Nutritional Improvement of Tannin-Containing Sorghums (*Sorghum bicolor*) by Sodium Bicarbonate

DRINAH B. C. BANDA-NYIRENDA and PRAN VOHRA[1]

ABSTRACT

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Broiler chicks were fed isonitrogenous diets containing either maize (corn) as a cereal constituent or different cultivars of tannin-containing sorghum (about 1% tannin measured as catechin equivalent). Compared with the diet containing maize, diets based on tannin-containing sorghum cultivars (Northrup King NK 300, Savanna 5-91906, Savanna X3174-63836, or BRY 936) significantly ($P < 0.01$) depressed growth of chickens. Growth depression was overcome and feed-gain ratio improved if the diet containing cultivar NK 300 was supplemented with 0.5% $NaHCO_3$ and those containing cultivars Savanna 5-91906, Savanna X3174-63836, or BRY 936 were supplemented with 0.25% $NaHCO_3$. Levels of 0.5 or 0.75% $NaHCO_3$ were inferior to the 0.25% level for improving growth of chickens for the latter three cultivars. Apparent nitrogen retention also increased with 0.25% $NaHCO_3$. Apparent metabolizable energy data were less consistent; nitrogen retention increased with ensilaging of sorghums but not body weight. $NaHCO_3$ supplementation is a practical and economic method for overcoming the nutritional effects of tannins in sorghum cultivars.

Agronomists have purposely increased the content of condensed tannins in sorghums (*Sorghum bicolor* (L.) Moench) to protect sorghums from ravaging pests in the field, specially birds (Bullard et al, 1980). Sorghum samples containing about 1% catechin equivalent are designated as high-tannin varieties by nutritionists (Radhakrishnan and Sivaprasad 1980, Muindi and Thomke 1981), but we refer here to these samples as "tannin-containing samples" and to those with less than 0.3% as "normal samples." The nutritive value of tannin-containing sorghums is reduced for monogastric animals such as poultry (Chang and Fuller 1964; Armstrong et al 1973, 1974; Rostagno et al 1973; Featherston and Rogler 1975; Ford and Hewitt 1979; Muindi et al 1981).

The nutritive value of tannin-containing sorghums may be improved by treatment with polyethylene glycol (Ford and Hewitt 1979, Savage et al 1980), ammonia (Savage et al 1980), Magadi soda ($Na_2CO_3{\cdot}NaHCO_3{\cdot}H_2O$) solution (Muindi and Thomke 1981, Muindi et al 1981), by germination (Reichert et al 1980, Chavan et al 1981), by high-moisture reconstitution (Mitaru et al 1983, Teeter et al 1986), or by supplementing diets with orthophosphoric acid or dicalcium phosphate (Ibrahim et al 1988). The animals used in these studies included rats, chickens, and pigs.

The production of tannin-containing sorghums is of economic importance in the livestock industry and as a food source in developing countries. Any inexpensive method of improving the nutritive value of tannin-containing sorghums is of great importance in improving food grain availability.

In the present study, a simple method using supplementation of tannin-containing sorghums with small quantities of sodium bicarbonate ($NaHCO_3$) is described and compared to sprouting, ensilaging, or supplementation of tannin-containing sorghums with barley malt for growing chickens.

MATERIALS AND METHODS

Four cultivars of normal sorghum, De Kalb DD 50T (DD 50T), O'Gold EXP 95206 (EXP 9520), De Kalb A 28+ (A 28+), Northrop King NK 1580 (NK 1580), and the tannin-containing cultivar Northrup King NK 300 (NK 300) were grown at Davis, CA, during 1981. The first three ranged from high to poor performance for *Tribolium* larvae growth, as reported by Banda-Nyirenda et al (1987). The tannin-containing cultivars Savanna 5-91906 (S-9190), Savanna X3174-63836 (5-6383), and BRY 936 were donated by Northrup King Co., Minneapolis, MN. Barley malt was purchased from Great Western Malt Co., Los Angeles, CA.

Three replicate samples of each grain were analyzed for dry matter, crude protein (Kjeldahl N $\times$ 6.25), ether extract, and ash according to AOAC (1975) procedures 14.003, 2.049, 7.045, and 14.006, respectively. Starch was determined by the method of Southgate (1969). Free sugars were determined as glucose by the glucose oxidase method (using Glucose diagnostic kit 115, Sigma Chemical Co., St Louis, MO). Available carbohydrate, the sum of starch plus free sugars, was calculated. The method of Hellendoorn et al (1975) was used for estimating indigestible residue. Tannins were measured as catechin equivalent by the procedure of Price et al (1978).

