Effects of Sorghum Tannins, a Tannin Binder (Polyvinylpyrrolidone) and Sorghum Inclusion Level on the Performance of Broiler Chicks

M. K. Ambula*, G. W. Oduho and J. K. Tuitoek

Department of Animal Science, Egerton University, Box 536 Njoro, Kenya

ABSTRACT : The feeding values of four indigenous Kenyan sorghum cultivars and the effects of polyvinylpyrrolidone (PVP) on the utilization of high tannin sorghum by broiler chicks were studied in two 3-week feeding trials. In Experiment 1, one hundred and five broiler chicks (initial average weight 97 g) were randomly assigned to each one of the seven grain-soybean meal diets. The diets consisted of maize [diet 1; no assayable tannin], white sorghum [diet 2; 0.59% catechin equivalents (CE)], cream sorghum [diet 3; 0.94% CE], light brown sorghum [diet 4; 2.71% CE] and dark brown sorghum [diet 5; 3.54% CE]. Diets 6 and 7 were included to test the possibility of overcoming the detrimental effects of sorghum tannins by adding PVP at 0.25% and 0.5% to dark brown sorghum, which resulted in dietary tannin levels of 3.46% and 3.38% CE respectively. In Experiment 2, the effects of tannin on dry matter digestibility (DMD) and nitrogen (N) retention were studied in a 3-week substitution assay in which high tannin sorghum (5% CE) was substituted for white maize at different inclusion levels. Ninety broiler chicks aged 7 days (initial average weight 102 g) were randomly assigned to each one of the six diets. The diets consisted of corn gluten meal and fishmeal as protein sources plus maize [diet 1] and high tannin sorghum at different inclusion levels [diets 2, 3, 4, 5 and 6], resulting in dietary tannin levels of 0, 1.25%, 1.66%, 2.08%, 2.5% and 3.2% CE respectively. Feed intake, feed efficiency and body weight gain were measured weekly. In Experiment 2, tannin absorption, DMD and N retention were measured on days 19, 20 and 21. The results of Experiment 1 showed that feed intake, feed efficiency and body weight gain were all affected by treatment ($p<0.05$). Diets 1, 2 and 3 gave similar body weight gains and all were better than diets 4 and 5 (i.e. 504, 517, 473 g, vs. 256, 267 g). Similarly, feed efficiencies were higher ($p<0.05$) for diets 1, 2 and 3 compared to diets 4 and 5 (0.4, 0.42, 0.39 vs. 0.21, 0.23). When 0.25% PVP was added to the dark brown sorghum (diet 6) there was no significant improvement in chick performance ($p>0.05$). However, addition of 0.5% PVP (diet 7) resulted in significant improvement ($p<0.05$) in body weight gain compared to the untreated dark brown sorghum. Overall, PVP did not completely overcome the deleterious effects of tannins. The results of Experiment 2 indicate that sorghum inclusion level and subsequent tannin level had no effect on feed intake, feed efficiency, weight gain, DMD and N retention. The above results suggest that tannin level should be limited to below 2.71% CE in broiler chick diets containing 20% CP and 0.4% methionine. However, in diets with 23% CP and 0.8% methionine tannin level of up to 3.2% will not affect performance. Consequently high tannin sorghum (5% CE) can be used to substitute for white maize by up to 100% in broiler chick diets. *(Asian-Aust. J. Anim. Sci. 2001. Vol 14, No. 9 : 1276-1281)*

Key Words : Broilers, Diets, Performance, Polyvinylpyrrolidone (PVP), Sorghum, Tannins

INTRODUCTION

A critical problem facing Kenya and many other developing countries is an insufficiency of cereal grains that can adequately cater for both humans and livestock. Stiff competition for maize between man and livestock requires that an alternative energy source be encouraged in feed formulation. Compared to maize, sorghum (*S. bicolor* (L) Moench) is more drought resistant, is relatively cheaper to produce and is spread across many households in the country. Although the nutritive value of sorghum is comparable to that of maize, one major limitation is the presence of anti-nutritive compounds collectively known as tannins. Several sorghum cultivars are grown in Kenya, the majority of which tend to have very high levels of tannin, limiting their use in chicken diets. However, compared to the hybrids (Serena, Seredo and Kari Mtama 1), local sorghum cultivars are more resistant to depredation by birds, do well in most types of soils, and give higher yields.

