# alternative feed resource for livestock

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## I Introduction

Livestock production in the developing countries has been one of the most important economic and social activities of human culture. Among the livestock, ruminants have served and will continue to serve a valuable role in sustainable agricultural systems. They are particularly useful in converting vast renewable resources from rangeland, pasture and crop residues into food edible for humans. India has a huge ruminant population comprising of 210.2 million of cattle, 111.3 million buffaloes, 74.0 million of sheep, 154 million of goats, producing 117.0 million tons of milk and 3.4 million tons of meat (FAOSTAT 2010). Since 1970, there has been a consistent rise in the production of milk (4.7%) and meat (3.4%). Growth in livestock output, with the exception of milk, has primarily been driven by an increase in animal numbers. Yield growth in meat has been negligible, more so in the case of sheep and goats. Nutrition remains by far the most critical constraint to increased animal productivity and more efficient performance across the developing countries (ILRI 1995) with the perpetual gap between the demand and supply of digestible crude protein (DCP) and total digestible nutrients (TDN); about 35 and 37 per cent (Ramachandra et al. 2005).

The sustainability of number-driven growth in livestock output would be severely constrained by declining per capita land availability and feed and fodder scarcity, implying higher prices. Further, due to population boom, the available land is mostly diverted for cultivation of cereal and commercial crops to meet the urgent human needs resulting in decrease in land for fodder cultivation and forcing ruminants to depend on crop residues/agricultural by-products. The rising cost of conventional crop residues like sorghum stover, maize stover and paddy straw, which are widely used for feeding lactating animals, is a growing concern. Therefore, exploration of alternate sources of crop residues/agricultural by-products is urgently needed to increase fodder supply and to decrease feeding costs. Under the prevailing circumstances, one option is sweet sorghum bagasse, an agro-industrial by-product of the bioethanol industry.

Sweet sorghum (Sorghum bicolor (L.) Moench) is well adapted to the semi-arid tropics and is one of the most efficient dryland crops to convert atmospheric CO2 into sugar. The crop is more water-use efficient than sugarcane and is recently gaining importance as a feedstock for ethanol production. It is grown in areas with an annual rainfall range of 400-750 mm worldwide on about 44 million hectares in almost one hundred different countries. The major producers are the United States, India, Nigeria, China, Mexico, Sudan and Argentina. Sudan (8.95 m ha) is the largest sorghum grower in the world followed by India (8.45 m ha) and Nigeria (7.81 m ha). India is the third largest producer after USA and Nigeria with 7.15 m tons (FAO 2007). The selling of sweet sorghum stover to distilleries after grain harvest can provide much needed income for dryland farmers, but it also diverts biomass away from livestock, thus potentially worsening problems of feed scarcity. A crop yielding 20-30 ton fresh stalk $ha^{-1}$ and 50% extractability would yield about 10.5-15.8 ton $ha^{-1}$ stalk residue (Ashok Kumar et al. 2010). Recycling of bagasse (residue remaining after extraction of juice from the stems for ethanol production) together with the leaves (Fig. 1), which are mechanically stripped from the stem at the distillery, could compensate for some of the fodder loss. Where juice extraction for bioethanol production is centralized (Fig. 2), conversion of bagasse and stripped leaves into a marketable fodder would provide an additional source of revenue in a sweet sorghum value chain.

*Fig. 1. Sweet sorghum bagasse.*

*Fig. 2. Extraction of juice from sweet sorghum stalks.*

## II. Physical evaluation

Physical processing methods like chopping, grinding and pelleting of the roughages increase the surface area, density and expose the lingo-cellulosic fractions for easy access to enzymatic digestion. The effect of processing can be evaluated by particle size, bulk density, modulus of uniformity, modulus of fineness and molasses absorbability of sweet sorghum bagasse (SSB). The average absorbability of molasses by ground SSB was 33.0% indicating that 100 kg of SSB has absorbed 33 kg molasses. An improvement of 62.5 per cent was observed in the bulk density of the chopped SSB to ground SSB with a reduction in particle size from 1.5-2.0 cm to 665.303±1.52 $\mu$ with 8 mm sieve. The modulus of uniformity (indicative of distribution of particles on coarse, medium and fine mesh screens, respectively) was 5:2:3 suggesting higher proportion of coarse particles. The modulus of fineness (indicative of coarseness of particles) was 5.33. The knowledge of physical characteristics of SSB is helpful in commercial processing and feed compounding.