Sorghum grains were soaked in water overnight, and the water was drained off. Soaked grains were covered with cheesecloth, soaked, and drained every day for three days, by which time sprouting was accomplished. Sprouted grains were spread in stainless steel trays and dried in a forced-air oven at 50°C for 12 hr.

For ensilage, ground sorghum grains were reconstituted with water to contain 30% moisture and then packed tightly into a plastic bag. After the air was squeezed out at the top, the bag was sealed, put into another bag, and stored in a room at 25 $\pm$ 1°C for six weeks. Silage with a pH of 4.2–4.3 was used in feeding experiments without drying.

Day-old broiler chicks of Arbor Acre breed were purchased from A and M Hatchery, Santa Rosa, CA. They were wing banded, weighed, and distributed eight chicks to a group in Experiments 1 and 3 and seven birds to a group in Experiment 2. The groups were approximately equal in weight in each experiment and were replicated once in a complete randomized block design. The groups were housed in Petersime battery cages (Petersime Incubator Co., Getteysburg, OH), with the temperature maintained at 35°C for the first week and reduced by 2.8°C every week for the next two weeks. The battery was in a room maintained at a temperature of 24 $\pm$ 1°C with 14 hr of light and 10 hr of darkness. Birds had access to feed and water all the time. The compositions of the isonitrogenous diets for Experiments 1 and 2 are given in Tables I and II, respectively. In Experiment 3, the inclusions (g/kg of diet) were as follows: corn or sorghum, 530; soybean meal, 380; and supplement, 90. The details are same as for Diet NK 300 in Table I. The chicks were weighed individually twice a week. Two 24-hr total collections of excreta were made during the third week of the experiment, and the corresponding feed intakes were also measured. The excreta were dried at 60°C in a forced-air oven. The gross energies of the diets and of corresponding excreta were determined, using a Parr Adiabatic Bomb Calorimeter (model 1141, Parr Instrument Co., Moline, IL). The apparent metabolizable energy (AME) of the diets was calculated

[1]Dept. of Avian Sciences, University of California, Davis 95616. Present address of the first author: 5015 Verano Place, Irvine, CA 92715. All correspondence should be addressed to the first author.

from these data.

Apparent nitrogen retention (ANR) of the diets was calculated from the nitrogen content of the diets and of excreta as determined by AOAC (1975) as follows:

$$ANR = 100\,[N \text{ intake (g)} - N \text{ in excreta (g)}]/\ N \text{ intake (g)}.$$

The data on feed efficiency (or grams of feed needed per gram of gain in body weight) and AME were subjected to one-way and, for body weights, two-way analysis of variance. Significantly different parameters were compared by Fisher's least significant difference (Snedecor and Cochran 1980), using a microcomputer program (MSTAT3, 1982).

RESULTS AND DISCUSSION

The ensilaging of tannin-containing sorghum cultivars S-9190 and S-6383 and the normal cultivar EXP 9520 significantly reduced their tannin contents (Table III). This agrees with the observations of Mitaru et al (1983) and Teeter et al (1986). The tannin content of the sprouted samples of NK 300 and S-9190 was also reduced, due to chemical breakdown in the grain during sprouting (Table III). These observations support the germination results of Reichert et al (1980) and Chavan et al (1981). Supplementation of cultivars NK 300, S-9190, and BRY 936 with 0.5% $NaHCO_3$ also lowered their tannin contents. This is in agreement with the studies of Muindi and Thomke (1981) and Muindi et al (1981).

No significant differences ($P < 0.01$) were observed in body weights of chickens fed diets containing normal sorghum cultivars DD 50T, EXP 9520, or corn in Experiment 1 (Table IV). However, normal cultivar A 28+ and tannin-containing cultivar NK 300 significantly depressed growth of chickens. The growth of chickens was significantly improved if cultivar NK 300 was sprouted and was further improved if the diet containing unsprouted NK 300 was supplemented with 0.5% $NaHCO_3$. Feed conversion ratios (feed divided by gain) for the control diet and for diets containing either the normal sorghum cultivars DD 50T and EXP 9520 or the tannin-containing cultivar NK 300 supplemented with $NaHCO_3$ were not significantly different and were superior to those for the diet containing sprouted or nonsprouted tannin-containing cultivar NK 300. $NaHCO_3$ may improve electrolyte balance in the diet, creating favorable conditions for an improvement in feed efficiency without influencing AME and ANR.

