Utilization of Reconstituted High-tannin Sorghum in the Diets of Broiler Chickens

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ABSTRACT : The present experiment was conducted to assess the effect of reconstitution (R) on utilization of red sorghum (S) in diets of broiler chickens. Day-old broiler chicks (n=360) were randomly divided into 36 groups of 10 chicks each, and 9 dietary treatments were allotted to 4 groups (replicates) in a completely randomized design. Out of the 9 treatments, one was corn-soy based control (D_1). The rest of the treatments were diets consisting of four levels (25, 50, 75 and 100% part of corn) of raw red sorghum (S25-S100) or four levels of reconstituted red sorghum (RS25-RS100). The tannin content reduced from 2.3% to 1.6% after reconstitution of red sorghum. Body weight gain reduced significantly ($p<0.01$) in diets containing unprocessed red sorghum beyond 33% in diet or reconstituted red sorghum at any level. However, during finishing growth phase the birds receiving either processed or unprocessed sorghum (barring S75) had statistically similar gains in body weight. During over all growth phase (0-6 wk), live weight gains in all the dietary treatments did not differ statistically. Feed intake during 0-6 wk was significantly higher ($p<0.05$) in diets containing sole red sorghum than corn-soy based control diets Feed conversion ratio during 0-3 wk period in control and unprocessed red-sorghum diets were similar but statistically poorer ($p<0.01$) FCR emanated from reconstituted groups, while during 3-6 wk of age FCR was poorer ($p<0.05$) in diets containing 75% red sorghum, either processed or unprocessed. FCR, in overall growth phases, in control diet was statistically similar to the groups fed diets containing up to 33% unprocessed or 16% reconstituted group. The carcass traits and yield of organs did not differ ($p>0.05$) due to the various levels of red-sorghum. It was concluded that though the tannin content was reduced by 30% by the reconstitution process, but this did not give any additional advantage in broiler performance. More over, red-sorghum can be used effectively up to 33% in diet replacing 50% of corn after proper adjustment of proteins, energy and amino acids. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 4 : 538-544)***

Key Words : Red Sorghum, Reconstitution, Broiler, Tannin, Growth Performance, Carcass Traits

INTRODUCTION

Sorghum is one of the major cereals grown in South Asian countries under rain-fed farming system and available at cheaper rates in many parts of the continent. Therefore, it forms a part of cost effective feed formulae for poultry under rain-fed farming system. Though several experiments have been conducted in past to assess its effective level of incorporation but speculations regarding its effective level still exists mainly due to variable concentration of tannins. The nutritive value of low tannin sorghum is comparable to that of corn for poultry feeding (Nagra et al., 1990; Reyes et al., 2001; Rama Rao et al., 2002; Sannamani, 2002; Tyagi et al., 2003). However, the major limitation in the use of red sorghum (high tannin sorghum) is the presence of anti-nutritive compound, tannin at high concentration. The production of high tannin sorghum (HTS) is being continued in some parts as it is bird resistant and has higher productivity. It is also available at cheaper rates. However, reduced feed intake, weight gain and feed conversion efficiency limit its incorporation in poultry diet (Ibrahim et al., 1988; Shamsaie and Salini, 1992; Reyes et al., 2000; Sannamani, 2002). Kim et al. (2000) observed increased efficiency with processed sorghum and processing provided an immediate solution to the problem of reduced utilization of sorghum. The effects of the enzyme (exogenous phytase and xylanase) in lysine-deficient diets containing wheat and sorghum were more pronounced than those of the individual feed enzymes (Selle et al., 2003a). The finishing pigs, fed diets with a sorghum-specific enzyme system, showed positive trends for improved growth performance (Park et al., 2003). Reduced nutrient specifications in terms of protein, amino acids, energy density and phosphorus (P) of standard diets had a negative impact on growth rates and feed efficiency, and phytase supplementation on sorghum or wheat-sorghum based diet had a positive influence on growth performance and protein efficiency ratios (Selle et al., 2003b).

