Factors and Mineral Bioavailability of Sorghum", Doctoral Dissertation, UOFK.
10. Brosnan J T and Brosnan M E (2006), "The Sulfur-Containing Amino Acids: An Overview", *The Journal of Nutrition*, Vol. 136, No. 6, pp. 1636S-1640S.
11. Chang S I and Fuller H L (1964), "Effect of Tannin Content of Grain Sorghums on their Feeding Value for Growing Chicks", *Poultry Science*, Vol. 43, No. 1, pp. 30-36.
12. Chung I M, Kim E H, Yeo M A, Kim S J, Seo M C and Moon H I (2011), "Antidiabetic Effects of Three Korean Sorghum Phenolic Extracts in Normal and Streptozotocin-Induced Diabetic Rats", *Food Research International*, Vol. 44, No. 1, pp. 127-132.
13. Dicko M H, Gruppen H, Traoré A S, Voragen A G J and Van Berkel W J H (2006), "Sorghum Grain as Human Food in Africa: Relevance of Content of Starch and Amylase Activities", *African Journal of Biotechnology*, Vol. 5, No. 5, pp. 384-395.
14. Douglas J H, Sullivan T W, Bond P L, Struwe F J, Baier J G and Robeson L G (1990), "Influence of Grinding, Rolling, and Pelleting on the Nutritional Value of Grain Sorghums and Yellow Corn for Broilers", *Poultry Science,* Vol. 69, pp. 2150-2156.
15. El-Beltagi H S, El-Salam S M A and Omran A A (2012), "Effect of Soaking, Cooking,

Germination and Fermentation Processing on Proximate Analysis and Mineral Content of Three White Sorghum Varieties (*Sorghum bicolor* L. *Moench*)", *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, Vol. 40, No. 2, pp. 92-98.

16. Elkhier M K S and Hamid A O (2008), "Effect of Malting on the Chemical Constituents, Antinutrition Factors and Ash Composition of Two Sorghum Cultivars (Feterita and Tabat) Grown in Sudan", *Research Journal of Agriculture and Biological Sciences*, Vol. 4, No. 5, pp. 500-504.

17. Elkin R G, Featherston W R and Rogler J C (1978), "Investigations of Leg Abnormalities in Chicks Consuming High Tannin Sorghum Grain Diets", *Poultry Science*, Vol. 57, No. 3, pp. 757-762.

18. Elkin R G, Freed M B, Hamaker B R, Zhang Y and Parsons C M (1996), "Condensed Tannins are only Partially Responsible for Variations in Nutrient Digestibilities of Sorghum Grain Cultivars", *Journal of Agricultural and Food Chemistry*, Vol. 44, No. 3, pp. 848-853.

19. Elmaki H B, Babiker E E and El Tinay A H (1999), "Changes in Chemical Composition, Grain Malting, Starch and Tannin Contents and Protein Digestibility During Germination of Sorghum Cultivars", *Food Chemistry*, Vol. 64, No. 3, pp. 331-336.

20. Ferket P R and Gernat A G (2006), "Factors that Affect Feed Intake of Meat Birds: A Review", *Int. J. Poult. Sci.*, Vol. 5, No. 10, pp. 905-911.

21. Hamad R M (2007), "Preliminary Studies on the Popping Characteristics of Sorghum Grains", M.Sc. Sudan: Thesis, p. 90, Sudan Academy of Science, Al-Zaiem Al-Azhari Univiversity.

22. Han Y and Baker D H (1993), "Effects of Excess Methionine or Lysine for Broilers Fed a Corn-Soybean Meal Diet", *Poultry Science*, Vol. 72, No. 6, pp. 1070-1074.

23. Harter J M and Baker D H (1978), "Factors Affecting Methionine Toxicity and its Alleviation in the Chick", *The Journal of Nutrition*, Vol. 108, No. 7, pp. 1061-1070.

24. Hassan I A G, Elzubeir E A and El Tinay A H (2003), "Growth and Apparent Absorption of Minerals in Broiler Chicks Fed Diets with Low or High Tannin Contents", *Tropical Animal Health and Production*, Vol. 35, No. 2, pp. 189-196.

25. Hind A A, Elagib H A and Elzubeir E A (2012), "The Effect of Feeding Different Levels of Methionine and Two Levels of Energy on Broiler Performance During Heat Stress", *Pakistan Journal of Nutrition*, Vol. 11, No. 9, p. 739.

26. Houshmand M, Hojati F and Parsaie S (2015), "Dietary Nutrient Manipulation to Improve the Performance and Tibia Characteristics of Broilers Fed Oak Acorn (Quercus Brantii Lindl)", *Revista Brasileira de Ciência Avícola*, Vol. 17, No. 1, pp. 17-24.

27. Hübner F and Arendt E K (2013), "Germination of Cereal Grains as a Way to Improve the Nutritional Value: A Review", *Critical Reviews in Food Science and Nutrition*, Vol. 53, No. 8, pp. 853-861.

28. Jacob J P, Mitaru B N, Mbugua P N and Blair R (1996), "The Feeding Value of Kenyan

Sorghum, Sunflower Seed Cake and Sesame Seed Cake for Broilers and Layers", *Animal Feed Science and Technology*, Vol. 61, Nos. 1-4, pp. 41-56.

