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REGULAR ARTICLES

# Effect of dietary utilisation of sugarcane press mud on production performance of Muzaffarnagari lambs

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**Abstract** Sugarcane press mud (SPM) is one of the potential agro-industrial by-products available in India and research exploring its utilisation in small ruminant nutrition is scanty. In this direction, the present study evaluated the feasibility of dietary incorporation of SPM at different levels in a feeding trial lasting 180 days. A total of 21 Muzaffarnagari ram lambs were randomly distributed into three groups of seven each based on comparable body weight (11.70 ± 0.29 kg) and age (3–5 months) following a completely randomised design. The three dietary treatments were (1) $SP_0$ (control), concentrate mixture without SPM; (2) $SP_{10}$, concentrate mixture comprising 10% SPM and (3) $SP_{20}$, concentrate mixture comprising 20% SPM on air-dry basis. The experimental lambs were offered weighed quantity of designated isonitrogenous (crude protein = 20.6%) and isoenergetic (metabolisable energy = 12.1 MJ/kg) concentrate mixture (coarse mash) and along with ad libitum wheat straw (threshed to 1–2-cm length) and a 9-day metabolism trial was conducted. Results revealed no significant ($P > 0.05$) differences in intake and digestibility of nutrients, nitrogen balance, nutritive value of diets, average daily gain, as well as feed conversion ratio among three groups. The serum concentration of triiodothyronine and tetraiodothyronine did not differ due to treatments. Likewise, wool yield and its quality, measured in terms of fibre diameter, medullation percentage and staple length were also comparable irrespective of dietary variation. Furthermore, the cost of concentrate mixture (Rs/day) was lower ($P \leq 0.05$) in $SP_{20}$ followed by $SP_{10}$ as compared to group $SP_0$. These findings suggested that SPM could be safely fed up to 20% level in the concentrate mixture for lambs substituting expensive traditional feed ingredients without negatively inflicting the performance of growing lambs.

**Keywords** Growth performance · Lamb diet · Nutrient utilisation · Sugarcane press mud · Unconventional feed · Wool quality

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## Introduction

Small ruminant production in India has been seriously constrained by the continuous depletion of grazing lands coupled with the raising cost of conventional concentrate feeds resulting in 32% deficit for concentrates (Sahoo et al. 2015). Therefore, under low-input production systems such as those prevalent in India, prioritising research to delineate alternative feed resources has become imperative for achieving sustainability and stepping towards smart livestock feeding practices (Makkar 2016). In this perspective, sugarcane press mud (SPM), also known as sugarcane filter cake, a by-product of cane sugar manufacturing could be utilised as a diet component owing to its moderate protein (10–15%) and rich mineral (15–30%) profiles (Tran 2015). It is a soft, spongy and amorphous dark brown residue obtained during filtration of sugarcane juice in sugar factories (Dotaniya et al. 2016) and there is an estimated annual availability to the magnitude of 8–10 million tonnes in India (Soloman 2011). The SPM has been investigated as a feed ingredient for ruminants (Gupta and Ahuja 1998; Mohamed and El-Saidy 2003; Suresh et al. 2006; Saha et al. 2015; Malapure 2015), swine (Sahu et al. 2014) and poultry (Suma et al. 2007, 2015; Suresh and Reddy 2011), besides its use as an ensiling agent (Tran 2015). Nevertheless, not many feeding trials have assessed its potential feeding value to be used convincingly in small ruminant feeding. It is generally agreed that generating reliable on-farm data supporting chemical characterisation enables ruminant nutritionists to formulate and further refine the diets based on alternative feedstuffs. Given this background, the present experiment was designed to incorporate SPM as a component of concentrate mixture to elucidate its effects of nutrient intake, digestion, growth performance, wool yield, thyroid status and economic feasibility in lambs.

## Materials and methods

### Lambs, diets and management

Twenty-one Muzaffarnagari ram lambs were randomly distributed into three groups of seven animals each following completely randomised design based on comparable body weight (BW = 11.70 ± 0.29 kg) and age (3–5 months). Animals were fed the three experimental diets: $SP_0$ (control), concentrate mixture without SPM; $SP_{10}$, concentrate mixture comprising 10% SPM and $SP_{20}$, concentrate mixture comprising 20% SPM, respectively. The SPM was procured locally from sugar factories and sun-dried before incorporating into experimental diets. The lambs were housed in a well-ventilated experimental animal shed of the institute that had facilities for individual feeding and watering. All the animal-related procedures done in the trial were duly approved by the Institutional Animal Ethics Committee. Before commencing experimental feeding, all the lambs were individually dewormed with albendazole oral suspension (5 mg/kg BW) and proper sanitation was maintained throughout the experimental period lasting 180 days. All the three groups of lambs were fed the weighed quantity of concentrate mixture and ad libitum wheat straw (threshed to 1–2-cm length) at 0900 hours daily fulfilling nutrient requirements as per ICAR (2013) feeding standards. The dry matter (DM) intake (DMI) was adjusted every fortnightly commensurate with the growth rate of lambs. A fixed amount (100 g) of green maize (*Zea mays*; chopped to 1–2 cm length) forage was provided twice a week to each lamb to meet their vitamin A requirement. Fresh drinking water was provided ad libitum round the clock.