Reconstitution is a process of conditioning the grains to raise its moisture content to 25-30% and storing in anaerobic condition for approximately 21 days. It results in disruption of the protein matrix of the grain and release of enzymes (amylase and proteases) also results in removal or inactivation of toxic substances. Fry et al. (1958) reported that reconstitution of feedstuffs result in breakdown of cellular carbohydrates and/or alteration in the structure of intracellular starch. It has been reported in the literature that

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Table 1. Ingredient (%) and chemical composition of broiler diets

Ingredient	Starter diet					Finisher diet				
	0%	25%	50%	75%	100%	0%	25%	50%	75%	100%
Corn	55.75	47.30	34.12	16.50	0.00	56.86	48.50	38.83	21.22	0.00
De-oiled rice bran	13.40	5.00	0.00	0.00	0.00	16.00	8.00	0.00	0.00	0.00
Soybean meal	27.70	28.7	29.00	29.00	29.00	24.00	24.50	25.00	25.00	25.00
Red sorghum	0.00	15.84	33.00	48.80	63.50	0.00	15.85	33.00	48.80	67.60
Oil	0.00	0.00	0.70	2.5	4.30	0.00	0.00	0.00	1.80	4.20
Constants *	3.17	3.17	3.17	3.17	3.17	3.17	3.17	3.17	3.17	3.17
Methionine	0.08	0.09	0.10	0.12	0.14	0.04	0.05	0.07	0.08	0.10
Nutrient composition										
ME (kcal/kg)***	2,803.00	2,808.00	2,801.00	2,796.00	2,798.00	2,802.00	2,806.00	2,801.00	2,796.00	2,804.00
CP (%)**	21.00	20.80	20.60	20.30	20.00	19.70	19.50	19.20	18.80	18.90
Lysine (%)***	1.14	1.14	1.14	1.14	1.14	1.04	1.03	1.02	1.03	1.03
Methionine (%)***	0.45	0.45	0.44	0.45	0.45	0.40	0.39	0.40	0.39	0.40
Threonine, (%)***	0.86	0.85	0.84	0.83	0.82	0.80	0.79	0.78	0.77	0.82
Calcium (%)**	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.00
Avail. P (%)***	0.44	0.43	0.42	0.42	0.41	0.44	0.43	0.42	0.41	0.41
Cost (US $/kg)	0.16	0.16	0.16	0.17	0.17	0.15	0.15	0.15	0.15	0.16

* Constant: 3.17% includes lime stone 1.3%, DCP 1.3%, Trace mineral premix 0.1%, Vit. Premix 0.1%, B-complex 0.02%, Choline 0.05% and Salt 0.3%.
Trace mineral premix supplied supplied mg/kg diet: Mg, 300; Mn, 55; I, 0.4; Fe, 56; Zn, 30; Cu, 4.
The vitamin premix supplied per kg diet: Vit. A, 8,250 IU; Vit. D_3, 1,200 ICU; Vit. K, 1 mg; Vit. E, 40 IU; Vit. B_1, 2 mg; Vit. B_2 4 mg; Vit. B_{12}, 10 mcg; niacin, 60 mg; pantothenic acid, 10 mg; choline, 500 mg.
Analysed values, * Calculated values.

reconstitution of HTS sorghums improves the daily body weight gains of broiler chickens (Mitaru et al., 1983). Rolling and grinding of reconstituted grains results in complete breakdown of the endosperm of the reconstituted grain (Sullins and Rooney, 1974). However, reconstituted grains being moist, may favour mould growth when added in mixed feed. The purpose of this study was, therefore, to investigate the possibility of replacing corn partially or completely in diets of broiler chickens, by red sorghum (high in tannin) as such, or reconstituted after sun-drying.

MATERIALS AND METHODS

Reconstitution of Red Sorghum

Red sorghum grains were reconstituted by adding water to whole grain to raise the moisture level to about 30% (DM 70%), followed by storage in sealed plastic buckets for 21 days at room temperature (25°C). Subsequently, the grains were sun-dried by spreading it on plastic sheet until moisture content reached to 10% level to avoid mould growth, if any.

Selection of chicks and experimental design

Three hundred and sixty (360) healthy unsexed, day old multi-coloured broiler chicks were selected, wing banded, weighed and randomly distributed into 36 groups of 10 each depending on their body weight after discarding the heavier and lighter ones. The experiment was conducted following completely randomized design having 9 dietary treatments with 4 replicates in each.

Housing and management

The experimental chicks were housed group wise in electrically heated battery brooder cages up to first three weeks of age and subsequently transferred to battery cages fitted with separate feeders, waterers and dropping trays. All the chicks were provided with 24 h lighting schedule.