## III. Chemical evaluation

Laboratory analysis suggested that SSB contained 3.94% crude protein and it was comparable with sorghum stover (3.8%) and lower than maize

stover (5.5%). The major elements Ca and P content was 0.82 and 0.47%, respectively and the trace elements Cu, Mn, Zn and Fe content of SSB was 57.40, 47.67, 48.78 and 0.27 ppm, respectively. The in vitro dry matter digestibility of SSB was 40.3%.The gross and metabolizable energy content (MJ $kg^{-1}$ DM) of SSB was 16.85 and 7.34, respectively. Metabolizable energy content was higher in SSB compared to maize stover (7.01 MJ $kg^{-1}$ DM) and comparable to sorghum stover (7.29 MJ $kg^{-1}$ DM) (Fig. 3). The DCP value of SSB was .58 and 1.86% in Murrah buffaloes and Deccani sheep, respectively.

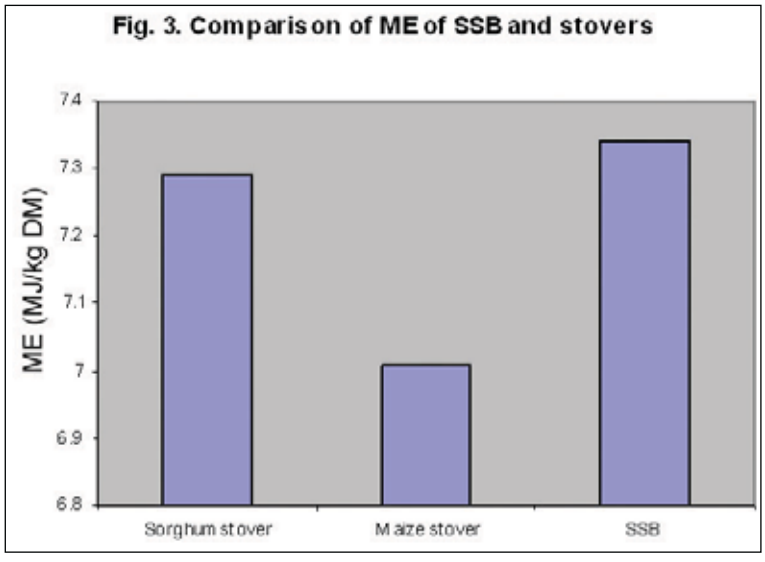


*Fig. 3. Comparison of ME of SSB and stovers.*

## IV. SSB silage

After extracting the juice, the moisture content of the SSB along with leaves was around 50-60 per cent and an attempt was made to ensile the fresh material-whole and chopped without any further addition of moisture or additives to make it cost effective. Chopping is the most commonly used processing method which improves intake and avoids selective feeding. The results have shown that there was no significant difference between Deccani sheep fed chopped and unchopped SSB silage in intake and nutrient utilization. It revealed that the SSB can be made into silage in whole form without reducing the particle size as the disintegrated fibre during the extraction of juice makes the fiber to be acted upon by the microbes in the rumen similar to that of reduced particles in chopping.

Negative average daily gain (ADG), feed conversion ratio (FCR) and cost economics were recorded in lambs fed sole SSB silage in chopped form (Table 1). However, when SSB silage was supplemented with 170, 225, 280 g of concentrate, the ADG and feed efficiency in ram lambs supplemented with 280 g was significantly higher than those supplemented with 170 g concentrate and sole feeding, but the ADG was comparable with those supplemented with 225 g concentrate. Cost kg live weight gain was lower (P>0.05) by 18.5 and 3 per cent in growing sheep supplemented with 280 g concentrate in comparison to those supplemented with 170 and 220 g concentrate per day to SSB silage. Hence, supplementation of 280 g concentrate to SSB silage is economical in growing Nellore sheep.