All the lambs were weighed individually at fortnightly intervals using an electronic digital balance before feeding and watering in the morning after overnight fast, and the BW recorded at two consecutive days was averaged. The average daily gain (ADG) was calculated by dividing the weight gain during the period by the number of days. Ratio of daily DMI to ADG gave feed conversion ratio (FCR).

### Metabolism trial, sampling and chemical analyses

A 9-day metabolism trial was conducted on 18 lambs (6 lambs per group) towards the end of growth trial. The initial 3 days were allowed for acclimatisation to metabolism cages followed by subsequent 6 days of collection period. The daily amount of DM offered, residue left, and total voidance of faeces and urine were recorded for preceding 24 h. For determining faecal nitrogen (N), an aliquot of 1/100th of the fresh faeces excreted by each lamb was sampled into a previously weighed glass bottle containing 15 mL of 25% (*v*/*v*) sulphuric acid during the collection period. For urinary N, 1/20th of daily urine excreted by each lamb was sampled into plastic bottles having 50% (*v*/*v*) sulphuric acid, and pooled for 6 days. Daily DMI was ascertained after calculating DM content in feeds and residues by oven drying them at 100 °C for 24 h. Based on the difference of intake and excretion of particular nutrient, apparent digestibility was worked out. The total digestible nutrients (TDN) was computed as per modified Morrison (1961) formula: TDN = digestible CP + [digestible ether extract (EE) × 2.25] + digestible carbohydrates (CHO).

The samples of feeds, residues and faeces were dried for 48 h at 65 ± 5 °C (AOAC 2005) and homogenised samples were ground to pass through 1-mm sieve, placed in airtight plastic bags awaiting further analysis. Thoroughly mixed samples of faeces (5 g) and urine (5 mL) were subjected for N determination using Kjeldahl apparatus (Pelican, India). Chemical analyses in terms of EE, total ash, CP (N × 6.25) and crude fibre (CF) were done in accordance with AOAC (2005). Fibre fractions like neutral detergent fibre (NDF) and acid detergent fibre (ADF) were assayed (Van Soest et al. 1991) without α-amylase and sodium sulphite, and expressed on ash-free basis. While the difference between NDF and ADF was hemicellulose, the CHO were calculated by subtracting ash, CP and EE from 100 (Sharma et al. 2014). The NFE was calculated by subtracting CF from CHO. The estimation of calcium (Ca) and phosphorus (P) (Talapatra et al. 1940) as well as sulphur (S) (AOAC 2005) was also carried out. The micro minerals such as iron (Fe), zinc (Zn) and copper (Cu) were determined by Atomic Absorption Spectroscopy (Model 4141, ECIL, Hyderabad, India).

About 4 mL of blood was collected in a sterile vacutainer from the jugular vein of all animals at 0, 60, 120, and 180 days of experiment. Serum was harvested to know the profile of triiodothyronine ($T_3$) and tetraiodothyronine ($T_4$) that were estimated (Chopra et al. 1971) using commercial ELISA kit (LDN Labour Diagnostika Nord Gmbh & Co. KG) as per manufacturer's recommendations.

### Wool quality

Shearing of wool from all experimental lambs was done at the start and end of the experiment to calculate wool yield. The representative quantity (10 g) of wool samples taken from each lamb was further sent to ICAR – Central Sheep and Wool Research Institute, Avikanagar, Rajasthan, India, for wool quality estimation in terms of fibre diameter, medullation percentage and staple length (Niven and Pritchard 1985).

### Economics of feeding

Economics of feeding was calculated based on the prevailing market prices of respective dietary ingredients and other charges incurred for preparing concentrate mixtures. The total feeding costs were calculated by multiplying the DMI from wheat straw and concentrate mixtures for 180 days with their corresponding prices. The cost of live weight gain was computed by dividing total feed cost (Rs) with total live weight gain (kg).

### Statistical analysis

The data generated in this experiment was expressed as means ± standard error for all parameters and analysed by one-way analysis of variance using Statistical Analysis System (SAS, 2012). The differences among the means were considered statistically significant at 5% level of probability ($P \leq 0.05$).