Experimental diets

Nine dietary treatments were formulated: one was corn-soy-based control diet (D1). The rest of the treatments were diets consisting of four levels (25, 50, 75 and 100% replacement of corn) of raw red sorghum (S25-S100) and four levels (25, 50, 75 and 100% of corn) of reconstituted red sorghum (RS25-RS100). Diets were made isocaloric (2,800 ME kcal/kg) and with similar lysine (1.14%) and methionine (0.45%) levels in the starter phase and with 2,800 ME kcal/kg, lysine (1.0%) and methionine (0.4%) in the finisher phase (Table 1). The ME and CP levels were according to breed type as envisaged in our earlier study (Pramod et al., 2003). The ingredients were procured one time and analyzed for proximate principles viz., crude protein, ether extract, crude fibre, total ash and phosphorus (AOAC, 1990), and calcium (Talapatra et al., 1940). In addition, red sorghum, as such and reconstituted was analyzed for tannin contents (Sastry et al., 1999).

Each dietary treatment was offered to 40 broiler chicks in four replicate of 10 chicks up to 6 weeks of age. They were supplied fresh drinking water daily *ad libitum*. The body weight of individual birds was recorded at weekly intervals. The feed intake of chicks was recorded at weekly intervals from 0-6 week of age by offering weighed

Table 2. Body weight gain, feed intake and feed utilization efficiency of broiler chicks

Diets	Treatments	Body wt. gain (g/b)			Feed intake (g/b)			FCR (feed/gain)		
		0-3 wk	3-6 wk	0-6 wk	0-3 wk	3-6 wk	0-6 wk	0-3 wk	3-6 wk	0-6 wk
D1	Control	390^{a}	745.0^{abc}	1,120	788^{a}	$1,666^{cd}$	$2,454^{bc}$	2.03^{d}	2.24^{c}	2.17^{d}
S25	RS_{25}	386^{a}	719.4^{c}	1,105	790^{a}	$1,622^{d}$	$2,411^{c}$	2.05^{d}	2.25^{c}	2.18^{d}
S50	RS_{50}	372^{ab}	814.6^{abc}	1,199	787^{a}	$1,840^{bc}$	$2,627^{abc}$	2.12^{cd}	2.29^{bc}	2.24^{cd}
S75	RS_{75}	330^{cd}	732.6^{abc}	1,077	736^{bc}	$1,880^{ab}$	$2,587^{abc}$	2.10^{cd}	2.54^{ab}	2.40^{abc}
S100	RS_{100}	343^{bc}	845.4^{a}	1,197	707^{ab}	$1,992^{ab}$	$2,727^{a}$	2.14^{cd}	2.35^{abc}	2.29^{bcd}
RS25	$RS_{25}R$	305^{de}	799.5^{abc}	1,106	685^{c}	$1,895^{ab}$	$2,549^{abc}$	2.26^{bc}	2.36^{abc}	2.31^{abcd}
RS50	$RS_{50}R$	286^{e}	834.2^{a}	1,146	629^{bc}	$2,051^{ab}$	$2,680^{ab}$	2.22^{bc}	2.43^{abc}	2.37^{abc}
RS75	$RS_{75}R$	316^{de}	724.0^{bc}	1,048	712^{b}	$1,866^{abc}$	$2,578^{abc}$	2.31^{ab}	2.57^{a}	2.49^{a}
RS100	$RS_{100}R$	247^{e}	835.4^{a}	1,133	716^{b}	$2,060^{a}$	$2,776^{a}$	2.43^{a}	2.48^{abc}	2.47^{ab}
SEM	-	7.18	12.74	12.74	9.39	23.310	2,2.02	0.025	0.025	0.019
Significance	-	p<0.01	p<0.05	NS	p<0.01	p<0.05	p<0.01	p<0.01	p<0.05	p<0.01

$^{a, b, c, d}$ Means bearing different superscript in a column differ significantly (p<0.01), (p<0.05).

25, 50, 75, 100: per cent replacement level of maize with red sorghum.

RS: Red sorghum. R: Reconstituted. NS: Non-significant.

quantity of feed and weighing their residues. The feed conversion ratio was calculated on the basis of unit feed consumed to unit body weight gain.