**Table 1. Effect of feeding SSB silage with different levels of concentrate supplementation on growth rate, feed conversion efficiency and cost economics in growing Nellore ram lambs**

| Parameter | Ration | | | |
|---|---|---|---|---|
| | Sole SSB silage | SSB silage+170g conc | SSB silage+220g conc | **SSB silage+280g conc** |
| Initial weight (kg) | 14.05 | 14.05 | 14.00 | 14.00 |
| Final weight (kg)** | 11.91$^{c}$ | 18.53$^{b}$ | 20.20$^{ab}$ | 21.53$^{a}$ |
| Total weight gain (kg)** | -2.14$^{c}$ | 4.48$^{b}$ | 6.20$^{ab}$ | 7.53$^{a}$ |
| Average daily gain (g)** | -17.91$^{c}$ | 37.26$^{b}$ | 51.70$^{ab}$ | 62.76$^{a}$ |
| Silage intake (kg/d) | 1.12 | 1.12 | 1.07 | 1.13 |
| Concentrate intake (g/d) | - | 170$^{c}$ | 225$^{b}$ | 280$^{a}$ |
| FCR (DM intake kg/kg gain)* | -19.61$^{c}$ | 13.61$^{a}$ | 10.38$^{b}$ | 9.67$^{b}$ |
| Cost of feed/kg (₹) silage | 1.25 | 1.25 | 1.25 | 1.25 |
| Concentrate | 11.09 | 11.09 | 11.09 | 11.09 |
| Cost/ kg weight gain (₹)* | -77.98$^{c}$ | 88.18$^{a}$ | 74.18$^{b}$ | 71.95$^{b}$ |

$^{a, b, c}$ values bearing different superscripts in a row differ significantly *(P<0.05), **(P<0.01)

# V. Processing of SSB

Any improvement in the nutritional quality of crop residues and agro-industrial by-products will enhance nutrient supply to the livestock. Nowadays there has been tremendous increase in the development and application of processing methods of feeds for ruminants. Processing methods reduce the wastage,

increase the bulk density and increase palatability and feed consumption. It also contributes to the ease of handling, feeding, storage and transport.

In a complete feed, all feed ingredients inclusive of roughages are proportioned, processed and mixed into a uniform blend, which is freely available to the animal to supply adequate nutrients. The product is fed as sole source of nutrients. This system ensures the supply of balanced nutrients, controls the ratio of concentrate to roughage, helps in improved utilization of low grade fibrous agricultural residues. The complete feed can be prepared either in mash, block or pellet (expander-extrusion) form. The expander-extrusion system combines the features of expanding (application of moisture, pressure and temperature to gelatinize the starch portion) and extruding (pressing the feed through constrictions under pressure).

# VI. Studies in buffaloes

**Table 2. Effect of feeding differently processed sweet sorghum bagasse based complete diets on growth rate, feed efficiency and cost economics in Murrah buffalo bull calves.**

| Parameter | Complete ration | | | |
|---|---|---|---|---|
| | Sorghum stover mash | SSB | | |
| | | Chopped | Mash | Pellets |
| Initial weight(kg) | 136.90 | 137.00 | 137.30 | 136.90 |
| Final weight (kg) ** | 209.60 $^{b}$ | 205.20 $^{b}$ | 209.70$^{b}$ | 224.70$^{a}$ |
| Weight gain (kg) ** | 72.70 $^{b}$ | 68.20 $^{b}$ | 72.40$^{b}$ | 87.80 $^{a}$ |
| Average daily gain(g/d) ** | 484.67 $^{b}$ | 454.66 $^{b}$ | 482.67 $^{b}$ | 585.33 $^{a}$ |
| Feed intake (g/d) * | 4.50 $^{ab}$ | 4.42 $^{b}$ | 4.49 $^{ab}$ | 4.56 $^{a}$ |
| Feed conversion ratio (kg/kg gain) ** | 9.29 $^{b}$ | 9.84 $^{b}$ | 9.36 $^{b}$ | 7.80 $^{a}$ |
| Cost of feed/kg (₹) | 7.93 | 6.33 | 6.43 | 6.63 |
| Cost/kg gain (₹) ** | 74.55$^{a}$ | 63.22$^{b}$ | 61.07 $^{b}$ | 52.44$^{c}$ |

$^{a, b}$ values bearing different superscripts in a row differ significantly,*P<0.05; **P<0.01

SSB-based complete diets (roughage to concentrate ratio of 50:50) processed into chopped (Fig. 4), mash (Fig. 5) and expander extruded pellets (Fig. 6) were evaluated in growing Murrah buffalo bull calves in comparison to conventional sorghum stover based complete diet (50R:50C) in mash form.