## Results

### Chemical composition of SPM and concentrate mixtures

The chemical composition of SPM, concentrate mixtures and wheat straw is furnished in Table 1. The dried SPM contained (DM basis) 16.2, 6.4, 13.7 and 18.4% of CP, EE, CF and ash, respectively. In addition, macro-mineral composition presented a mean concentration of 5.07, 1.01 and 0.61% for Ca, P and S, respectively, whilst trace minerals such as Fe, Zn and Cu were in the level of 2124, 69.7 and 25.8 mg/kg, respectively, in SPM. The concentrate mixtures formulated for three groups contained CP of 20.6% and metabolisable energy of 12.1 MJ/kg.

### Voluntary intake, nutrient utilisation, N metabolism and growth performance

The intake of concentrate mixture, wheat straw as well as total DMI was similar ($P > 0.05$) among three groups (Table 2). Apparent digestibility of all the nutrients including fibre fractions and nutritive value of diets did not differ ($P > 0.05$) due to treatments. Further, the average daily N intake, its excretion through faeces and urine as well as N balance were comparable ($P > 0.05$) among the groups irrespective of feeding regimen (Table 2). Fortnightly BW changes were not influenced by the inclusion of different levels of SPM in the diet (Fig. 1). A similar trend was also evident for net gain in BW, ADG and FCR as these did not vary among the groups (Table 3). Furthermore, the wool yield for the period of 180 days did not differ significantly ($P > 0.05$). Similarly, wool quality expressed in terms of fibre diameter, medullation percentage and staple length were also comparable among three groups of lambs (Table 3).

### Thyroid status

The concentrations of thyroid hormones ($T_3$ and $T_4$) in serum were unaffected ($P > 0.05$) due to different treatments and periods with no interaction existed between the two (Table 4).

### Economic feasibility

Table 5 illustrates economic feasibility of feeding SPM to growing lambs. The cost of consumed concentrate mixture (Rs/day) was significantly ($P \leq 0.05$) lower in $SP_{20}$ (7.61) followed by $SP_{10}$ (8.62) as compared to $SP_0$ (9.46) (Table 5). Whereas, the cost of wheat straw was comparable among treatment groups. Similarly, the cost (Rs) of total feed consumed was lower ($P \leq 0.05$) in $SP_{20}$ (8.88) followed by $SP_{10}$ (9.87) than $SP_0$ (10.69) group. Consequently, the feed cost per kilogram BW gain (Rs) was comparable upon addition of SPM in groups $SP_{10}$ and $SP_{20}$ as compared to $SP_0$.

## Discussion

The abundantly available fresh SPM is a high moisture by-product that, unless disposed of properly, is a source of environmental pollution (Dotaniya et al. 2016). Present study explores the possibility of its use as an alternative feed ingredient for sheep to economise the ration.

The composition of SPM concurs broadly with prior reports (Suma et al. 2007; Suresh and Reddy 2011; Tran 2015), although a slightly higher CP and EE have been noticed in the present study. Factors like quality of the cane crushed and process followed for clarification of cane juice in the sugar industry might explain varied CP concentration,

**Table 1** Composition of experimental diets offered to Muzaffarnagari lambs

| Particular | $SP_0$ | $SP_{10}$ | $SP_{20}$ | Sugarcane press mud | Wheat straw |
|---|---|---|---|---|---|
| Gross composition (%, as mixed) | | | | | |
| Maize | 44 | 43 | 41 | | |
| Wheat bran | 27 | 19 | 13 | | |
| Soya bean meal | 26 | 25 | 23 | | |
| Sugarcane press mud (sun-dried) | – | 10 | 20 | | |
| Mineral mixture[a] | 02 | 02 | 02 | | |
| Salt (as NaCl) | 01 | 01 | 01 | | |
| Chemical composition (% dry matter)* | | | | | |
| Organic matter | 93.5 | 92.1 | 91.5 | 81.6 | 95.5 |
| Crude protein | 20.6 | 20.7 | 20.6 | 16.2 | 3.42 |
| Ether extract | 2.66 | 2.77 | 2.79 | 6.4 | 0.85 |
| Crude fibre | 4.12 | 5.10 | 5.62 | 13.6 | 46.2 |
| Total ash | 6.52 | 7.88 | 8.48 | 18.4 | 4.47 |
| Nitrogen-free extractives | 66.2 | 63.5 | 62.5 | 45.4 | 45.1 |
| Total carbohydrates | 70.2 | 68.6 | 68.1 | 59 | 91.3 |
| Non-fibrous carbohydrates[b] | 41.7 | 38 | 36.1 | 0.6 | 8.7 |
| Metabolisable energy[c] | 12.3 | 12.1 | 12.0 | 9.75 | 6.9 |
| Neutral detergent fibre | 28.5 | 30.6 | 32.0 | 58.4 | 82.6 |
| Acid detergent fibre | 9.56 | 11.1 | 11.6 | 31.3 | 55.4 |
| Hemicellulose | 18.9 | 19.5 | 20.5 | 27.0 | 27.2 |
| Mineral profile | | | | | |
| Calcium (%) | 1.04 | 1.32 | 1.72 | 5.07 | 0.51 |
| Phosphorus (%) | 0.97 | 1.03 | 1.06 | 1.01 | 0.12 |
| Sulphur (%) | 0.17 | 0.20 | 0.24 | 0.61 | 0.12 |
| Iron (mg/kg) | 112 | 252 | 458.4 | 2124 | 145.9 |
| Zinc (mg/kg) | 43.7 | 44.4 | 44.7 | 69.7 | 9.15 |
| Copper (mg/kg) | 10.3 | 10.4 | 10.5 | 25.8 | 4.54 |