TABLE I
Composition (g/kg) of the Diets for Experiment 1

	Diet				
Ingredient	Control	NK 300	EX 9520	DD 50T	A28+
Maize (corn)	520.0	...	...	...	...
Sorghum cultivar[a,b]					
NK 300	...	530.0	...	...	...
EXP 9520	...	...	535.0	...	...
DD 50T	...	...	...	540.0	...
A28+	...	...	...	...	545.0
Soybean meal[c]	390.0	380.0	375.0	370.0	365.0
Supplement[d]	90.0	90.0	90.0	90.0	90.0
Total[e]	1,000.0	1,000.0	1,000.0	1,000.0	1,000.0

[a] NK 300 = Northrup King NK 300, EXP 9520 = O'Gold EXP 95206, DD 50T = De Kalb DD 50T; A28+ = De Kalb A 28+.
[b] $NaHCO_3$, when added, replaced 5 g of cereal.
[c] Crude protein = 48%.
[d] Supplement supplied (g/kg of diet): DL-methionine, 4.5; $CaCO_3$, 10; $CaHPO_4 \cdot 2H_2O$, 28.5; soybean oil, 17.4; KCl, 2.97; KH_2PO_4, 4.95; $MSO_4 \cdot 7H_2O$, 3.97; NaCl, 5.5; $MnSO_4 \cdot H_2O$, 0.297; $CuSO_4 \cdot 5H_2O$, 0.097; ZnO, 0.12; $Co(C_2H_3O_2) \cdot 4H_2O$, 0.02; $Na_2MoO_4 \cdot 2H_2O$, 0.009; KIO_3, 0.009; $Na_2SeO_3 \cdot 5H_2O$, 0.00066; $FeSO_4 \cdot 7H_2O$, 0.664; vitamin mix, 10. The vitamin mix contained vitamin A, 4,000 IU; vitamin D-3, 500 ICU; vitamin E, 40 IU; and the following (in milligrams): biotin, 0.4; calcium pantothenate, 30; choline chloride, 2,400; folic acid, 5; menadione, 10; niacin, 120; pyridoxin HCl, 10; riboflavin, 10; thiamin HCl, 10; vitamin B-12, 0.01; butylated hydroxy toluene, 100.
[e] Calculated metabolizable energy, about 2,900 kcal/kg; crude protein, 23%; lysine, 1.3%; methionine + cystine, 1.1%; Ca, 1.2%; and available P, 0.7%.

TABLE II
Composition[a] (g/kg) of the Diets for Experiment 2

	Ingredient				
Diet	Cereal	Soybean Meal	Premix[b]	$NaHCO_3$	Malt
Control (corn)	515.0	395.0	90.0	...	...
Sorghum cultivar[c]					
S-9190	545.0	365.0	90.0	...	...
+ 0.25% $NaHCO_3$	542.0[d]	365.0	90.0	2.5	...
+ 0.5% $NaHCO_3$	539.0[d]	366.0	90.0	5.0	...
+ 0.75% $NaHCO_3$	534.0[d]	367.0	90.0	7.5	...
+ 5% malt[e]	495.0	365.0	90.0	...	50.0
+ 10% malt	445.0	365.0	90.0	...	100.0
Sprouted	560.0	350.0	90.0	...	...
S-6383	555.0	355.0	90.0	...	...
+ 5% malt[e]	505.0	355.0	90.0	...	50.0
+ 10% malt	455.0	355.0	90.0	...	100.0
BRY 936	535.0	375.0	90.0	...	...
+ 0.25% $NaHCO_3$	531.0[d]	376.0	90.0	2.5	...
+ 0.5% $NaHCO_3$	527.0[d]	377.0	90.0	5.0	...
+ 0.75% $NaHCO_3$	524.0[d]	377.0	90.0	7.5	...