Significantly higher feed intake (kg/d) was observed in buffalo calves fed expander extruded diet compared to those fed chopped ration which might be due to more palatability of expander extruded pelleted ration compared to chopped form (Table 2). Significantly higher average daily gain (Fig. 7) and lower feed conversion ratio (FCR) observed in buffalo calves fed expander-extruded pelleted ration compared to chopped, mash and sorghum stover mash rations might be due to higher feed intake and efficient digestibility of

*Fig. 4. Concentrate and Chopped SSB.*

*Fig. 5. Mash form.*

*Fig. 6. Expander extruded pellets.*

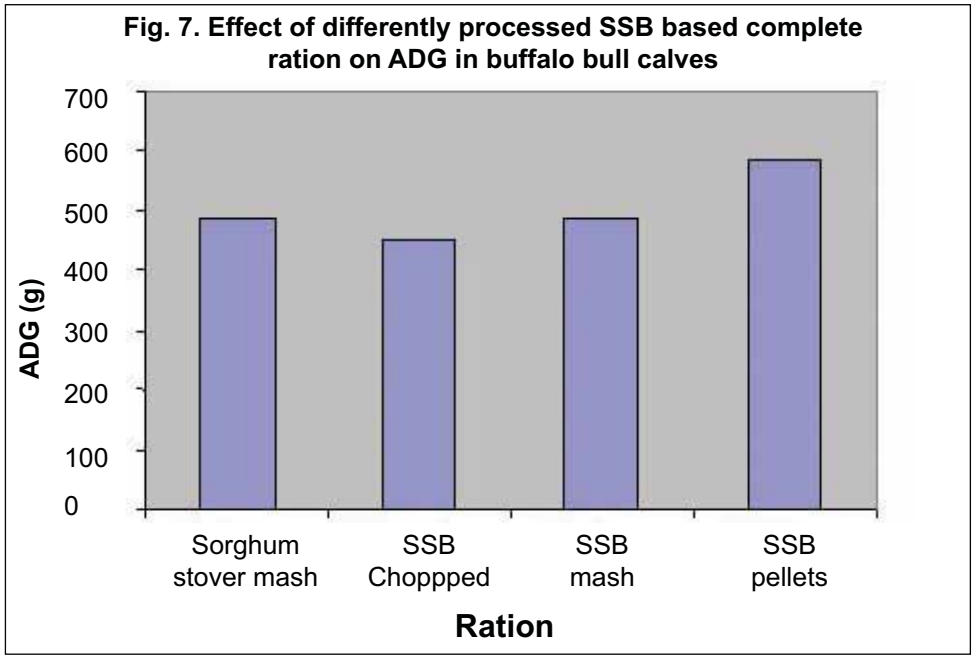


*Fig. 7. Effect of differently processed SSB based complete ration on ADG in buffalo bull.*

nutrients in expander-extruder rations than chopped and mash form of the rations. However, the average daily gain (g) and FCR was almost similar in buffalo calves fed either sorghum stover or SSB based rations in mash form (Table 2).

The cost per kg gain in buffalo calves fed expander-extruded pelleted ration was significantly lower ($P<0.01$) compared to those fed chopped, mash and sorghum stover mash rations due to lower FCR in pelleted ration as well as lower cost of SSB than sorghum stover.

In lactating graded Murrah buffaloes feed intake (kg/d) was significantly higher for pelleted ration in comparison to chopped form of SSB based ration but comparable among SSB based (chopped and mash form) and sorghum stover based (mash form) rations. The milk yield (Fig. 8), 6% FCM yield (kg/d) feed efficiency and total solids, solids not fat (SNF), milk fat and protein yields (g/d) (Fig. 9) was significantly higher in the buffaloes fed expander-extruded SSB based ration than those fed SSB based chopped, mash rations and sorghum stover based rations (Table 3). However, the total solids, SNF, milk fat and protein per cent in lactating graded Murrah buffaloes fed differently processed