Several researchers have reported that high tannin sorghum (HTS) when used as a sole grain source depresses feed intake, body weight gain and feed efficiency in broiler chicks. Nelson et al. (1975) reported a significant negative correlation between tannin content of high tannin sorghum and DM digestion and energy utilization in broiler chicks. Certain feed additives like polyvinylpyrrolidone (PVP) that have strong affinity for tannins have been used to deactivate them, thus preventing their binding to proteins. Tannins are more readily bound to PVP than to proteins and once bound they are not able to interfere with digestion and cannot be absorbed along the gastro-intestinal tract of the animal. Featherston et al. (1982) showed that 1% PVP in sorghum-based diets improved weight gain and nitrogen retention in broiler chicks. The use of PVP at a lower level (less than 1%) would most likely decrease the feeding costs and increase the profit margins in a broiler enterprise. The purpose of this study was to investigate the possibility of replacing maize as sole grain source in broiler starter rations with local sorghum cultivars grown in Kenya. The efficacy

* Corresponding Author: M. K. Ambula. Tel: +254-37-61276, Fax: +254-37-61442, E-mail: owuor@africaonline.co.ke.

Received January 31, 2001; Accepted April 20, 2001

of deactivating sorghum tannins using PVP at 0.25% and 0.5% was also examined.

MATERIALS AND METHODS

Experiment 1

Experimental protocol : Two hundred day-old commercial broiler chicks of mixed sex (Arbo Acres) were obtained from a local hatchery and used for the experiment. The chicks were kept under normal brooding conditions and received a standard maize-soybean meal diet calculated to contain 23% crude protein and 3190 kcal ME/kg diet. After 7 days, all the chicks were individually weighed and 105 birds within the middle-weight range (initial average weight 97 g) were wing-banded and randomly assigned to the 7 dietary treatments. Each treatment consisted of 3 replicate pens of 5 chicks each. A raised floor pen of 84 cm × 78 cm × 43 cm with five chicks formed an experimental unit. Four indigenous sorghum cultivars of different seed coat color (white, cream, light brown and dark brown) were used for the experiment. The tannin content of the four sorghum cultivars was analyzed to be 0.98%, 1.56%, 4.52% and 5.9% catechin equivalents (CE). The different sorghum cultivars and maize were used as grain energy sources to formulate diets designed to meet the nutrient requirements of broiler chicks (NRC, 1984). Two additional diets (6 and 7) were included to test the effects of PVP when added at either 0.25% or 0.5% respectively (table 1). Soybean meal (45.6% CP) and fishmeal (53.8% CP) were the major protein sources. Throughout the experimental period, feeding was done twice daily, at 09:00 h and at 16:00 h, and all the diets were fed in mash form. Water was provided *ad libitum*. Data collection was initiated on day 8 and terminated on day 28. Body weight gain, feed consumption and feed efficiency were measured on weekly basis.

Experiment 2

Experimental protocol : Two hundred day-old broiler chicks (Arbo Acres) of mixed sex were obtained from a local commercial hatchery and used for the experiment. The management of the chicks during the first 7 days of life was as described for the chicks of Experiment 1. At the end of 7 days all the chicks were weighed and 90 chicks within the middle-weight group (initial average weight 102 g) were wing-banded and randomly distributed among the six dietary treatments. Diet 1 contained maize as the sole grain