[a] Calculated metabolizable energy, about 2,900 kcal/kg; crude protein, 23%; lysine, 1.3%; methionine + cystine, 1.1%; Ca, 1.2%; available P, 0.7%.
[b] Composition given in Table I.
[c] S-9190 = Savanna 5-91906; S-6383 = Savanna X3174-63836.
[d] Weight adjusted to 1,000 g with cellulose.
[e] Barley malt contained 4.4% moisture and 12.02% crude protein.

The data indicate that the antinutrient factor, tannin, present in cultivar NK 300 is rendered innocuous by merely supplementing the feed with $NaHCO_3$, confirming the earlier observations of Muindi and Thomke (1981) and Muindi et al (1981), who used Magadi soda solutions.

Sprouting of the tannin-containing cultivar NK 300 significantly increased its AME value and decreased ANR and feed efficiency of the diet. The diet containing normal cultivar A 28+ had the lowest digestibility, as is evident from the significantly lower AME value relative to that of the control diet or the diets containing other cultivars of sorghum. The ANR value was significantly lower for the diet containing cultivar A 28+ than for diets containing other sorghum cultivars, which were still lower than the ANR for the control diet. The poor performance of chickens on cultivar A 28+ is consistent with the poor performance of *Tribolium* larvae (Banda-Nyirenda et al 1987).

In Experiment 2, body weights of chickens fed diets containing sorghum cultivars S-9190, S-6383, and BRY 936, which contained tannins, were significantly lower than those of chickens fed the control diet containing corn (Table V). The growth was not improved by the sprouting of cultivar S-9190. This was contrary to the observation with cultivar NK 300, which was improved by sprouting in Experiment 1 (Table IV). This may be explained by the fact that crude protein had increased from 11.6 to 12.5% for NK 300 but decreased from 11.8 to 9.9% for S-9190 (Table III) on sprouting. AME, ANR, and feed efficiency were not improved by sprouting of S-9190 (Table V). Diets containing cultivars S-9190 or S-6383 supplemented with malt still did not support as good a growth as did the control diet. However, supplementation of the diets based on tannin-containing sorghum cultivars S-9190 or BRY 936 with 0.25% $NaHCO_3$ resulted in significantly better growth of chickens than that from the control diet. An increase in ANR but not in AME was observed for S-9190, which may improve the growth of birds. However, it is hard to explain the improvement of BRY 936 by 0.25% $NaHCO_3$ on the basis of ANR or AME alone. Increases in dietary $NaHCO_3$ to 0.5 and to 0.75% caused a significant depression in body weights. A possible explanation for the depression in body weight is that

TABLE III
Proximate Composition[a] of Various Cultivars of Sorghums With and Without Various Treatments

Cultivar[b]	DM	CP	EE	Ash	Sugar	ACHO	IDR	Tannin[d]
NK 300	91.4	11.6	3.6	1.76	1.26	72.3	12.7	1.15
	0.23	*0.15*	*0.06*	*0.04*	*0.06*	*0.90*	*0.35*	*0.04*
Sprouted	91.1	12.3	2.7	1.49	4.60	73.4	14.9	0.82
	0.27	*0.15*	*0.03*	*0.02*	*0.13*	*1.17*	*0.07*	*0.02*
+0.5% $NaHCO_3$	...	...	...	...	...	...	...	0.73
S-9190	91.4	11.8	4.3	1.88	2.52	73.7	16.5	1.04
	0.06	*0.26*	*0.03*	*0.03*	*0.02*	*1.60*	*0.10*	*0.06*
Sprouted	90.0	9.9	1.8	1.96	4.80	73.5	14.9	0.87
	0.03	*0.15*	*0.03*	*0.02*	*0.06*	*0.81*	*0.23*	*0.02*
Ensilaged	71.0	14.8	2.4	2.18	2.80	73.2	17.6	0.22
	0.35	*0.12*	*0.26*	*0.01*	*0.06*	*0.07*	*0.70*	*0.02*
+0.5% $NaHCO_3$	...	...	...	...	...	...	...	0.87
BRY 936	92.6	10.6	3.0	1.92	2.77	71.7	15.5	1.00
	0.06	*0.29*	*0.06*	*0.03*	*0.01*	*1.08*	*0.09*	*0.11*
	...	...	...	...	...	...	...	0.74
S-6383	92.8	12.2	3.8	1.45	1.31	58.2	12.7	0.80
	0.22	*0.06*	*0.00*	*0.31*	*0.04*	*0.82*	*0.12*	*0.04*
Ensilaged	71.6	15.8	3.8	4.16	5.10	75.2	18.2	0.36
	0.09	*0.27*	*0.09*	*0.08*	*0.06*	*1.39*	*0.29*	*0.01*
DD 50T	89.6	12.2	5.3	1.91	1.17	69.0	9.9	0.28
	0.27	*0.22*	*0.32*	*0.02*	*0.08*	*0.43*	*0.45*	*0.01*
A28+	91.9	12.0	2.9	2.82	1.12	73.4	15.3	0.25
	0.15	*0.12*	*0.12*	*0.04*	*0.01*	*0.55*	*0.41*	*0.01*
EXP 9520	91.0	10.1	4.1	2.07	1.14	71.1	9.76	0.27
	0.76	*0.32*	*0.03*	*0.02*	*0.05*	*0.9*	*0.8*	*0.01*
NK 1580	90.1	11.6	3.9	1.66	2.64	84.7	12.3	0.29
	1.10	*0.35*	*0.06*	*0.01*	*0.02*	*0.82*	*0.35*	*0.03*
Ensilaged	77.3	12.2	2.2	1.82	2.77	80.7	10.4	0.09
	0.13	*0.06*	*0.35*	*0.02*	*0.07*	*0.56*	*0.58*	*0.02*
LSD ($P < 0.01$)	1.5	0.8	0.6	0.15	0.23	6.1	1.4	0.13