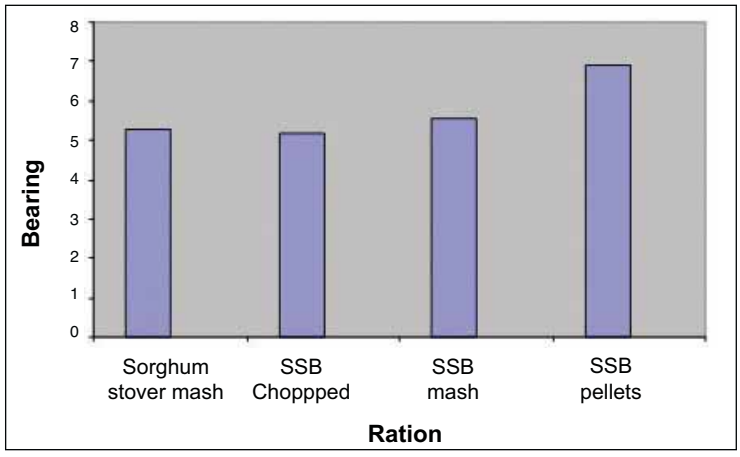


*Fig. 8. Effect of differently processed SSB based complete ration on milk yield (kg/d) in lacting Murrah buffaloes.*

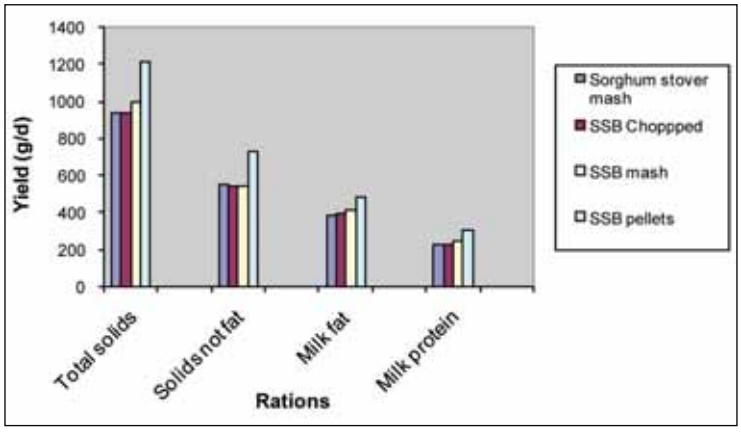


*Fig. 9. Effect of differently processed SSB based complete diet on milk constituents.*

SSB complete rations and sorghum stover complete mash were comparable. The higher daily milk, milk constituent and feed efficiency was due to efficient digestibility of nutrients in buffaloes fed expander-extruded ration than those fed chopped, mash rations and sorghum stover based rations, which in turn led to lower cost per kg milk yield and per kg FCM yield.

# VII. SSB based complete feed blocks

A feeding trial with growing bulls was conducted at ILRI, comparing the SSB based (50%) complete feed block with sorghum stover based (50%) complete

**Table 3. Effect of feeding differently processed SSB based complete rations on quality, quantity and economics of milk production in lactating graded Murrah buffaloes.**

| Parameter | Complete ration | | | |
|---|---|---|---|---|
| | Sorghum stover mash | SSB | | |
| | | Chopped | Mash | Pellets |
| Milk yield (kg/d) | 5.29[b] | 5.17[b] | 5.54[b] | 6.91[a] |
| 6% FCM yield (kg/d) | 6.29[b] | 6.24[b] | 6.51[b] | 7.74[a] |
| Milk constituents yield (g/d) | | | | |
| Total solids | 937.92[b] | 940.94[b] | 998.31[b] | 1217.54[a] |
| Solids not fat | 549.10[b] | 546.99[b] | 546.69[b] | 731.08[a] |
| Milk fat | 388.82[b] | 393.44[b] | 411.62[b] | 486.46[a] |
| Milk protein | 228.53[b] | 226.45[b] | 242.65[b] | 306.80[a] |
| Feed intake (kg/d) | 12.04[a] | 11.76[b] | 12.13[a] | 12.16[a] |
| Feed conversion ratio (kg/kg FCM) | 1.91[b] | 1.88[b] | 1.86[b] | 1.57[a] |
| Cost of feed/kg (₹) | 7.93 | 6.33 | 6.43 | 6.63 |
| Cost of feed/kg milk (₹) | 18.26[a] | 14.61[b] | 14.29[b] | 11.83[c] |
| Cost of feed/kg FCM (₹) | 15.36[a] | 12.11[b] | 12.16[b] | 10.57[c] |

[a, b, c] values bearing different superscripts in a row differ significantly ($P<0.05$)

feed block. It is promising to observe that, there was no difference in feed intake between the SSB based block (7.52 kg/d) and sorghum stover based feed block (7.31 kg/d) fed bulls. There was also no significant difference between the daily live weight gains of the bulls fed SSB based block (0.73 g/d) and sorghum stover based feed block (0.82 g/d) which confirms the value of SSB as feed block ingredient (Blümmel et al. 2009).