Table 1. Composition of diets[1] (air-dry basis) used in Experiment 1

Ingredient (% of diet)	1	2	3	4	5	6	7
White maize (7.6% CP[2])	60.00	-	-	-	-	-	-
White sorghum (8.4% CP[2])	-	60.00	-	-	-	-	-
Cream sorghum (8.4% CP[2])	-	-	60.00	-	-	-	-
Light brown (9.1% CP[2])	-	-	-	60.00	-	-	-
Dark brown (10.2% CP[2])	-	-	-	-	60.00	59.75	59.50
Soybean meal (45.6% CP[2])	27.00	26.50	26.50	26.50	26.50	26.50	26.50
Fishmeal (53.8% CP[2])	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Limestone	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Dicalcium phosphate	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Corn oil	2.50	3.00	3.00	3.00	3.00	3.00	3.00
Iodized salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Broiler premix[3]	0.20	0.20	0.20	0.20	0.20	0.20	0.20
PVP[4]	-	-	-	-	-	0.25	0.50
Calculated composition							
CP (%)	19.60	19.81	19.81	20.23	20.89	20.87	20.84
ME (kcal ME/kg)[5]	3,042	3,025	3,025	3,025	3,025	3,025	3,025
Methionine (%)[5]	0.47	0.45	0.45	0.45	0.45	0.45	0.45
Lysine (%)[5]	1.57	1.54	1.54	1.54	1.54	1.54	1.54
Tannin (% CE)	-	0.59	0.94	2.71	3.54	3.46	3.38

[1] Sorghum-based diets: 2 = Ochuti (0.98 % CE); 3 = Andiwo White (1.56% CE); 4 = Ochuti Red (4.52% CE); 5 = Ofunjo Red (5.90% CE); 6 = Ofunjo Red + 0.25% PVP, 7 = Ofunjo Red + 0.5% PVP.

[2] Determined analysis.

[3] Supplied per kg diet: Vit. A, 8,000 IU; Vit. D3, 1,600 IU; Vit. E, 6.4 mg; Vit. K3, 1.6 mg; Vit. B2, 4.8 mg; Pantothenic acid, 8 mg; Niacin, 24 mg; Vit. B12, 0.008 mg, Folic acid, 0.8 mg; Choline Chloride, 120 mg; Lysine, 0.4 mg; Methionine, 0.096 mg; Manganese, 53.6 mg; Iron, 19.2 mg; Zinc, 53.6 mg; Copper, 11.2 mg; Iodine, 1.6; Selenium, 0.08 mg; BHT, 96 mg.

[4] Polyvinylpyrrolidone.

[5] Adapted from NRC (1984). ME (kcal) - maize 3,350; sorghum 3,288; soybean meal 2,440; fishmeal 2,820; corn oil 8,800. Lysine - maize 0.24%; sorghum 0.21%; soybean meal 2.93%; fishmeal 4.83%. Methionine- maize 0.2%; sorghum 0.16%; soybean meal 0.65%; fishmeal 1.78%.

source, while diets 2, 3, 4, 5 and 6 contained high tannin sorghum (5% CE) which was substituted for maize at different inclusion levels (table 2). Total fecal collection was done on days 19, 20 and 21. Two pens from each treatment were selected at random and a polyethylene plastic sheet was spread beneath each pen to collect the excreta. A known amount of feed was weighed and given to the chicks and after 24 h the feces were collected, weighed and kept in airtight bottles for freeze drying. The apparent dry matter digestibility, nitrogen retention and tannin absorption were obtained by comparing the values in the feed and in the feces. Other performance data on feed consumption, feed efficiency and weight gain were recorded on weekly basis as described for Experiment 1.

Chemical and statistical analyses : Analysis for moisture, dry matter and nitrogen in the cereal grains, compounded diets and in the feces were done by standard procedures as outlined in the Official Methods of Analysis (AOAC, 1984). The modified vanillin-HCL method of Price et al. (1978) was used to determine the tannin content of both sorghum grain and fecal samples. Data were subjected to analysis of variance for a completely randomized design using the Statistical Analysis System (SAS, 1997). When F-value was significant, means were separated using the Least Significant Difference at the 5% level (Steel and Torrie, 1980).

