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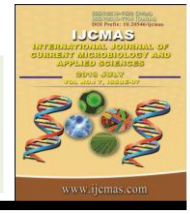


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# *In vitro* Nutrient Digestibility and Fermentation Pattern of Concentrate Mixtures Containing Incremental Levels of Sugar Beet Pulpin Goat Inoculum

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**A B S T R A C T**

The main objective of the present study was to investigate the effect of incorporation of graded levels of dried sugar beet pulp in the concentrate mixtures on *in vitro* nutrient digestibility and rumen fermentation pattern using goat inoculum. Maize grain based conventional concentrate mixture was prepared and maize grains in the concentrate mixture were replaced by dried sugar beet pulp at graded levels of 20, 40, 60, 80 and 100 per cent. The nutritional worth of various concentrate mixtures was assessed by *in vitro* gas production technique. The *in vitro* study of concentrates containing graded levels of DSBP revealed that net gas production, OM digestibility, NDF digestibility, DM digestibility and ME availability increased ($P<0.05$) with the increasing level of DSBP in the concentrate mixture. Microbial mass production in concentrate mixture 2 (20% DSBP), concentrate mixture 3 (40% DSBP), concentrate mixture 4 (60% DSBP) and concentrate mixture 5 (80% DSBP) was similar to that of control concentrate mixture 1 (0% DSBP). The *in vitro* acetic acid production increased ($P<0.05$) and propionic acid decreased ($P<0.05$) with increasing level of DSBP replacing maize grains in concentrate mixtures. The TVFA production and A:P ratio increased ($P<0.05$) with increasing level of DSBP in the concentrate mixtures. The methane production was highest ($P<0.05$) in concentrate 6 when maize grains were completely replaced with DSBP. Hence, it was concluded that dried sugar beet pulp could be considered as promising energy supplement for livestock and can replace conventional cereal grains viz., maize upto 80 % on w/w basis in the concentrate mixture without any adverse effect on nutrient digestibility, fermentation parameters and methane production.

## Introduction

India's livestock sector (512 million nos.) is one of the largest in the world. The contribution of livestock sector to the national economy in terms of Gross Domestic Product (GDP) is 4.1% (National Livestock Census, 2012). But, productivity of our animals is 20-60% lower than the global average due to improper nutrition, inadequate health-care, management and also lack of scientific breeding of animals. Half of the total losses in livestock productivity are contributed by the scarcity and fluctuating quantity and quality of year round feed supply. To provide adequate good quality feed to livestock to maintain their productivity is and will be a major challenge to agricultural scientists and policy makers all over the world.

Currently, feed and fodder are in short supply to the tune of 63% green fodder, 24% dry fodder and 76% concentrates (Patil, 2017). Thus, to meet the nutrient requirements of animals, we need to improve either the efficiency of utilization of already existing feed ingredients/nutrients or need to tap new non-conventional feed resources.

Sugar beet pulp is a by-product from the processing of sugar beets into sugar. It is used as livestock feed and it can be fed fresh, dried and ensiled (fermented beet pulp). It contains highly digestible fiber which is suited to ruminants as it maintains rumen conditions and encourages acetate production.

The present work examines the effect of replacement of maize grains with dried sugar beet pulp in the concentrate mixtures at graded levels on *in vitro* nutrient digestibility, methane production and rumen fermentation parameters in goat inoculum.

## Materials and Methods

### Sample collection and preparation

Maize based conventional concentrate mixture containing maize grains 35, soybean meal 27, wheat bran 13.75, rice polish 7.25, deoiled rice bran 13, bypass fat 1.0, mineral mixture 2 common salt 1 part each was prepared. Maize grains in the conventional concentrate mixture were replaced by dried sugar beet pulp at graded levels of 20, 40, 60, 80 and 100 per cent on w/w basis to prepare 6 concentrate mixtures (Table 1).