*$SP_0$* concentrate mixture without sugarcane press mud (control), *$SP_{10}$* concentrate mixture with 10% sugarcane press mud, *$SP_{20}$* concentrate mixture with 20% sugarcane press mud

*Each value is a mean of triplicate readings

[a] Commercial mineral mixture composition (%): Ca 20, P 12, Mg 5, Fe 0.4, Cu 0.01, I 0.026, Zn 0.08, Co 0.012 and Mn 0.12

[b] Total carbohydrates—neutral detergent fibre

[c] Total digestible nutrients × 0.15 (Owens et al. 2010; Sharma et al. 2014)

whereas presence of high quantity of wax elevates EE content in SPM (Suma et al. 2015). Furthermore, the fibre fractions (NDF and ADF) of SPM are in close proximity with the earlier findings of Gupta and Ahuja (1998). Among the macro-mineral constituents, Ca and P are nearer to the data of Sahu et al. (2014); however, the trace minerals (Fe, Zn and Cu) are found relatively lower than Suresh and Reddy (2011). Such disagreements might have stemmed due, in part, to seasonal variation, stage of maturity, variety, agro-climatic conditions, agronomic practices and soil characteristics, among others. The chemical analysis of SPM clues that it compares favourably with cereal by-products like brans in terms of protein, while additionally containing rich minerals and therefore, appear to be a potential alternative feed ingredient for ruminants. Accordingly, isonitrogenous and isoenergetic concentrate mixtures further allowed us eliminating confounding effect, if any, due to dietary factors other than SPM during succeeding feeding trial.

The optimum DMI ensures availability of various nutrients for maintenance and physiological functions (Kumar et al. 2016). A lack of effect of SPM on DMI along with almost uniform forage to concentrate ratio of 40:60 reflects a status to negate any ill effects of SPM that would have otherwise interfered with the appetite and intake of nutrients. In addition, the DMI of ~3% of BW observed in this study has been found adequate for indigenous lambs (ICAR 2013) and hence, the results are of practical significance, because the marginal sheep farmers cannot afford expensive concentrate mixtures (Sahoo et al. 2015) and beneficially, the SPM inclusion also

**Table 2** Nutrient intake and digestibility by Muzaffarnagari lambs-fed graded levels of SPM in concentrate mixture

| Particular | $SP_0$ | $SP_{10}$ | $SP_{20}$ | *P* value |
|---|---|---|---|---|
| Intake | | | | |
| Concentrate mixture (g/day) | 438 ± 17.1 | 446 ± 22.8 | 422 ± 17.6 | 0.67 |
| Wheat straw (g/day) | 296 ± 10.5 | 291 ± 19.8 | 304 ± 14.6 | 0.83 |
| Total dry matter intake (g/day) | 735 ± 17.6 | 737 ± 41.8 | 726 ± 27.7 | 0.97 |
| Overall dry matte intake (g/day)* | 645 ± 32.5 | 640 ± 33.2 | 634 ± 32.1 | 0.97 |
| Dry matter intake (g/kg $W^{0.75}$) | 72.1 ± 1.28 | 71.9 ± 1.11 | 73.3 ± 1.20 | 0.67 |
| Crude protein intake (g/kg $W^{0.75}$) | 11.0 ± 0.14 | 11.3 ± 0.34 | 11.3 ± 0.19 | 0.73 |
| Total digestible nutrient intake (g/kg $W^{0.75}$) | 51.6 ± 0.86 | 50.8 ± 1.99 | 52.3 ± 1.17 | 0.76 |
| Digestibility of nutrients (%) | | | | |
| Dry matter | 61.6 ± 0.68 | 60.2 ± 0.97 | 60.0 ± 0.92 | 0.42 |
| Organic matter | 65.5 ± 0.63 | 64.7 ± 0.89 | 64.5 ± 0.71 | 0.62 |
| Crude protein | 68.4 ± 2.46 | 66.5 ± 1.63 | 66.5 ± 1.61 | 0.72 |
| Ether extract | 67.2 ± 0.99 | 66.4 ± 1.50 | 65.4 ± 0.95 | 0.56 |
| Neutral detergent fibre | 54.7 ± 0.83 | 54.8 ± 1.13 | 54.5 ± 0.68 | 0.96 |
| Acid detergent fibre | 45.0 ± 0.76 | 43.3 ± 1.20 | 44.9 ± 1.01 | 0.42 |
| Nutritive value of diet (%) | | | | |
| Digestible crude protein | 9.38 ± 0.49 | 9.28 ± 0.15 | 9.0 ± 0.28 | 0.67 |
| Total digestible nutrients | 64.1 ± 0.61 | 62.8 ± 0.73 | 62.3 ± 0.67 | 0.20 |
| Nitrogen (N) metabolism | | | | |
| N intake (g/day) | 16.1 ± 0.55 | 16.4 ± 0.86 | 15.7 ± 0.62 | 0.73 |
| Faecal N (g/day) | 5.02 ± 0.28 | 5.46 ± 0.29 | 5.22 ± 0.22 | 0.52 |
| Urinary N (g/day) | 6.25 ± 0.72 | 6.31 ± 0.46 | 6.37 ± 0.49 | 0.98 |
| N balance (g/day) | 4.79 ± 0.90 | 4.65 ± 0.87 | 4.05 ± 0.89 | 0.82 |