RESULTS

The results of the effects of grain energy source and PVP on broiler performance are shown in table 3. The tannin content of diets used in experiment 1 ranged from 0.59% to 3.54% CE. Addition of 0.25% and 0.5% PVP to high tannin sorghum diet reduced the amount of assayable tannin by approximately 2.9% and 5.73%, respectively. Feed intake was affected by treatment such that chicks fed diets 1, 2, and 3 had similar feed intake which was higher ($p<0.05$) compared to that of chicks fed diets 4, 5, 6 and 7. Chicks fed diets 1, 2 and 3 attained similar body weight gain, which was significantly higher than diets 4, 5, 6 and 7. Chicks fed diets 4, 5 and 6 had similar body weight gain but this was statistically lower than that of chicks fed on diet 7. Feed efficiency was better for chicks on diets 1, 2 and 3 compared to that of diets 4, 5, 6 and 7, all of which had similar feed efficiency. Although the addition of 0.5% PVP to diet 7 improved weight gain significantly compared to 0.25% PVP added to diet 6, this was not so with feed consumption or feed efficiency. The performance of chicks on maize, white sorghum and cream sorghum was better than that of chicks on either light brown, dark brown or dark brown sorghum treated with PVP.

Table 4 gives a summary of the results of the effect of different inclusion levels of a high tannin sorghum on the performance of broiler chicks. There were no significant differences among treatment means for weight gain and feed efficiency. However, chicks on diets 5 and 6 had similar feed intake which was significantly lower than that of chicks on diets 1, 2, 3 and 4, these being similar amongst themselves. In addition, there were no significant differences among treatment means for dry matter intake and N retention. The mean tannin absorption across the treatments was 30% and except for diet 2, which showed significantly lower tannin absorption, there were no statistical differences in the absorption of tannins among chicks given diets 3, 4, 5 and 6.

Table 2. Composition of diets[1] (air-dry basis) used in Experiment 2

	1	2	3	4	5	6
Ingredient (% of diet)						
White maize (7.6% CP)	60.00	40.00	30.00	20.00	10.00	-
HTS[2] (10.2% CP)	-	20.00	30.00	40.00	50.00	60.00
Corn gluten meal (60% CP)	27.50	26.50	26.50	26.50	26.50	26.50
Fishmeal (53.8% CP)	5.00	5.00	5.00	5.00	5.00	5.00
Limestone	3.00	3.50	3.50	3.50	3.50	3.50
Dicalcium phosphate	2.00	2.00	2.00	2.00	2.00	2.00
Corn oil	2.00	2.50	2.50	2.50	2.50	3.00
Iodized salt	0.30	0.30	0.30	0.30	0.30	0.30
Broiler premix[3]	0.20	0.20	0.20	0.20	0.20	0.20
Calculated composition						
CP (%)	23.02	23.24	23.50	23.76	24.02	24.28
ME (kcal/kg)	3,372	3,346	3,338	3,320	3,312	3,295
Methionine (%)	0.84	0.82	0.81	0.79	0.79	0.77
Lysine (%)	1.07	1.06	1.05	1.02	1.04	1.03
Tannin (%CE)	-	1.25	1.66	2.08	2.50	3.20

[1] Maize and sorghum substituted on energy and protein basis to get isocaloric and isonitrogenous diets.
[2] Nyaod Akur (Tannin level 5% CE), [3] See table 1.

Table 3. Effect of grain source on 21-day feed intake, weight gain and feed conversion of broiler chicks[1]

	Diets[2]							
	1	2	3	4	5	6	7	SEM[3]
Tannin (% CE)	-	0.59	0.94	2.71	3.54	3.46	3.38	
Feed intake, g/bird	1,256[a]	1,228[a]	1,231[a]	1,039[b]	921[c]	1,003[b]	999[b]	± 43.8
Weight gain, g/bird	504[a]	517[a]	473[a]	256[c]	267[c]	289[c]	350[b]	± 25.9
Gain/feed	0.40[a]	0.42a	0.39[a]	0.21[b]	0.23[b]	0.23[b]	0.30[b]	± 0.018

[a,b,c] Means in the same row with different superscripts are significantly different ($p<0.05$).