### Proximate and cell wall constituents

Concentrate mixtures were analysed for dry matter (DM), Kjeldahl N, ether extract (EE) and total ash content using the standard procedures (AOAC, 2005). Crude protein (CP) content of samples was determined as Kjeldahl N × 6.25 by digesting in sulphuric acid and digestion mixture (consisting of sodium/potassium sulphateandcoppersulphatein10:1ratio) using semiauto-analyser (Kel PlusClassic-DX, Pelican). Cell wall fractions, *viz.* NDF, ADF, cellulose and lignin were estimated sequentially using the standard procedure (Van Soest *et al.*, 1991). NDF and ADF were expressed inclusive of residual ash. Lignin was determined by solublization of cellulose with 72 per cent sulphuric acid. Acid detergent insoluble protein and neutral detergent insoluble protein were determined as per Licitra *et al.*, (1996).

### *In vitro* evaluation

The nutritional worth of various concentrates formulated was assessed by *in vitro* gas production technique (Menke *et al.*, 1979; Menke and Steingass, 1988). Rumen contents of goats (maintained mainly on tree leaves and available grains like sorghum, maize, wheat and bajra) were collected from slaughter house. Two sets of samples were incubated in triplicates. In the I$^{st}$ set, about 375 mg of the ground sample (dry matter basis) was incubated at 39°C for 24h in triplicate in 100 ml calibrated glass syringes with buffered rumen fluid for assessing the net gas production, digestibility of nutrients and metabolizable energy (ME) availability. Individual volatile fatty acids were determined by using GLC equipped with a glass column (6 ft length and 1/8 inch diameter) packed with chromosorb 101. Samples were prepared by adding 0.2 ml of 25% metaphosphoric acid per ml of rumen liquor, allowing it to stand for

2 h followed by centrifugation at 4000 rpm for 7 min. Supernatant was used for estimation of individual volatile fatty acids (IVFA).

In the 2nd set, total gas production was recorded after 24 h of incubation. From the headspace of each syringe, 100 µl gas was collected by puncturing the silicon tube and injected in gas chromatograph for the estimation of methane. Standard calibration gas (Sigma gases, New Delhi) consisted of equal proportion of methane and carbon dioxide. The flow rates for nitrogen, hydrogen and zeroair were 30, 30, 320 ml/min respectively. Blank and standard hay (berseem hay) were run in triplicate with each set.

### Statistical analysis

The data were subjected to one-way analysis of variance procedure of SAS (2003) using the linear model. The post-hoc comparison of means was done for the significant difference by Tukey's b. Significant differences of treatments were considered at P<0.05 level.

## Results and Discussion

### Chemical composition of experimental concentrate mixtures

The chemical composition of various concentrates formulated is presented in Table 2. The OM of concentrates varied from 91.23 to 91.77%. The CP content of concentrates varied from 22.52 to 23.44 %. The ether extract content of the concentrate mixtures was in the range of 3.04 to 3.35%. The NDF content varied from 29.00 to 39.20%. All the concentrate mixtures prepared were isonitrogeneous and isoenergetic. The total carbohydrates (TCHO) in concentrate mixtures varied from 64.74 to 65.81% whereas the non-fiber carbohydrates (NFC) of the concentrate mixtures varied from 26.36 to 35.74%.

### *In vitro* evaluation

### Net gas production

The net gas production was higher (P<0.05) (229.24ml/g DM/ 24h) in concentrate mixtures containing graded levels of DSBP replacing maize grains as compared to concentrate mixture 1 (control) (Table 3). However, the NGP in concentrate mixture 3 (40% DSBP), concentrate mixture 4 (60% DSBP) and concentrate mixture 5 (80% DSBP) was similar. The NGP in the current study increased (P<0.05) with increasing levels of DSBP inclusion. The results are in accordance to Pragya (2016) who replaced maize fodder with sugar beet silage and observed that at higher inclusion level of sugar beet silage there was increase (P<0.05) in net gas production. The amount of truly degraded substrate (TDS) was similar in all the concentrate mixtures with values ranging from 341.66 to 344.14 mg.