The energy (metabolizable energy intake in kcal:live weight gain in g) and protein efficiency (crude protein intake in g:gain in g) was calculated on the basis of unit energy or protein consumed to unit body weight gain for each replicate separately. Mortality was also taken into consideration.

Statistical analysis

Data were subjected to one-way analysis of variance in a completely randomized design as per methods of Snedecor and Cochran (1989). The means in the different treatment were tested for statistical significance using Duncan's multiple range test (DMRT) as described by Duncan (1955).

RESULT AND DISCUSSION

On chemical analysis, each kg of red sorghum DM was found to contain 102.3 g CP; 37.6 g EE; 48.0 g CF, 32.5 g total ash and 23.0 g tannic acid equivalent tannin, whereas, reconstituted red sorghum had almost similar composition except for lower tannin content (16.0 g tannic acid equivalent), which is about 30% lower. In earlier study also, high-moisture storage of high-tannin sorghum decreased their extractable tannin content (Mitaru et al., 1983).

Body weight gain, feed intake and feed efficiency

During starter phase (0-3 wk), chicks fed on corn based control diet recorded highest body weight gain (Table 2). In case of raw red sorghum groups, higher the red sorghum level, the weight gain was lower (p<0.01). However, statistically similar body weight gain to that of control was observed in diets containing 16 or 33% as such red sorghum replacing corn at the rate of 25 and 50%, respectively. In birds fed on reconstituted red sorghum (0-3 wk), lower (p<0.01) weight gain observed at all levels in comparison to either control or unprocessed sorghum fed groups. Though the body weight gain of chicks in all the test diet group were lower during the first 3 weeks of age but was overcome in most of the groups during finisher phase wherein most of the groups recorded similar or higher weight gain than those of control fed groups. During overall period (0-6 wk), body weight gain in control group was statistically similar (p>0.05) to the chicks in all the dietary treatments, still the live weight gain was higher in both the 100% replacement levels of corn by sorghum i.e. as such and reconstituted. In case of reconstituted red sorghum fed birds, body weight gain was lower (p<0.01) in RS75 than in RS50 or RS100 but was similar to RS25.

During 0-3 wk of age, feed intake (Table 2) showed a decreasing trend as the level of unprocessed red sorghum increased in diets (S25 to S100). However, feed intake did not differ significantly (p>0.05) up to 50% replacement level. In reconstituted groups, however, feed intake was more (p<0.01) at higher levels of sorghum in comparison to its lower levels. After 3 wk of age, there was an increase (p<0.01) in the feed intake as the level of red sorghum increased in the diet. During 0-6 wk, in case of raw red sorghum group, significantly (p<0.01) higher intake was observed at higher inclusion levels in comparison to chicks fed 25% replacement of corn. In case of reconstituted red sorghum group, higher (p<0.01) intake was observed in 100% replacement level in comparison to 25% replacement levels. In overall trend, feed intake increased with the inclusion levels of red sorghum in diet, either as such or on reconstitution.

During 0-3 week of age, the FCR (Table 2) of the birds fed raw red sorghum diet was statistically similar (p>0.05) to those fed on control diet. All the reconstituted red sorghum based diets were statistically similar, but RS50 and RS75 were significantly (p<0.01) poorer than control diet.

Table 3. Energy and protein efficiency of broiler as influenced by dietary treatments

Diets	Treatments	ME efficiency			CP efficiency		
		0-3 wk	3-6 wk	0-6 wk	0-3 wk	3-6 wk	0-6 wk
D1	Control	5.41^{e}	6.29^{c}	6.09^{c}	0.428^{c}	0.471^{c}	0.456^{b}
S25	RS25	5.75^{e}	6.31^{c}	6.11^{c}	0.429^{c}	0.473^{c}	0.457^{b}
S50	RS50	5.94^{cde}	6.44^{abc}	6.28^{abc}	0.438^{bc}	0.482^{bc}	0.468^{cd}
S75	RS75	5.88^{de}	7.13^{ab}	6.72^{ab}	0.428^{c}	0.535^{ab}	0.500^{abc}
S100	RS100	6.01^{cde}	6.39^{bc}	6.28^{bc}	0.431^{c}	0.491^{abc}	0.474^{bcd}
RS25	RS25 R	6.35^{bc}	6.63^{abc}	6.55^{abc}	0.473^{a}	0.497^{abc}	0.490^{abcd}
RS50	RS50 R	6.23^{bcd}	6.81^{abc}	6.65^{ab}	0.459^{ab}	0.510^{abc}	0.496^{abc}
RS75	RS75 R	6.47^{ab}	7.19^{a}	6.97^{a}	0.470^{a}	0.539^{a}	0.519^{a}
RS100	RS100 R	6.82^{a}	6.74^{abc}	6.75^{ab}	0.488^{a}	0.519^{abc}	0.510^{ab}
SEM		0.071	0.085	0.067	0.005	0.006	0.005
Significance		$p<0.01$	$p<0.05$	$p<0.01$	$p<0.01$	$p<0.05$	$p<0.01$