*$SP_0$* concentrate mixture without sugarcane press mud (control), *$SP_{10}$* concentrate mixture with 10% sugarcane press mud, *$SP_{20}$* concentrate mixture with 20% sugarcane press mud

*Average DM intake of 12 fortnights

did not alter forage intake. Akin to our findings, Ankita et al. (2015) also documented similar effect of SPM when included at 20% in kids.

Diets with or without SPM resulted in similar digestibility pattern for all nutrients. Previous researchers have also registered non-significant effect on nutrient digestibility when SPM comprised 3 and 20% of concentrate mixture for lambs (Suresh et al. 2006) and calves (Malapure 2015), respectively. As nutritive value is dictated by intake and digestibility, it is obvious that three diets contained similar nutritive value expressed as digestible CP and TDN. It is also interesting to note here that none of the experimental lambs displayed any signs of illness or digestive disturbance but remained healthy throughout 180 days of trial, reaffirming the safe

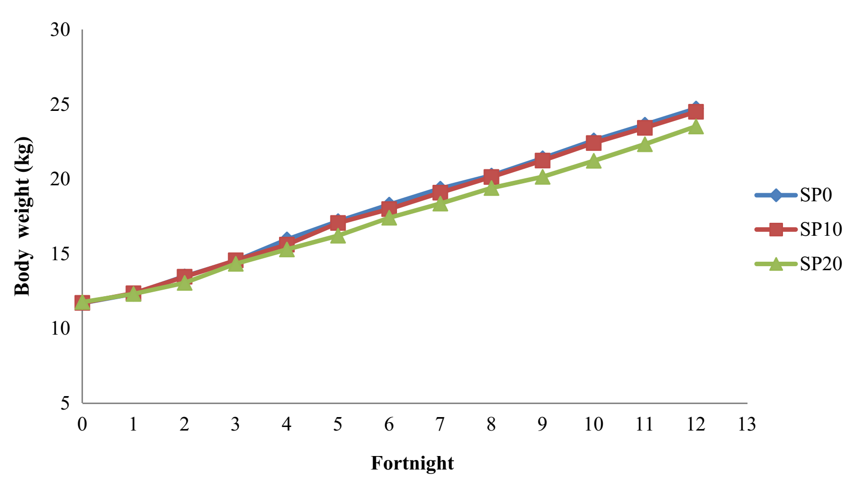


**Fig. 1** Effect of feeding sugarcane press mud-based diets on fortnightly body weight changes (kg/day) in lambs. *$SP_0$* concentrate mixture without sugarcane press mud (control), *$SP_{10}$* concentrate mixture with 10% sugarcane press mud, *$SP_{20}$* concentrate mixture with 20% sugarcane press mud