The partitioning factor (PF) was higher (P<0.05) in concentrate mixture 1 (3.57) as compared to experimental concentrate mixtures. However, the PF in concentrate mixture 3 (40% DSBP), concentrate mixture 4 (60% DSBP), concentrate mixture 5 (80% DSBP) and concentrate mixture 6 (100% DSBP) was similar. The PF is the ratio of organic matter degraded (mg) *in vitro* to the volume of gas (ml) produced. Pragya (2016) carried out *in vitro* evaluation of sugar beet pulp silage and maize fodder and reported that increasing inclusion level of sugar beet pulp silage decreased (P<0.05) the partitioning factor.

### Nutrient digestibility

The OM digestibility (%) was higher (P<0.05) in concentrate mixture 5 (83.96) and concentrate mixture 6 (84.19) than control concentrate mixture (Table 3). However, the

OMD (%) in concentrate mixture 1 (0% DSBP) and concentrate mixture 2 (20% DSBP) was similar. The NDF digestibility (%) was higher (P<0.05) in concentrate mixture 5 (80% DSBP) and concentrate mixture 6 (100% DSBP) than concentrate mixture 1 (containing 0% DSBP replacing maize grains). The microbial mass production (MMP, mg) was highest (P<0.05) (106.73) in concentrate mixture 1 whereas MMP was lowest (P<0.05) in concentrate mixture 6 (98.79) containing 100% DSBP replacing maize grains. However, the MMP in concentrate mixture 2 (20% DSBP), concentrate mixture 3 (40% DSBP), concentrate mixture 4 (60% DSBP) and concentrate mixture 5 (80% DSBP) was similar.

The EMMP (%) was higher (P<0.05) in concentrate mixture 1 (38.42) than DSBP containing concentrate mixtures. However, the EMMP in concentrate mixture 3 (40% DSBP), concentrate mixture 4 (60% DSBP), concentrate mixture 5 (80% DSBP) and concentrate mixture 6 (100% DSBP) was similar.

The DM digestibility increased (P<0.05) with increasing level of DSBP in the concentrate mixtures evaluated. However, the DMD in concentrate mixture 3 (40% DSBP) and concentrate mixture 4 (60% DSBP) was similar. The SCFA (mmole) production was highest (P<0.05) in concentrate mixture 6 (1.01) whereas SCFA was lowest (P<0.05) in concentrate mixture 1 (0.92) containing 0% DSBP replacing maize grains. However, the SCFA in concentrate mixture 3 (40% DSBP), concentrate mixture 4 (60% DSBP) and concentrate mixture 5 (80% DSBP) was similar. However, Munnich *et al* (2017) observed that SCFA concentration was not affected when maize grains were replaced with sugar beet pulp. The ME (MJ/kg DM) availability was highest (P<0.05) in concentrate mixture 6 (10.14) whereas ME availability was lowest (P<0.05) in concentrate mixture 1 (9.76) containing 0% DSBP replacing maize grains indicating that ME availability increased (P<0.05) with increasing level of DSBP in the concentrate mixture. Kilic and Saricicek (2011) reported that there was higher (P<0.05) ME in untreated sugar beet pulp as compared to sugar beet pulp treated with additives. The ammonia nitrogen (mg/dl) in the current study was highest (P<0.05) in concentrate mixture 6 (24.70) and it was lowest (P<0.05) in concentrate mixture 1 (19.50) containing 0% DSBP replacing maize grains. However, $NH_3$-N in concentrate mixture 3 (40% DSBP), concentrate mixture 4 (60% DSBP) and concentrate mixture 5 (80% DSBP) was similar.