[a, b, c, d] Means bearing different superscript in a column differ significantly ($p<0.01$), ($p<0.05$).

25. 50. 75, 100: per cent replacement level of maize with red sorghum.

RS: Red sorghum. R: Reconstituted. NS: Non-significant.

During 3-6 week of age, a different trend was observed as most of the dietary groups had similar FCR, though S75 and RS75 had poorer ($p<0.05$) FCR in comparison to D1 (corn based control) or S25. The data suggested that as the age advanced chicks were able to better utilize the red sorghum. During 0-6 week of age, best FCR was emanated from groups fed on control diet (2.17), which was statistically similar to the dietary treatments S25 (corn 75%+raw sorghum 25%), S50 (corn 50%+raw sorghum 50%), S100 (raw sorghum 100%), and RS25 (corn 75%+reconstituted sorghum 25%) i. e. the FCR emerged in control diet was statistically similar to the groups fed diets containing up to 33% unprocessed or 16% reconstituted sorghum group.

Contradictory results are available on the growth performance in chicks fed high tannin sorghum. Weight gain of chicks was significantly less with resistant (2.66% tannin) than with non-resistant sorghum (Armstrong et al., 1974). The reduction in body weight gain was also reported by several other workers (Douglas et al., 1990; Treveno et al., 1992; Elkin et al., 1996; Sannamani, 2002). In the study of Ambula et al. (2001), it was found that high tannin sorghum (5% catechin equivalent) could be used to substitute for white corn up to 100% in broiler chick diets. In another experiment (Nyachoti et al., 1996), HTS-fed chickens had higher feed intake and gained more weight during 1-9 days than their corn-fed counterparts, although overall performance in terms of live weight gain and feed conversion efficiency was similar. Results of the study of Jacob et al. (1996) suggested that high tannin sorghum could be substituted for white corn in broiler starter diets with no significant adverse effects on growth or feed efficiency.

Chickens fed on diets containing the reconstituted sorghums had greater daily body weight gains of 23 to 83 g (Mitaru et al., 1983). In the study of Pour-Reza and Edriss (1997), it was observed that an inclusion of tannin 2.6 g/kg in broiler diets was tolerated but above this level performance decreased. Addition of tallow did not affect broiler performance except in the groups fed diet with the highest tannin content, where weight gain and feed efficiency improved. In the present experiment, the tannin percent in diets, S25 to S100 was although 0.36, 0.76, 1.12 and 1.55% but did not exert any appreciable influence on live weight gain even at higher inclusion i.e. 75 and 100% level of red sorghum in diet. It might be due to the supplementation of fat up to even 4% in 100% replacement diet as well as balancing of amino acids especially, lysine and methionine in all the diets. Reconstitution of red sorghum was not found to be beneficial in the present experiment even though the level of tannin in red sorghum decreased from 2.30 to 1.60%.

Earlier researchers (Chang and Fullar, 1964; Darnron et al., 1968; Nyachoti and Atkinson, 1995) also reported higher consumption for chicks fed on high tannin sorghum as compared to corn based. Sannamani (2002) observed that chicks fed red sorghum had statistically similar feed intake as that of corn based control diet. On the contrary, Shamsaie and Salimi (1992) reported a decrease in feed intake on high tannin containing sorghum-based diets. Results on the higher feed intake obtained in birds fed 100% reconstituted red sorghum based diet are similar to finding of Mitaru et al. (1983) who reported that the reconstitution of high tannin sorghum increased feed intake probably due to decrease in the extracted tannin content. The present study also indicated that the feed intake of broiler chick increased with the graded levels of red sorghum either raw or reconstituted.