# VIII. Studies in sheep

The level of roughage and concentrate in the complete feed is of major importance for efficient utilization of dietary nutrients for production. Complete diets with different proportions of SSB in mash form were studied in growing lambs with an objective to determine the optimum roughage to concentrate ratio for economic meat production.

In the growth study, four complete diets containing 60, 50, 40 and 30% SSB were fed to growing Nellore x Deccani ram lambs (Fig. 10). The roughage to concentrate ratio did not significantly influence the total weight gain (kg) as well as average daily gain (ADG), feed intake and FCR (Table 4). Higher cost of feed/kg gain in 40% and 30% SSB based diets might be due to increased proportion of concentrates in the above diets. No significant difference and trend was observed in pre slaughter weight, empty body weight, carcass weights, dressing percentage, wholesale cuts and edible and non-edible portions of experimental animals. No significant variation could be seen in bone and meat yield (%) and their ratios in various wholesale cuts among dietary treatments. The roughage to concentrate ratio could not affect the chemical composition of meat. Hence, SSB can be included at 50 to 60 per cent level in the rations of growing ram lambs for economic meat production since there was no significant improvement observed in feed conversion efficiency compared to 50, 40 and 30 per cent levels.

Feeding of SSB based complete diet containing 50:50 roughage to concentrate ratio processed into chopped, mash, expander extruded form in comparison to sorghum stover based complete diet (50:50) in mash form in Nellore x Deccani ram lambs revealed that processing complete diets into different forms significantly influenced body weight gains of lambs (Fig. 11). The total weight gain, average daily gain and feed conversion efficiency of ram lambs fed expander-extruded SSB-based complete diet was significantly

**Table 4. Average daily gain, feed conversion efficiency and cost of feeding in growing Nellore x Deccani ram lambs fed rations with different ratios of SSB and concentrate.**

| | Complete ration | | | |
|---|---|---|---|---|
| Parameter | 60% SSB | 50% SSB | 40% SSB | 30% SSB |
| Initial body weight (kg) | 10.68 | 10.65 | 10.53 | 10.60 |
| Final body weight (kg) | 24.60 | 25.37 | 25.98 | 26.13 |
| Average daily gain (g) | 77.31 | 81.76 | 85.83 | 86.30 |
| Feed intake (g/d) | 866.82 | 847.53 | 867.45 | 853.10 |
| Feed conversion ratio (kg feed/kg gain) | 11.42 | 10.57 | 10.17 | 9.96 |
| Cost of feed/kg (₹) | 5.50 | 6.53 | 7.55 | 8.58 |
| Cost/kg gain (₹) | 62.83$^{c}$ | 69.00$^{bc}$ | 76.76$^{ab}$ | 85.43$^{a}$ |

$^{a, b, c}$ values bearing different superscripts in a row differ significantly (P<0.01)

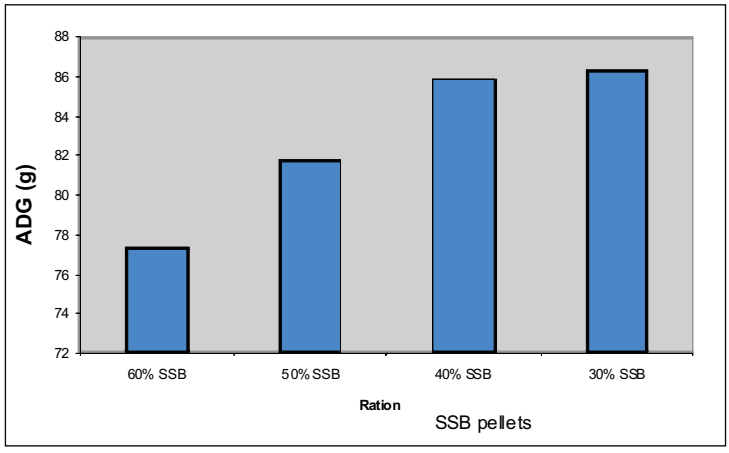


*Fig. 10. Effect of different SSB to concentrate proportions of complete ration on ADG in Nellore X Deccani ram lambs.*