**Table 3** Performance characteristics of Muzaffarnagari lambs-fed graded levels of sugarcane press mud

| Particular | $SP_0$ | $SP_{10}$ | $SP_{20}$ | *P* value |
|---|---|---|---|---|
| Body weight (BW) changes | | | | |
| Initial BW (kg) | 11.7 ± 0.53 | 11.7 ± 0.57 | 11.8 ± 0.51 | 0.99 |
| Final BW (kg) | 24.7 ± 0.60 | 24.5 ± 0.79 | 23.5 ± 0.84 | 0.49 |
| Net gain (kg) | 13.0 ± 0.44 | 12.8 ± 0.48 | 11.8 ± 0.53 | 0.17 |
| Average daily gain (g/day) | 72.3 ± 2.43 | 71.1 ± 2.65 | 65.3 ± 2.97 | 0.17 |
| Feed conversion ratio | 8.96 ± 0.36 | 9.05 ± 0.32 | 9.79 ± 0.36 | 0.22 |
| Wool yield and quality | | | | |
| Total yield (g) | 1530 ± 44.3 | 1545 ± 33.6 | 1520 ± 29.5 | 0.89 |
| Fibre diameter (μ) | 49.3 ± 2.29 | 50.9 ± 2.32 | 46.5 ± 2.08 | 0.39 |
| Staple length (cm) | 7.92 ± 0.15 | 8.00 ± 0.27 | 7.90 ± 0.35 | 0.96 |
| Medullation (%) | | | | |
| Hetero | 11.8 ± 1.17 | 12.07 ± 1.06 | 10.9 ± 0.99 | 0.74 |
| Hairy | 34.2 ± 2.74 | 36.4 ± 2.47 | 34.1 ± 3.52 | 0.82 |
| Total | 46.0 ± 3.35 | 48.5 ± 3.36 | 45.0 ± 4.17 | 0.79 |

$SP_0$ concentrate mixture without sugarcane press mud (control), $SP_{10}$ concentrate mixture with 10% sugarcane press mud, $SP_{20}$ concentrate mixture with 20% sugarcane press mud

incorporation of SPM. Furthermore, pattern of DMI and nutrient digestibility observed in the present study once again deduces that SPM holds potential as feed for lambs without affecting palatability and digestion.

If all the N losses are accounted for and debited against N intake, the balance represents the amount of N retained by the animal. As the present experiment involved growing lambs, it is physiologically necessary to maintain positive N balance, as observed in three groups. Current findings are in concordance with those of Suresh et al. (2006) and Malapure (2015), who did not detect any changes in N metabolism between conventional- and SPM-based diets in ruminants. Furthermore, when the observed N balance of ~4.5 g is translated into tissue accretion assuming standard biological value (Castillo et al. 2000), a corresponding theoretical ADG almost double the actual value (135 vs 70 g) would be obtained. It is supposed that inevitable N losses via volatile compounds during sampling and/or storage might have proportionally underestimated total N excretion (Castillo et al. 2000; Gami et al. 2015). Nonetheless, absence of compromise in growth rate of lambs is a good indication that SPM supports growth function equivalent with that of conventional concentrate mixture. Besides, a similar FCR observed in all the groups is coherent with the nutrient intake, N balance and digestibility.

The level of nutrition affects wool production in sheep (ICAR 2013). It has been well established that wool growth and yield are the manifestation of protein and energy intake by sheep (Khan et al. 2012). Because the essence of diet

**Table 4** Serum thyroid hormones in lambs-fed graded levels of sugarcane press mud

| Group | Period (days) | | | | Mean ± SE | *P* value | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 60 | 120 | 180 | | G | P | G × P |
| Triiodothyronine ($T_3$; ng/dL) | | | | | | | | |
| $SP_0$ | 176.7 ± 7.48 | 175.2 ± 4.32 | 174.3 ± 4.21 | 174.6 ± 4.59 | 175.2 ± 2.45 | 0.95 | 0.99 | 1.0 |
| $SP_{10}$ | 176.4 ± 9.12 | 175.4 ± 7.58 | 177.5 ± 6.59 | 176.0 ± 6.39 | 176.3 ± 3.45 | | | |
| $SP_{20}$ | 175.8 ± 6.27 | 175.4 ± 6.49 | 174.8 ± 5.05 | 174.3 ± 4.45 | 175.1 ± 2.59 | | | |
| Mean ± SE | 176.3 ± 4.12 | 175.3 ± 3.36 | 175.5 ± 2.90 | 175.0 ± 2.80 | | | | |
| Tetraiodothyronine ($T_4$; μg/dL) | | | | | | | | |
| $SP_0$ | 9.59 ± 0.70 | 9.64 ± 0.73 | 9.43 ± 0.59 | 9.44 ± 0.58 | 9.52 ± 0.30 | 0.97 | 0.92 | 1.0 |
| $SP_{10}$ | 9.51 ± 0.44 | 9.45 ± 0.44 | 9.30 ± 0.39 | 9.45 ± 0.33 | 9.43 ± 0.18 | | | |
| $SP_{20}$ | 9.75 ± 0.52 | 9.55 ± 0.54 | 9.39 ± 0.43 | 9.25 ± 0.40 | 9.48 ± 0.22 | | | |
| Mean ± SE | 9.61 ± 0.30 | 9.54 ± 0.31 | 9.37 ± 0.26 | 9.38 ± 0.24 | | | | |