[a] Mean ± standard error in italics of three replicates, dry matter basis.
[b] NK 300 = Northrup King NK 300; NK 1580 = Northrop King NK 1580; S-9190 = Savanna 5-91906; DD 50T = De Kalb DD 50T; A28+ = De Kalb A 28+; S-6383 = Savanna X3174-63836; EXP = O'Gold EXP 95206.
[c] DM = dry matter, CP = crude protein, EE = ether extract, ACHO = available carbohydrate (= percent starch + percent free sugar), IDR = indigestible residue.
[d] Tannin as catechin equivalent.

the electrolyte balance was upset due to an increase in Na ions, since the diet already contained 0.55% NaCl. A level of 0.25% dietary $NaHCO_3$ appears to be optimal for improving these tannin-containing sorghum cultivars. Improvement in body weights are thus not a result of improvement of the AME or ANR of the diets, but of a reduction in the antinutrient effects of tannins.

An improvement in protein digestibility and a decrease in the tannin content of high-moisture sorghum were reported by Mitaru et al (1983) and Teeter et al (1986) respectively. Both of these observations were confirmed in our studies for cultivars S-9190, S-6383, and NK 1580 (Table VI), but a lack of improvement in body weights of chickens fed ensilaged tannin-containing sorghum was unexpected, as the ANR and AME of the diets were significantly improved. However, the improvement in growth of chickens was not dependent on these two parameters.

An improvement in the nutritive value of tannin-containing sorghum by germination has been observed by Chavan et al (1981) and Reichert et al (1980), and our results on cultivar NK 300 confirm these findings. However, supplementation of the diets containing high-tannin cultivar NK 300 with $NaHCO_3$ improved the growth of chickens significantly better than did sprouting. Any treatment that involves ensilage, soaking, or sprouting of sorghums is not very practical because the treated grain must be dried before being fed to chickens and other animals. This implies an additional expenditure for fuel, which is costly. The most practical method is to supplement the diet with some relatively inexpensive and easily available chemical that belongs to the category GRAS (generally recognized as safe). Phosphoric acid and calcium phosphate are acceptable but are more expensive than $NaHCO_3$. Our results confirm the observations of Muindi and Thomke (1981) and of Muindi et al (1981) that antinutritive properties of tannin-containing sorghums are overcome by treatment with $NaHCO_3$. However, Muindi and coworkers (1981) had soaked sorghum for three days in Magadi soda. Our procedure is much simpler because it involves only the supplementation of the diets with $NaHCO_3$.

We conclude that tannin-containing sorghums depress the growth of chickens and have an inconsistent effect on AME and ANR. A dietary level of 0.25% $NaHCO_3$ overcame the antinutrient effects of tannin-containing sorghums to produce optimal growth in chickens. Sprouting of tannin-containing NK 300 was less effective in improving its feeding value than was the addition of $NaHCO_3$. Ensilaging of tannin-containing cultivars S-9190 and S-6383 and normal variety NK 1580 did not improve their feeding value. Supplementation of diets based on tannin-containing sorghums with 0.25% $NaHCO_3$ is a practical method for improving their feeding value.