[1] 105 chicks (7×3×5).

[2] Diets: 1= maize; 2 = white sorghum; 3 = cream sorghum; 4 = light brown sorghum; 5 = dark brown sorghum; 6 = dark brown sorghum + 0.25% PVP; 7 = dark brown sorghum+ 0.5% PVP.

[3] Standard error of the mean.

Table 4. Effect of sorghum inclusion level on 21-day feed intake, feed efficiency and body weight gain, DM intake, N retention and tannin absorption of broiler chicks[1]

	Diets[2]						
	1	2	3	4	5	6	SEM[3]
Tannin (% CE)	-	1.25	1.66	2.08	2.50	3.20	
Feed intake, g/bird	917[a]	901[a]	961[a]	949[a]	865[b]	877[b]	±39.71
Weight gain, g/bird	370[a]	34[a]	334[a]	361[a]	343[a]	358[a]	±18.62
Gain/feed	0.40[a]	0.40[a]	0.35[a]	0.38[a]	0.39[a]	0.40[a]	±0.021
DMD[4], %	85.6[a]	84.5[a]	85.2[a]	82.5[a]	83.0[a]	81.6[a]	±4.09
Nitrogen retention, %	61.80[a]	62.30[a]	61.08[a]	59.80[a]	61.45[a]	60.10[a]	±2.88
Tannin absorption, %	-	25.30[b]	31.80[a]	34.40[a]	28.95[a]	28.57[a]	±3.92

[a,b] Means in the same row with different superscripts are significantly different ($p<0.05$)

[1] 90 chicks (6×3×5)

[2] Diets: 1 = Maize 60%; 2 = Maize 40% + 20% HTS; 3 = Maize 30% + 30% HTS; 4 = Maize 20% + 40% HTS; 5 = Maize 10% + 50% HTS; 6 = 60% HTS. [3] Standard error of the mean. [4] Dry matter digestibility

DISCUSSION

There was approximately a 17 to 27% reduction in feed intake associated with increased tannin levels, which agrees with some reports. Mitaru et al. (1983) obtained a 19.4% reduction in feed intake with dietary tannin of 2.76% CE. However, at lower dietary tannin levels (1.3% CE and 1.57% CE, respectively) Jacob et al. (1996a) and Nyachoti et al. (1998) failed to observe any negative effect of tannins on feed intake by broiler chicks. The 6.63% reduction in feed intake reported by Jacob et al. (1996b) may be attributed to the slightly higher tannin level examined (2.39% CE). The marked reduction in feed intake reported in the current study is probably due to the high levels of dietary tannins tested (i.e. 2.71 to 3.54% CE). In Experiment 2, tannin levels of 1.25 to 3.2% did not adversely affect feed consumption. A possible explanation for this is the increased total protein and consequently methionine level of diets used in this experiment. Increased methionine level has been shown to alleviate the deleterious effects of tannins on feed consumption and other performance variables in broiler chicks (Armstrong et al., 1973). Although taste acuity in chicken is not well developed, it seems likely that both the astringency and bitter taste of high tannin sorghum affects feed intake. This might explain the relatively greater reduction in feed intake observed among broiler chicks fed a starter diet containing 3.54% CE.

Deactivating tannins by adding PVP at either 0.25% or 0.5% gave some improvement of 8.45% and 8.9% in feed consumption, respectively. This is slightly higher than the value obtained by Featherston et al. (1982) who reported a 5.26% increase in feed intake when 1% PVP was added to diets containing 1.74% tannins expressed as tannic acid equivalents. Differences in tannin measurement and diet composition make it difficult to compare these results. The observed improvement in feed consumption when PVP was added to the diets is probably due to a reduction in the formation of tannin-protein complexes with the resultant reduction in astringency and improved intake. It is logical to infer that PVP whether used at either 0.25% or 0.5% gives a similar effect on feed intake. There was a 26 to 50% reduction in weight gain among broiler chicks fed diets containing high levels of tannins in Experiment 1, although no effect was observed in Experiment 2. Literature is more consistent with the effects of dietary tannins on body weight gain. Several workers have reported a negative effect on weight gain when high tannin sorghum is incorporated in