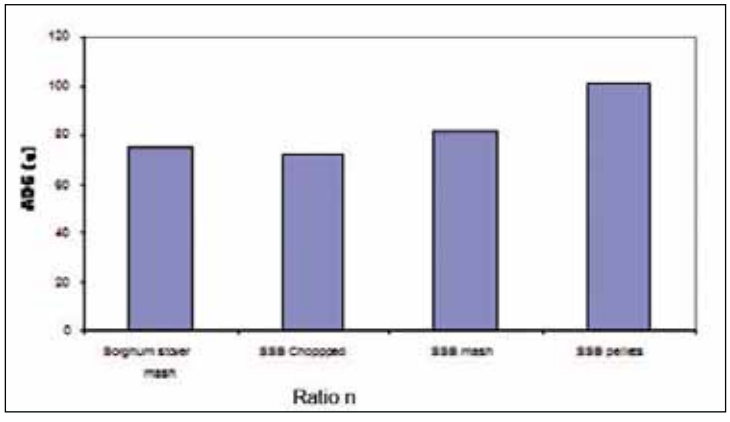


*Fig. 11. Effect of differently processed SSB to concentrate proportions of complete ration on ADG in Nellore X Deccani ram lambs.*

higher than chopped, mash and sorghum stover mash diets but it was comparable among SSB (chopped and mash form) and sorghum stover (mash form) based complete diets (Table 5). Though feed intake was not significantly different among all the rations, lambs fed pellet and mash diets consumed 16.74 and 6.14 per cent more compared to chopped form was due to the increased palatability.

Efficient utilization of absorbed nitrogen due to matching supply of energy and minerals provided optimum environment on pelleted diet reflected in an increased ADG. The expander-extruded SSB-based complete diet was more economical to gain one kg of body weight than the chopped and sorghum stover mash and it was comparable in ram lambs fed sorghum stover and SSB-based mash diets. The feed intake of lambs fed SSB mash and sorghum stover mash diet was comparable, which indicated the higher palatability and acceptability of SSB as roughage source and it was also equally acceptable and palatable with sorghum stover.

The pre-slaughter weight was significantly higher in lambs fed expander-extruded form ration compared to those fed chopped, mash and sorghum stover mash rations. The carcass weight of pelleted diet fed lambs was 33.37, 21.44 and 24.93 per cent higher than chopped, mash and sorghum stover mash diets. Processing could not influence the dressing percentage, proportions of whole sale cuts, edible and inedible portions, yield of visceral organs, and per cent yield of bone, meat and fat and bone, meat ratio in different wholesale cuts as well as carcass and meat quality.

**Table 5. Effect of feeding differently processed SSB-based complete diets on growth rate, feed intake, feed efficiency and cost economics in growing Nellore x Deccani ram lambs.**

| Parameter | Complete ration | | | |
|---|---|---|---|---|
| | Sorghum stover Mash | SSB | | |
| | | Chopped | Mash | Pellets |
| Initial body wt. (kg) | 10.57 | 10.57 | 10.65 | 10.53 |
| Final body wt. (kg)** | 24.13$^{b}$ | 23.53$^{b}$ | 25.37$^{b}$ | 28.77$^{a}$ |
| Average daily gain (g)** | 75.37$^{b}$ | 72.04$^{b}$ | 81.76$^{b}$ | 101.30$^{a}$ |
| Feed Intake (g/d) | 804.70 | 790.31 | 847.53 | 910.791 |
| Feed conversion ratio (kg feed/kg gain)* | 10.69$^{b}$ | 11.13$^{b}$ | 10.57$^{b}$ | 9.05$^{a}$ |
| Cost of feed/kg (₹) | 7.03 | 6.43 | 6.53 | 6.73 |
| Cost/kg gain (₹)* | 75.15$^{b}$ | 71.56$^{b}$ | 69.00$^{ab}$ | 60.89$^{a}$ |

## Conclusion

Sweet sorghum bagasse (SSB), an agro-industrial by-product, can replace the traditional sorghum stover as feed resource for ruminants and it can be effectively conserved as silage. The SSB allows incorporation into complete feed at 50-60 per cent level in feeding of growing lambs to meet the growth requirements provided, sufficient digestible protein is made available in the form of concentrate in the ration for economic rearing of ram lambs. Further, feeding of complete rations in the form of expander-extruder pellets proved superior over chopped and mash form of SSB and mash form of sorghum stover rations in sheep and growing and lactating buffaloes.

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