TABLE IV
Nutritional Value of Some Varieties of Sorghums for Growing Chickens (Experiment 1)

Cultivar[a]	Body Weight (g)	F/G[b]	Dietary AME[c] (kcal/kg)	ANR[d] (%)
Corn (control)	530	1.66	3,487	73.1
Tannin-containing				
NK 300	482	1.92	3,458	71.6
Sprouted	516	2.02	3,605	70.8
+ 0.5% $NaHCO_3$	562	2.02	3,427	71.5
Normal				
DD 50T	527	1.67	3,352	70.8
EXP 9520	517	1.67	3,405	71.5
A 28+	474	1.88	3,086	65.1
Mean	515	1.80	3,389	70.0
± SD	*32*	*0.2*	*15*	*0.3*
F ratio	55.2	61.5	1,735	11.6
LSD ($P < 0.01$)	16	0.28	42	6.8

[a] NK 300 = Northrup King NK 300, DD 50T = De Kalb DD 50T, EXP 9520 = O'Gold EXP 95206, A 28+ = De Kalb A 28+.
[b] Feed intake divided by gain in body weight.
[c] Apparent metabolizable energy.
[d] Apparent nitrogen retention.

TABLE V
Effect of Barley Malt, Sprouting, and $NaHCO_3$ Supplementation of Sorghums on Growth of Chickens (Experiment 2)

Cultivar[a] and Treatment	Body Weight (g)	F/G[b]	Dietary AME[c] (kcal/kg)	ANR[d] (%)
Corn (control)	624	1.99	3,450	65.4
Sorghum, tannin-containing				
S-9190	583	2.01	3,318	63.4
Sprouted	586	2.11	3,273	66.0
+ 5% malt	599	2.01	3,428	68.4
+ 10% malt	566	2.03	3,214	62.0
+ $NaHCO_3$ 0.25%	616	1.91	3,443	72.1
+ $NaHCO_3$, 0.5%	582	2.00	3,362	71.0
+ $NaHCO_3$, 0.75%	555	2.24	3,455	70.1
S-6383	583	2.02	3,312	67.0
+ 5% malt	586	1.96	3,156	66.0
+ 10% malt	591	2.10	3,158	60.8
BRY 936	580	2.00	3,377	66.8
+ $NaHCO_3$, 0.25%	639	1.95	3,095	65.5
+ $NaHCO_3$, 0.5%	605	2.03	3,157	68.5
+ $NaHCO_3$, 0.75%	569	1.97	3,133	73.1
Mean	589	2.02	3,278	67.2
± SD	*22*	*0.1*	*128*	*4.0*
F ratio	31	3.1	88.8	17.3
LSD ($P < 0.01$)	13	0.33	52	3.4

[a] S-9190 = Savanna 5-91906; S-6383 = Savanna X3174-63836.
[b] Feed intake divided by gain in body weight.
[c] Apparent meabolizable energy.
[d] Apparent nitrogen retention.

TABLE VI
Effect of Feeding Ensilage of a Low-Tannin and Two High-Tannin Sorghums on Growing Chickens (Experiment 3)

Cultivar[a] Treatment	Body Weight (g)	Feed/Gain	AME[b] (kcal/kg)	ANR[c] (%)
Corn (control)	575	1.62	3476	68.9
Normal-tannin cultivar NK 1580				
Untreated	566	1.81	3321	61.5
Ensilaged	565	1.74	3536	67.0
Tannin-containing cultivars				
S-9190 Untreated	571	1.74	3394	65.8
Ensilaged	559	1.81	3400	73.9
S-6383 Untreated	582	1.69	3139	65.9
Ensilaged	577	1.69	3520	75.3
Mean	572	1.74	3392	68.3
± SD	*32*	*0.04*	*30*	*4.0*
F ratio	0.8	5	270	16.1
LSD ($P < 0.01$)		0.19	33	5.1

[a] S-9190 = Savanna 5-91906, S-6383 = Savanna X3174-63836. NK 1580 = Northrup King NK 1580, which had 0.26% tannin as catechin equivalent.
[b] Apparent metabolizable energy.
[c] Apparent nitrogen retention.

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