The poor FCR values for red sorghum based diets in broiler chicken were observed by Banda-Nyirenda and Vohra (1990), Douglas et al. (1991), Elkin et al. (1996) and Sannamani (2002). The decreased FCR might have been due to presence of high tannin, which reduced the utilization of energy, protein and specific amino acid (Douglas et al., 1990; Elkin et al., 1996). The reconstitution did not have any added advantage. These findings are

Table 4. Carcass characteristics (%live weight) of broilers as influenced by dietary treatments

Diets	Treatments	Feather	Blood	Eviscerated	Giblet	Heart	Liver	Gizzard	Abdominal fat
D1	Control	7.07	4.03	69.9	5.59	0.58	2.50	2.50	0.54
S25	RS25	7.60	3.94	70.12	5.70	0.58	2.54	2.57	1.01
S50	RS50	8.01	3.71	69.63	5.40	0.57	2.57	2.25	0.92
S75	RS75	8.65	3.79	68.38	5.46	0.58	2.51	2.33	1.16
S100	RS100	7.67	3.84	69.49	5.48	0.63	2.37	2.48	0.73
RS25	RS25 R	8.16	4.13	68.89	5.72	0.65	2.54	2.53	1.26
RS50	RS50 R	8.17	4.06	69.47	5.50	0.67	2.46	2.36	0.85
RS75	RS75 R	8.44	3.89	69.39	6.29	0.65	2.82	2.81	1.11
RS100	RS100 R	8.39	4.02	68.42	5.73	0.64	2.59	2.49	1.38
SEM		0.14	0.057	0.20	0.061	0.60	0.04	0.037	0.11
Significance		NS	NS	NS	NS	NS	NS	NS	NS

25. 50. 75, 100: per cent replacement level of maize with red sorghum.
RS: Red sorghum. R: Reconstituted. NS: Non-significant.

Table 5. Cut-up parts (% live weight) of broilers as influenced by dietary treatments

Diets	Treatments	Wings	Breast	Back	Neck	Drumstick	Thigh
D1	Control	8.65	15.69	12.90	5.54	10.80	10.08
S25	RS25	8.86	12.20	14.88	4.53	10.09	10.30
S50	RS50	8.74	15.51	13.69	4.50	9.97	10.31
S75	RS75	8.92	15.26	14.92	4.12	9.76	10.10
S100	RS100	9.12	14.93	14.69	4.61	9.78	10.30
RS25	RS25 R	9.12	14.89	14.45	4.43	9.54	9.99
RS50	RS50 R	8.70	15.56	14.97	4.38	9.39	10.29
RS75	RS75 R	8.93	15.16	14.44	4.29	9.21	10.04
RS100	RS100 R	8.55	15.13	14.05	4.39	9.43	9.91
SEM		0.89	0.16	0.25	0.11	0.12	0.082
Significance		NS	NS	NS	NS	NS	NS

25. 50. 75, 100: per cent replacement level of maize with red sorghum.
RS: Red sorghum, R: Reconstituted, NS: Non-significant.

contrary to findings of Reichert et al. (1980). Mitaru et al. (1983) and Teeter et al. (1986) who reported improvement in feed efficiency after reconstitution of high tannin sorghum.

Energy and protein efficiency

Among birds fed red sorghum as such, overall ME efficiency became poorer with the increased level of red sorghum in diets (Table 3). However, the efficiency of energy utilization did not differ significantly ($p<0.01$) in groups fed raw sorghum from control group. On the other hand, the birds received reconstituted sorghum consumed more energy per unit gain than in control group. During finishing phase, barring RS75 (25% corn+75% reconstituted sorghum), the broilers raised on other diets utilized energy with similar efficiency to that of control group.

The overall CP efficiency in all groups were comparable to control. however, birds fed red sorghum, as such at 75% replacement level of corn had significantly ($p<0.01$) poorer CP efficiency as compared to control (Table 3). However, in birds fed on reconstituted red sorghum (RS25, RS50, RS75 and RS100), the overall CP efficiency became poorer with increasing inclusion of reconstituted red sorghum.