## Individual volatile fatty acids

The effect of levels of DSBP in total mixed rations on total and individual volatile fatty acids is presented in (Table 4). The acetic acid production (mM/dl) was highest (P<0.05) in concentrate mixture 6 (5.02) whereas acetic acid level was lowest (P<0.05) in concentrate mixture 1 (4.12) containing 0% DSBP replacing maize grains. However, acetic acid in concentrate mixture 4 (60% DSBP) and concentrate mixture 5 (80% DSBP) was similar. However, Munnich *et al* (2017) reported that acetic acid concentration was not affected when maize grains were replaced with dried sugar beet pulp. In other study, Pragya (2016) reported that the production of acetic acid increased (P<0.05) with increased supplementation of ensiled sugar beet pulp replacing maize fodder *in vitro*.

The propionic acid production (mM/dl) was highest (P<0.05) in concentrate mixture 1 (2.11) whereas propionic acid was lowest (P<0.05) in concentrate mixture 6 (1.88) containing 100% DSBP replacing maize grains. However, propionic acid in concentrate mixture 4 (60% DSBP) and concentrate mixture 5 (80% DSBP) was similar. The isobutyric acid (mM/dl) was higher (P<0.05) in concentrate mixture 1 (0.048) than other concentrate mixtures evaluated. However, isobutyric acid in concentrate mixture 4 (60% DSBP), concentrate mixture 5 (80% DSBP) and concentrate mixture 6 (100% DSBP) was similar. The isobutyric acid decreased (P<0.05) with increasing level of sugar beet pulp in in the diet.

The butyric acid (mM/dl) was highest (P<0.05) in concentrate mixture 1 (0.599) whereas it was lowest (P<0.05) in concentrate mixture 6 (0.552) containing 100% DSBP replacing maize grains. The butyric acid followed the trend similar to isobutyric acid and declined (P<0.05) with increasing level of DSBP in the concentrate mixture. However, Pragya (2016) reported that by replacing maize fodder with different levels of sugar beet pulp (0:100, 20:80, 40:60, 60:40, 80:20 and 100:0), there was increase (P<0.05) in butyric acid proportion with increased level of sugar beet pulp. In other study, Munnich *et al* (2017) reported that there was increased proportion of butyric acid when maize grains were replaced with sugar beet pulp.

The iso valeric acid varied significantly (P<0.05) among the concentrate mixtures evaluated with highest (P<0.05) value in the concentrate mixture 5 (80% DSBP). The valeric acid production (mM/dl) was highest (P<0.05) in concentrate mixture 6 (0.096) whereas valeric acid was lowest (P<0.05) in concentrate mixture 1 (0.090) containing 0% DSBP replacing maize grains. The valeric acid increased (P<0.05) with increasing level of DSBP in the concentrate mixture.

The TVFA production (mM/dl) was highest (P<0.05) in concentrate mixture 6 (100% DSBP) (7.69) whereas the TVFA was lowest (P<0.05) in concentrate mixture 1 containing 0% DSBP replacing maize grains. TVFA production increased (P<0.05) with increasing level of DSBP in the concentrate mixtures. Hend and Kholif (2015) reported that in the *in vitro* study, there was higher production of TVFA in sugar beet pulp treated with fungus, yeast and bacteria as compared to untreated sugar beet pulp. The A: P ratio was highest (P<0.05) in concentrate mixture 6 (2.67) whereas A: P ratio was lowest (P<0.05) in concentrate mixture 1 (1.95) containing 0% DSBP replacing maize grains. The A: P ratio increased (P<0.05) with increasing level of DSBP in the concentrate mixture.