29. Kiprotich F K, Cheruiyot E K, Mwendia C M, Wachira F N and Owuoche J (2014), "Biochemical Quality Indices of Sorghum Genotypes from East Africa for Malting and Brewing", *African Journal of Biotechnology*, Vol. 13, No. 2.

30. Kyarisiima C C, Okot M W and Svihus B (2004), "Use of Wood Ash in the Treatment of High Tannin Sorghum for Poultry Feeding", *South African Journal of Animal Science*, Vol. 34, No. 2, pp. 110-115.

31. Li E T S and Anderson G H (1983), "Amino Acids in the Regulation of Food Intake", *Nutr. Abs. and Rev: Rev in Clin. Nutr.*, Vol. 53, No. 3, pp. 169-181.

32. Medugu C I, Kwari I D, Igwebuike J, Nkama I, Mohammed I D and Hamaker B (2010), "Performance and Economics of Production of Broiler Chickens Fed Sorghum or Millet as Replacement for Maize in the Semi-Arid Zone of Nigeria", *Agriculture and Biology Journal of North America*, Vol. 1, No. 3, pp. 321-325.

33. Mitaru B N, Reichert R D and Blair R (1983), "Improvement of the Nutritive Value of High Tannin Sorghums for Broiler Chickens by High Moisture Storage (Reconstitution)", *Poultry Science*, Vol. 62, No. 10, pp. 2065-2072.

34. Mohamed A, Urge M and Gebeyew K (2015), "Effects of Replacing Maize with Sorghum on Growth and Feed Efficiency of Commercial Broiler Chicken", *Veterinary Science & Technology*, Vol. 6, No. 3, p. 1.

35. Mwadalu R and Mwangi M (2013), "Potential Role of Sorghum in Enhancing Food Security in Semi-Arid Eastern Kenya the Potential Role of Sorghum in Enhancing Food Security in Semi-Arid Eastern Kenya: A Review", *J. Appl. Biosci.*, pp. 5786-5799.

36. Nour A A M, Ibrahim M A E M, Abdelrahman E E, Osman E F and Khadir K E (2016), "Effect of Processing Methods on Nutritional Value of Sorghum (*Sorghum bicolor* L. *Moench*) Cultivar", *Am J Food Sci Health*, Vol. 1, No. 4, pp. 104-108.

37. Ogbonna A C, Abuajah C I, Ide E O and Udofia U S (2012), "Effect of Malting Conditions on the Nutritional and Anti-Nutritional Factors of Sorghum Grist", *Annals of the University Dunarea de Jos of Galati, Fascicle VI: Food Technology*, Vol. 36, No. 2, pp. 64-72.

38. Oke F O, Fafiolu A O, Jegede A V, Oduguwa O O, Adeoye S A, Olorunsola R A and Muhammed A I (2016), "Performance and Nutrient Utilization of Broilers Fed Malted Sorghum Sprout (msp) or Wheat-Offal Based Diets Supplemented with Yeast Culture and Enzyme", *Online Journal of Animal and Feed Research*, Vol. 5, No. 3, pp. 78-84.

39. Okoh P N, Kubiczek R P, Njoku P C and Iyeghe G T (1989), "Some Compositional Changes in Malted Sorghum (Sorghum Vulgare) Grain and its Value in Broiler Chicken Diet", *Journal of the Science of Food and Agriculture*, Vol. 49, No. 3, pp. 271-279.

40. Osuntogun B A, Adewusi S R A, Ogundiwin J O and Nwasike C C (1989), "Effect of Cultivar, Steeping, and Malting on Tannin,

Total Polyphenol, and Cyanide Content of Nigerian Sorghum", *Cereal Chemistry,* USA.

41. Pauzenga U (1985), "Feeding Parent Stock", *Zootecnica International*, Vol. 17, pp. 22-24.

42. Phattanakulkaewmorie N, Paseephol T and Moongngarm A (2011), "Chemical Compositions and Physico-Chemical Properties of Malted Sorghum Flour and Characteristics of Gluten Free Bread", *World Academy of Science, Engineering and Technology*, Vol. 5, No. 7, pp. 532-538.

43. Sell D R and Rogler J C (1984), "The Effects of Sorghum Tannin and Methionine Level on the Performance of Laying Hens Maintained in Two Temperature Environments", *Poultry Science*, Vol. 63, No. 1, pp. 109-116.

44. Shem M N, Lekule F P, Zakayo G Z and Eggum B O (1990), "Nutritive Value of Germinated and Ungerminated High Tannin Sorghum for Growing Pigs", *Acta Agriculturae Scandinavica*, Vol. 40, No. 3, pp. 253-258.

45. Taylor J R and Dewar J (2001), "Developments in Sorghum Food Technologies", *Advances in Food and Nutrition Research*, Vol. 43, pp. 217-264.

46. Waterland R A (2006), "Assessing the Effects of High Methionine Intake on DNA Methylation", *The Journal of Nutrition*, Vol. 136, No. 6, pp. 1706S-1710S.

47. Wen C, Chen X, Chen G Y, Wu P, Chen Y P, Zhou Y M and Wang T (2014), "Methionine Improves Breast Muscle Growth and Alters Myogenic Gene Expression in Broilers", *Journal of Animal Science*, Vol. 92, No. 3, pp. 1068-1073.

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