The present study indicates that best efficiency for both energy and protein was obtained in corn-soybean diet. however, closer efficiency was obtained in 25% red sorghum (raw) replacement group. Several workers (Halley et al., 1986; Elkin et al., 1996; Nyachoti et al., 1996; Jacob et al., 1997) reported lower ME efficiency in high tannin sorghum based diets. In contrary, Mitaru et al. (1983) reported that reconstitution of red sorghum improved dietary metabolizable energy (0.1 to 0.3 kcal/g) for broiler chicken.

Carcass characteristics

In carcass traits, weight of vital organs and cut up parts of broiler chicken did not differ ($p>0.05$) due to dietary treatments (Tables 4 and 5). In the present study, live weight gain at 6 weeks of age did not differ statistically ($p>0.05$), which may be the reason for non-significant difference in carcass yield. The results pertaining to carcass characteristics were similar to findings of Rama Rao et al. (2002); Tyagi et al. (2003) and Sannamani (2002) who reported that feeding of sorghum in place of corn did not affect blood loss, feather loss, eviscerated yield and heart and liver weight. The cut-up parts especially the breast yield also did not differ significantly ($p>0.05$) indicating that the tannin present in diet did not exert any effect on the availability of methionine and cysteine as the breast yield is

Table 6. Feed cost (US $/kg gain or meat) of broiler production at 6 weeks of age

Diets	Treatments	Starting	Finishing	Overall	Cost of feed/kg meat (US dollar)
D1	Control	0.328^{ef}	0.345^{c}	0.339^{d}	0.433^{cd}
S25	RS25	0.323^{f}	0.337^{c}	0.332^{d}	0.422^{d}
S50	RS50	0.334^{def}	0.334^{c}	0.334^{d}	0.415^{d}
S75	RS75	0.348^{def}	0.389^{ab}	0.376^{bc}	0.474^{b}
S100	RS100	0.374^{bc}	0.385^{ab}	0.383^{b}	0.496^{bc}
RS25	RS25 R	0.356^{cd}	0.354^{bc}	0.354^{cd}	0.466^{b}
RS50	RS50 R	0.350^{cde}	0.352^{ab}	0.352^{cd}	0.477^{b}
RS75	RS75 R	0.383^{b}	0.391^{a}	0.389^{ab}	0.503^{b}
RS100	RS100 R	0.424^{a}	0.407	0.411^{a}	0.560^{a}
SEM		0.006	0.006	0.006	0.005
Significance		$p<0.01$	$p<0.05$	$p<0.01$	$p<0.01$

Means bearing different superscript in a column differ significantly ($p<0.01$), ($p<0.05$).

influenced by the methionine and cyteine levels in diet (Williams, 1997). The average weight of gizzard did not significantly differ among sorghum group. It was in agreement with the findings of Tyagi et al. (2003). In contrary, Sannamani (2002) reported significantly higher weight of gizzard in broilers fed red sorghum based diet which was attributed to lower dietary energy level on inclusion of sorghum in diet. The development of digestive tract depends upon the type and amount of feed being consumed and since the energy level of the diets and thus feed intake was similar in all the dietary treatments, the digestive tract development did not differ significantly ($p>0.05$). Widodo et al. (1996) reported that feeding of high tannin sorghum resulted in decrease in carcass weight and increased abdominal fat in broiler chickens. In the present experiment, the abdominal fat was low in all the experimental groups and did not differ statistically ($p>0.05$) due to the dietary treatments, which may be attributed to the breed characteristics and narrower calorie to protein ratio.

Economics of broiler production

The feed cost of production differed significantly ($p<0.01$) due to the dietary treatments (Table 6). The feed cost of unit gain calculated in dietary treatments S25, S50, RS25 and RS50 were statistically similar to that of control diet, but numerically the values were lesser for S25 and S50. Similar was the trend for feed cost per unit meat production. Though, red sorghum is cheaper than corn, but the cost of feed increased due to supplementation of fat and amino acids for balancing the diets, which resulted in increased feed cost of production.

CONCLUSION

It was concluded that though the tannin content was reduced by 30% by reconstitution process but did not give any additional advantage on broiler performance. More over, red-sorghum can be used effectively up to 33% in diet replacing 50% of corn after proper adjustment of proteins, energy and limiting amino acids.

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