The relative proportion (%) of acetic acid was highest (P<0.05) in concentrate mixture 6 (65.23) whereas AA% was lowest (P<0.05) in concentrate mixture 1 (58.14) containing 0% DSBP replacing maize grains. The acetic acid proportion increased (P<0.05) with increasing level of DSBP in the concentrate mixture. The relative proportion (%) of propionic acid was highest (P<0.05) in concentrate mixture 1 (29.79) whereas it was lowest (P<0.05) in concentrate mixture 6 (24.47) containing 100% DSBP replacing maize grains. However, propionic acid proportion in concentrate mixture 4 (60% DSBP) and concentrate mixture 5 (80% DSBP) was similar. The molar proportion of propionic acid decreased (P<0.05) with increasing level of DSBP in the concentrate mixture. The relative proportion (%) of butyric acid varied significantly (P<0.05) among the concentrate mixtures evaluated and was lowest (P<0.05) in concentrate mixture 6 (100% DSBP).

## Methane production

The methane (%) was highest (P<0.05) in concentrate mixture 6 (16.74) containing 100% DSBP replacing maize grains than other concentrate mixtures evaluated (Table 5). However, methane (%) in concentrate mixture 2 (20% DSBP) and concentrate mixture 3 (40% DSBP) and concentrate mixture 4 (60% DSBP) was similar. The methane production followed an increasing (P<0.05) trend with higher inclusion of DSBP in the concentrate mixtures.

## *In vitro* fermentation parameters

The fermentable $CO_2$ (mmole) was lower (P<0.05) in concentrate mixture 1 (0% DSBP) and concentrate mixture 2 (20% DSBP) than other concentrate mixtures evaluated (Table 6). But, beyond that level, the fermentable $CO_2$ increased (P<0.05) in concentrate mixtures 3, 4, 5 and 6 containing 40, 60, 80 and 100% DSBP respectively, replacing maize grains. The fermentable $CH_4$ (mmole) was highest (P<0.05) in concentrate mixture 6 (100% DSBP). The fermentable $CH_4$ (mmole) was lowest in concentrate mixture 1 (0% DSBP) replacing with maize grain. However, fermentable $CH_4$ (mmole) in concentrate mixture 4 (60% DSBP) and concentrate mixture 5 (80% DSBP) was similar.

The H-recovery was highest (P<0.05) in concentrate mixture 1 (0% DSBP). The H-recovery was lowest (P<0.05) in concentrate mixture 6 (100% DSBP replacing with maize grain). However, H-recovery in concentrate mixture 4 (60% DSBP) and concentrate mixture 5 (60% DSBP) was similar. H-recovery decreased (<0.05) with increasing level of DSBP in the concentrate mixture.

The H consumed via CH4 was highest (P<0.05) in concentrate mixture 6 (100% DSBP). However, the H-consumed via CH4 was similar in other concentrate mixtures evaluated. The fermentation efficiency was highest (P<0.05) in concentrate mixture 1 (0% DSBP). The fermentation efficiency was lowest (P<0.05) in concentrate mixture 6 (100% DSBP replacing maize grains). The fermentation efficiency decreased (P<0.05) with increasing level of DSBP in the concentrate mixtures.

**Table.1** Ingredient composition of concentrate mixtures (parts/100 parts)

| Ingredient | CONC 1 | CONC 2 | CONC 3 | CONC 4 | CONC 5 | CONC 6 |
|---|---|---|---|---|---|---|
| **Maize** | 35.00 | 28.00 | 21.00 | 14.00 | 7.00 | 0 |
| **Soyabean meal** | 27.00 | 27.00 | 27.00 | 27.00 | 27.00 | 27.00 |
| **Sugar beet pulp** | 0 | 7.00 | 14.00 | 21.00 | 28.00 | 35.00 |
| **Wheat bran** | 13.75 | 13.75 | 13.75 | 13.75 | 13.75 | 13.75 |
| **Rice polish** | 7.25 | 7.00 | 6.75 | 6.60 | 6.50 | 6.25 |
| **Deoiled rice bran** | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| **By-pass fat** | 1.00 | 1.25 | 1.50 | 1.65 | 1.75 | 2.00 |
| **Mineral mix.** | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| **Salt** | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