broiler chick diets (Mitaru et al., 1983; Elkin et al., 1990). Reductions in body weight gain of up to 40% have been reported with diets ranging from 2.76% to 3.6% CE. However, other studies have found no negative effects on weight gain (Jacob et al., 1996a; Nyachoti et al., 1998). It is important to note that the diets used by the preceding authors contained relatively low levels of tannins (1.3% and 1.57% CE, respectively), which possibly explains the lack of negative effect on weight gain. There appears to be a positive correlation between dietary tannin level and the magnitude of reduction in body weight gain. The highest dietary tannin level tested in Experiment 1 was 3.54% CE which resulted in a 50% reduction in body weight gain. In Experiment 2 tannin levels of up to 3.2% CE had no negative effect on body weight gain, possibly due to the same reason alluded to earlier. The addition of PVP at 0.25% and 0.5% resulted in 8.2% and 31% increase in weight gain, respectively compared to the untreated diet. This finding agrees with the observation made by Featherston et al. (1982). It can therefore be concluded that PVP when used at a lower level (0.25%) is less effective in alleviating the negative effects of tannins on body weight gain of broiler chicks. Hence for effective deactivation of sorghum tannins, PVP should be added at levels higher than 0.25% for example 0.5% or more.

A negative effect of dietary tannins on feed efficiency was observed only in Experiment 1. A 23 to 42.5% reduction in feed efficiency was observed among chicks fed diets with high tannin levels. Nyachoti et al. (1998) reported a 6.5% reduction in feed efficiency among chicks fed a diet containing 1.57% CE. The highest dietary tannin level in Experiment 1 was 3.54% CE, which gave a 42.5% reduction on feed efficiency. In Experiment 2 the highest dietary tannin level tested was 3.2% CE, which had no effect on feed efficiency. Similar reasons advanced for the effect of tannins in experiment 1 account for the observation in feed efficiency. The addition of PVP at 0.25% did not have any affect on feed efficiency, but when used at 0.5% there was 30.4% improvement in feed efficiency. Although it is possible that PVP when used at a slightly higher level (0.5%) improves the utilization of grain sorghum by broiler chicks, it does not completely remove the adverse effects of tannins on feed efficiency. Moreover, using PVP is most likely to inflate feeding costs and reduce profit margins in a broiler enterprise. In addition, there was no negative effect attributable to dietary tannins on apparent dry matter digestibility (DMD) or nitrogen (N) retention. This is possibly due to alleviation of any deleterious effects of tannins by methionine. More recently, Nyachoti et al. (1998) obtained a 9% and 14% reduction in DMD and N retention, respectively among chicks fed sorghum-based diets containing 1.57% CE tannin content. This reduction was probably due to the lower methionine content of the experimental diets used in the study cited above (0.5% vs. 0.82% used in the current study). Work by Chang and Fuller (1964) showed that methionine was the main source of methyl groups for the 0-methylation of gallic acid, a principal metabolite of tannins. The current results indicate that different inclusion levels with resultant different tannin content (1.25 to 3.2% CE) gave similar DMD and N retention. It seems likely that there were sufficient methyl groups that aided in the removal of tannins (as 4-0-methyl-gallic acid) thus diminishing their effect in binding at the absorptive sites along the gastro-intestinal tract.

The results of this study suggest that tannin levels in broiler chick diets should be limited to below 2.71% CE in diets containing 20% protein and 0.45% methionine. However, at increased dietary protein (23%) and methionine (0.8%) levels, high tannin sorghum (5% CE) can be used to substitute for maize by up to 100%.

ACKNOWLEDGEMENTS

The authors would like to thank Egerton University for providing a grant that made this work possible. The technical assistance provided by staff of Animal Science Department in laboratory analyses and the care of the birds is gratefully acknowledged.

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