*G* group, *P* period, *G* × *P* interaction between group and period, *SE* standard error, $SP_0$ concentrate mixture without sugarcane press mud (control), $SP_{10}$ concentrate mixture with 10% sugarcane press mud, $SP_{20}$ concentrate mixture with 20% sugarcane press mud

**Table 5** Economic feasibility in lambs-fed graded levels of sugarcane press mud

| Particular | $SP_0$ | $SP_{10}$ | $SP_{20}$ | *P* value |
|---|---|---|---|---|
| Concentrate mixture (Rs/day)* | 9.46a ± 0.28 | 8.62b ± 0.28 | 7.61c ± 0.19 | 0.01 |
| Wheat straw (Rs/day) | 1.23 ± 0.03 | 1.24 ± 0.03 | 1.27 ± 0.02 | 0.71 |
| Total feed cost (Rs/day) | 10.7a ± 0.31 | 9.86b ± 0.10 | 8.88c ± 0.22 | 0.01 |
| Total gain (kg) | 13.0 ± 0.44 | 12.8 ± 0.48 | 11.8 ± 0.53 | 0.17 |
| Feed cost (Rs/kg gain) | 148.8 ± 6.48 | 139.6 ± 4.95 | 137.2 ± 5.16 | 0.32 |

$SP_0$ concentrate mixture without sugarcane press mud (control), $SP_{10}$ concentrate mixture with 10% sugarcane press mud, $SP_{20}$ concentrate mixture with 20% sugarcane press mud

Means bearing different letters within a row differ significantly at $P \leq 0.05$

*Based on current market prices (Rs/kg fresh ingredients): maize 15, wheat bran 14, soya bean meal 36, sugarcane press mud 1, mineral mixture 50, salt 5 and wheat straw 4.5

formulation was to keep uniform nutrient levels across the groups, which resulted in similar nutritive value and ultimately yielded non-significant wool production by lambs.

Thyroid hormones, being biomarkers of basal metabolism, did not vary among the groups implying normal metabolic activities in the body. Todini et al. (2007) have reported a direct relationship of DMI with circulating levels of $T_3$ and $T_4$, and the present results demonstrate absence of any negative impact of dietary treatments on thyroid functions.

The feed cost of live weight gain is largely dependent on the cost of feed and FCR. The data revealed that feeding SPM in concentrate mixture up to 20% decreases the cost of feeding in lambs, bearing a direct implication over farm profitability. In agreement with the present data, Mohamed and El-Saidy (2003) and Malapure (2015) have formulated economically feasible diets using SPM for lactating goats and crossbred calves, respectively.

In summary, the present study concludes that the dietary utilisation of SPM up to 20% in the concentrate mixture of lambs could be possible without exerting any deleterious effects on intake, digestibility, N metabolism, growth as well as wool production. Therefore, in addition to economising the ration, promoting SPM as an alternative feed ingredient could potentially help cut down the negative environmental consequences associated with its disposal, thereby proving win-win situation.

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**Compliance with ethical standards**

**Conflict of interest** All authors of present study declare that there is no financial or any other conflict of interest.

**Ethical approval** The experimental design and plan of the present study was approved by the Academic Council and strictly followed the norms of Institutional Animal Ethics Committee (IAEC) of Indian Veterinary Research Institute (IVRI), Izatnagar, UP, India.

## References

Ankita, Saha, S.K., Malapure, C.D., Sahoo, S., 2015. Effect of feeding sugarcane press mud on dry matter intake, FCR and average daily gain in goat. Indian Veterinary Journal, 92, 90–91

AOAC, 2005. Official Methods of Analysis of AOAC International, 18th revised edition. AOAC International, Gaithersburg

Castillo, A.R., Kebreab, E., Beever, D.E., France, J., 2000. A review of efficiency of nitrogen utilisation in lactating dairy cows and its relationship with environmental pollution. Journal of Animal and Feed Sciences, 9, 1–32

Chopra, I.J., Solomon, D.H., Ho, R.S., 1971. A radioimmunoassay of triiodothyronine. Journal of Clinical Endocrinology and Metabolism, 33, 865

Dotaniya M.L., Datta, S.C., Biswas, D.R., Dotaniya, C.K., Meena, B.L., Rajendiran, S., Regar, K.L., Lata, M., 2016. Use of sugarcane industrial by-products for improving sugarcane productivity and soil health. International Journal of Recycling Organic Wastes in Agriculture 5, 185–194

Gami, R., Thakur, S.S., Mahesh, M.S., 2015. Protein sparing effect of dietary rumen protected lysine plus methionine in growing Murrah buffaloes (*Bubalus bubalis*). Proceedings of the National Academy of Sciences, India, Section B: Biological Sciences, DOI 10.1007/s40011-015-0662-2 (in press)