**Table.2** Chemical composition of concentrates mixtures containing graded levels of DSBP, % DM basis

| Parameters | CONC 1 | CONC 2 | CONC 3 | CONC 4 | CONC 5 | CONC 6 |
|---|---|---|---|---|---|---|
| **OM** | 91.53 | 91.77 | 91.66 | 91.58 | 91.45 | 91.23 |
| **CP** | 23.44 | 23.16 | 22.72 | 22.52 | 22.87 | 22.54 |
| **EE** | 3.35 | 3.13 | 3.17 | 3.25 | 3.04 | 3.13 |
| **Total ash** | 8.47 | 8.23 | 8.38 | 8.42 | 8.55 | 8.77 |
| **NDF** | 29.00 | 32.80 | 34.67 | 36.73 | 38.27 | 39.20 |
| **ADF** | 11.33 | 12.87 | 15.40 | 16.7 | 18.90 | 20.17 |
| **Hemicellulose** | 17.67 | 19.93 | 19.27 | 20.57 | 19.37 | 19.03 |
| **ADL** | 2.60 | 3.00 | 3.30 | 3.46 | 3.47 | 3.57 |
| **TCHO** | 64.74 | 65.48 | 65.73 | 65.81 | 65.54 | 65.56 |
| **NFC** | 35.74 | 32.68 | 31.06 | 29.08 | 27.27 | 26.36 |

OM-organic matter, CP- crude protein, EE- ether extract, NDF- neutral detergent fibre, ADF- acid detergent fibre, ADL- acid detergent lignin, TCHO- total carbohydrates, NFC-non fibre carbohydrates

**Table.3** *In vitro* utilization of nutrients of concentrate mixtures containing graded levels of DSBP (24 h)

| Parameter | CONC 1 | CONC 2 | CONC 3 | CONC 4 | CONC 5 | CONC 6 | SEM |
|---|---|---|---|---|---|---|---|
| **NGP, ml/g DM/ 24h** | $207.61^{a}$ | $213.33^{a}$ | $220.29^{b}$ | $221.71^{b}$ | $224.00^{bc}$ | $229.24^{c}$ | 2.18 |
| **TDS, mg** | 342.78 | 344.14 | 343.12 | 343.92 | 342.94 | 341.66 | 0.31 |
| **PF, mg/ml** | $3.57^{b}$ | $3.48^{ab}$ | $3.41^{a}$ | $3.42^{a}$ | $3.43^{a}$ | $3.35^{a}$ | 0.02 |
| **OMD,%** | $81.04^{a}$ | $80.82^{a}$ | $82.08^{ab}$ | $82.70^{b}$ | $83.96^{c}$ | $84.19^{c}$ | 0.40 |
| **NDFD,%** | $40.15^{a}$ | $46.34^{b}$ | $52.64^{c}$ | $56.86^{d}$ | $61.67^{e}$ | $63.22^{e}$ | 2.48 |
| **MMP, mg** | $106.73^{b}$ | $102.14^{ab}$ | $100.12^{ab}$ | $101.27^{ab}$ | $103.14^{ab}$ | $98.79^{a}$ | 0.85 |
| **EMMP,%** | $38.42^{b}$ | $36.72^{ab}$ | $35.55^{a}$ | $35.61^{a}$ | $35.82^{a}$ | $34.34^{a}$ | 0.40 |
| **DMD,%** | $80.51^{a}$ | $80.8^{a}$ | $82.11^{b}$ | $82.96^{b}$ | $84.27^{c}$ | $85.05^{c}$ | 0.51 |
| **SCFA, mmole** | $0.92^{a}$ | $0.94^{a}$ | $0.97^{b}$ | $0.98^{b}$ | $0.99^{bc}$ | $1.01^{c}$ | 0.01 |
| **ME, MJ/kgDM** | $9.76^{a}$ | $9.85^{ab}$ | $9.96^{abc}$ | $10.01^{bc}$ | $10.02^{bc}$ | $10.14^{c}$ | 0.04 |
| **$NH_3$-N, mg/dl** | $19.50^{a}$ | $21.00^{ab}$ | $22.85^{bc}$ | $23.63^{c}$ | $24.10^{c}$ | $24.70^{c}$ | 0.57 |

NGP- Net gas production, TDS-truly degraded substrate, PF- partition factor, D- digestibility, OM- organic matter, NDF- neutral detergent fibre, MMP- microbial mass production, EMMP- efficiency of microbial mass production, DM-dry matter, SCFA- short chain fatty acids, ME- metabolizable energy $NH_3$-N-ammonical nitrogen, Means bearing different superscripts in a row differ significantly ($P<0.05$)

**Table.4** In vitro volatile fatty acids production (mM/dl) in concentrate mixtures containing graded levels of DSBP (24 h)

| Parameter | CONC 1 | CONC 2 | CONC 3 | CONC 4 | CONC 5 | CONC 6 | SEM |
|---|---|---|---|---|---|---|---|
| **Acetate** | $4.12^{a}$ | $4.20^{b}$ | $4.46^{c}$ | $4.57^{d}$ | $4.62^{d}$ | $5.02^{e}$ | 0.09 |
| **Propionate** | $2.11^{e}$ | $2.07^{d}$ | 1.95c | 1.91b | 1.91b | 1.88a | 0.03 |
| **Isobutyrate** | $0.048^{d}$ | $0.044^{c}$ | $0.040^{b}$ | $0.032^{a}$ | $0.034^{a}$ | $0.032^{a}$ | 0.002 |
| **Butyrate** | $0.599^{d}$ | $0.582^{c}$ | $0.581^{c}$ | $0.576^{bc}$ | $0.570^{b}$ | $0.552^{a}$ | 0.004 |
| **Isovalerate** | $0.118^{d}$ | $0.116^{c}$ | $0.116^{bc}$ | $0.115^{b}$ | $0.121^{e}$ | $0.113^{a}$ | 0.001 |
| **Valerate** | $0.090^{a}$ | $0.091^{ab}$ | $0.090^{ab}$ | $0.094^{bc}$ | $0.093^{abc}$ | $0.096^{c}$ | 0.001 |
| **TVFA** | $7.08^{a}$ | $7.10^{a}$ | $7.24^{b}$ | $7.30^{bc}$ | $7.35^{c}$ | $7.69^{d}$ | 0.06 |
| **A:P** | $1.95^{a}$ | $2.03^{b}$ | $2.29^{c}$ | $2.39^{d}$ | $2.42^{d}$ | $2.67^{e}$ | 0.07 |
| Relative proportion, % | | | | | | | |
| **Acetate** | $58.14^{a}$ | $59.17^{b}$ | $61.64^{c}$ | $62.60^{d}$ | $62.84^{d}$ | $65.23^{e}$ | 0.71 |
| **Propionate** | $29.79^{e}$ | $29.10^{d}$ | $26.94^{c}$ | $26.20^{b}$ | $26.02^{b}$ | $24.47^{a}$ | 0.55 |
| **Isobutyrate** | $0.678^{d}$ | $0.615^{c}$ | $0.554^{b}$ | $0.443^{a}$ | $0.457^{a}$ | $0.419^{a}$ | 0.029 |
| **Butyrate** | $8.462^{e}$ | $8.199^{d}$ | $8.023^{c}$ | $7.894^{bc}$ | $7.756^{b}$ | $7.170^{a}$ | 0.122 |
| **Isovalerate** | $1.662^{d}$ | $1.635^{c}$ | $1.597^{b}$ | $1.579^{b}$ | $1.650^{cd}$ | $1.465^{a}$ | 0.001 |
| **Valerate** | 1.272 | 1.280 | 1.247 | 1.288 | 1.272 | 1.246 | 0.006 |