Gupta, N.S., Ahuja, A.K., 1998. Use of sugarcane press mud as cattle feed. Feed Trends, 15, 6

ICAR, 2013. Nutrient Requirements of Sheep, Goat and Rabbit. Indian Council of Agricultural Research, Krishi Anusandhan Bhawan, Pusa, New Delhi, India

Khan, M.J., Abbas, A., Ayaz, M., Naeem, M., Akhter, M.S., Soomro, M.H., 2012. Factors affecting wool quality and quantity in sheep. African Journal of Biotechnology, 73, 13761–13766

Kumar, R., Thakur, S.S., Mahesh, M.S., 2016. Rice gluten meal as an alternative by-product feed for growing dairy calves. Tropical Animal Health and Production 48, 619–624

Makkar, H.P.S., 2016. Smart livestock feeding strategies for harvesting triple gain – the desired outcomes in planet, people and profit dimensions: a developing country perspective. Animal Production Science, 56, 519–534

Malapure, C.D., 2015. Evaluation of sugarcane press mud as a feed resource in crossbred calves. Ph.D. thesis submitted to Deemed University, ICAR- Indian Veterinary Research Institute, Izatnagar, UP, India

Mohamed, A.H., El-Saidy, B.E., 2003. Effect of including filter cake blocks in lactating goats rations on digestibility and productive performance. Egyptian Journal of Nutrition Feeds, 6, 59–67

Morrison, F.B., 1961. Feeds and Feeding, Abridged. 9th ed. Morrison Publ. Co., Clinton, IA, USA

Niven, D.R., Pritchard, D.A., 1985. Effect of control of the sheep body louse (*Damalinia ovis*) on wool production and quality. Australian Journal of Experimental Agriculture, 25, 27–31

Owens, F.N., Sapienza, D.A., Hassen, A.T., 2010. Effect of nutrient composition of feeds on digestibility of organic matter by cattle: A review. Journal of Animal Science 88, E151-E69

Sahoo, A., Bhat, R.S., Tripathi, M.K., 2015. Stall feeding in small ruminants: emerging trends and future perspectives. Indian Journal of Animal Nutrition 32, 353–372

Sahu, S., Patel, B.H.M., Dutta, T., Verma, A.K., 2014. Effect of graded levels of sugarcane press mud in ration on carcass characteristics of crossbred (Landrace × Desi) pigs. Indian Journal Animal Sciences, 84, 1109–1112

SAS, 2012. User's Guide: Statistics. Version 9.3, Statistical Analysis System, SAS Institute, Cary, New York, USA

Sharma, V.C., Mahesh, M.S., Mohini, M., Datt, C., Nampoothiri, V.M., 2014. Nutrient utilisation and methane emissions in Sahiwal calves differing in residual feed intake. Archives of Animal Nutrition, 68, 345–357

Soloman, S., 2011. Sugarcane by-products based industries in India. Sugar Tech, 13, 408–416

Suma, N., Reddy, B.S.V., Doss, R.G.G., Rao, R., Singh, K.C., Rekha, M.T., Gomes, A.R., 2007. Egg quality traits of layers influenced by supplementation of different levels of sugarcane press residue. International Journal of Poultry Science, 6, 102–106

Suma, N., Reddy, B.S.V., Doss, R.G.G., Prabhu, T.M., Kumar, C.B., Suresh, B.N., Shilpa, V.T., 2015. Egg shell and yolk quality characteristics of layers fed with sugarcane press residue in soya and fish-based diets. Veterinary World, 8, 232–238

Suresh, B.N., Reddy, B.S.V., 2011. Dried sugarcane press residue as a potential feed ingredient source of nutrients for poultry. Asian-Australasian Journal of Animal Sciences, 24, 1595–1600

Suresh, B.N., Reddy, B.S.V., Prabhu, T.M., Gloridoss, R.G., Jagadish, B., 2006. Nutritional evaluation of sugarcane press mud in lambs. Indian Journal of Animal Nutrition, 23, 47–49

Talapatra, S.K., Ray, S.C., Sen, K.C., 1940. The analysis of mineral constituents in biological materials. Indian Journal of Veterinary Science and Animal Husbandry, 10, 143–158

Todini L., Malfatti, A., Valbonesi, A., Trabalza-Marinucci, M., Debenedetti, A., 2007. Plasma total T3 and T4 concentrations in goats at different physiological stages, as affected by the energy intake. Small Ruminant Research, 68, 285–290

Tran, G., 2015. Sugarcane press mud. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/563 (last accessed on 08 February 2017)

Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fibre, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. Journal of Dairy Science, 74, 3583–3597