TVFA-Total volatile fatty acids, A:P- acetate: propionate, Means bearing different superscripts in a row differ significantly (P<0.05)

**Table.5** Methane production from fermentation of concentrate mixtures containing graded levels of DSBP (24 h)

| Parameters | CONC 1 | CONC 2 | CONC 3 | CONC 4 | CONC 5 | CONC 6 | SEM |
|---|---|---|---|---|---|---|---|
| **$CH_4$, %** | $15.48^{a}$ | $15.68^{ab}$ | $15.82^{ab}$ | $15.92^{ab}$ | $16.22^{b}$ | $16.74^{c}$ | 0.13 |
| **$CH_4$, ml/100mg DM** | $3.21^{a}$ | $3.35^{ab}$ | $3.49^{bc}$ | $3.53^{bc}$ | $3.63^{c}$ | $3.84^{d}$ | 0.06 |
| **$CH_4$, ml/100mg DMD** | $3.99^{a}$ | $4.14^{ab}$ | $4.24^{abc}$ | $4.25^{abc}$ | $4.31^{bc}$ | $4.51^{c}$ | 0.05 |
| **$CH_4$,ml/100mg OMD** | $4.33^{a}$ | $4.51^{ab}$ | $4.64^{b}$ | $4.66^{b}$ | $4.73^{bc}$ | $5.00^{c}$ | 0.06 |

Means bearing different superscripts in a row differ significantly (P<0.05)

**Table.6** Fermentation parameters and hydrogen balance of concentrate mixtures containing graded levels of DSBP (24h)

| Parameter | CONC 1 | CONC 2 | CONC 3 | CONC 4 | CONC 5 | CONC 6 | SEM |
|---|---|---|---|---|---|---|---|
| **Fer $CO_2$, mmoles** | 49.21[a] | 49.16[a] | 49.59[bc] | 49.69[c] | 49.56[bc] | 49.49[b] | 0.06 |
| **Fer $CH_4$, mmoles** | 25.85[a] | 26.41[b] | 28.09[c] | 28.69[d] | 28.80[d] | 30.08[e] | 0.44 |
| **H-Recovery, %** | 78.77[e] | 78.26[d] | 76.37[c] | 75.64[b] | 75.27[b] | 72.50[a] | 0.62 |
| **HC *via* $CH_4$/VFA** | 6.07[a] | 6.03[a] | 6.05[a] | 6.05[a] | 6.06[a] | 6.16[b] | 0.01 |
| **FE, %** | 78.10[e] | 77.74[d] | 76.73[c] | 76.36[b] | 76.26[b] | 75.43[a] | 0.27 |
| **VFA UI** | 2.46[a] | 2.53[b] | 2.80[c] | 2.90[d] | 2.92[d] | 3.14[e] | 0.07 |

Fer- Fermentable, H- Hydrogen, FE- Fermentation efficiency, VFA UI- volatile fatty acids utilization index, Means bearing different superscripts in a row differ significantly (P<0.05)

The VFA utilization index (VFA UI) was highest (P<0.05) in concentrate mixture 6 (100% DSBP). The VFA UI was lowest (P<0.05) in concentrate mixture 1 (0% DSBP replacing with maize grain). However, VFA UI in concentrate mixture 4 (60% DSBP) and concentrate mixture 5 (80% DSBP) was similar. The VFA UI followed a trend reverse to that of fermentation efficiency. The VFA UI is the ratio of non-glucogenic to glucogenic VFAs. The VFA UI might be increasing (P<0.05) due to higher acetate and lower propionate production with increased level of inclusion of DSBP in the concentrate mixtures.

The results conclusively revealed that dried sugar beet pulp can be safely used as a replacement of maize grains up to 80 percent on w/w basis in the diet of goats without any adverse effect on the *in vitro* nutrient digestibility, rumen fermentation parameters and methane production.

**Conflict of interest**

The authors declare no conflict of interest.

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