

Nutrient Profiling and *In-Vitro* Fermentation Dynamics of Maize, Bajra, Soybean Meal, and CoFS-31 Fodder used in Stall-Fed Sheep Systems

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ABSTRACT

Efficient lamb production relies on balanced rations using local feed resources. The present study evaluated the proximate composition, fibre fractions, and *in-vitro* metabolizable energy (ME) using standard laboratory protocols for commonly used feed ingredients such as maize, bajra, soybean meal (SBM), and CoFS-31 fodder used in stall-fed sheep production systems in northern Karnataka. Crude protein (CP) varied widely from 4.10% in CoFS-31 to 46.06% in SBM. Maize and bajra showed comparable CP contents (8.29% and 8.33%) and low crude fibre (2.21-2.29%), indicating their high energy potential. Gas production increased with incubation time in all samples, showing a rapid rise between 4 to 12 h and stabilizing thereafter. Net gas production (mL/g DM) was higher for maize (324.95), followed by bajra (311.55), SBM (243.05), and CoFS-31 (152.10). Corresponding ME values (MJ/kg DM) were 12.62, 12.22, 12.34, and 7.19, respectively. SBM recorded the higher digestibility (IVDMD 73.08%; IVOMD 79.33%), while CoFS-31 exhibited high fibre (NDF 59.73%) and lower ME, confirming its role as structural roughage. Overall, maize and bajra are rich in fermentable carbohydrates, SBM is an excellent protein source, and CoFS-31 provides essential fibre. A balanced combination of these feeds offers a region-specific, economical, and nutritionally efficient ration to enhance sheep productivity in northern Karnataka.

Key words: Bajra, CoFS-31, Maize, Metabolizable energy, Proximate composition, Soybean meal.

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INTRODUCTION

In Karnataka, most semi-intensive and intensive sheep rearing systems depend on a limited range of feed resources - typically one or two cereal fodders, cereal grains, and an oilseed cake. The use of compounded feed mixtures as part of the ration remains limited, mainly due to their higher cost, limited availability in rural markets, and lack of awareness among farmers about balanced ration formulation. In the northern region of the state, cereal grains such as maize and bajra serve as the major energy sources, while oilseed cake like SBM is commonly used as a protein supplement. Dry fodder such as CoFS-31 is preferred due to its high yield potential and year-round availability (Dombar *et al.*, 2022). These feed components form the foundation of most stall-fed and semi-intensive sheep rearing systems in the region, where farmers depend on locally available, cost-effective, and familiar feed resources to meet the nutritional needs of their flocks.

Ensuring balanced nutrition that supports optimal growth, feed utilization, and overall performance in sheep requires efficient ration formulation based on accurate information about the chemical composition and energy value of feed ingredients. However, the nutrient composition and energy content of feeds can vary considerably due to varietal, environmental, and agronomic factors (ICAR, 2013; Langyan *et al.*, 2022; Patil *et al.*, 2022). To address this variability and support region-specific ration formulation

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using maize, bajra, soybean meal, and CoFS-31, being economical and widely used in northern Karnataka, the present study was undertaken to evaluate the proximate composition, fibre fractions, and *in-vitro* gas production characteristics, including fermentability and ME, to assess their nutritive potential.

MATERIALS AND METHODS

Feed samples of maize, bajra, and SBM were procured locally, while CoFS-31 dry fodder (multi-cut sorghum) was harvested from the Department of Livestock Farm Complex, Veterinary

College, Bidar (Karnataka, India). CoFS-31 was shade-dried, ground through a 1 mm sieve, and all samples were stored in airtight containers for analysis. Proximate composition (DM, CP, CF, EE, TA, and NFE) was determined according to AOAC (2023), and fibre fractions (NDF, ADF, ADL) were analysed as per Van Soest *et al.* (1991), with hemicellulose and cellulose calculated by difference. *In-vitro* gas production (Menke and Steingass, 1988) was used to assess fermentability and metabolizable energy. ME (MJ/kg DM) was estimated using the regression equation:

For concentrate supplements: $ME = 1.06 + 0.1570 GP + 0.0084 CP + 0.022 EE - 0.0081 TA$

For roughages: $ME = 2.2 + 0.1357 GP + 0.0057 CP + 0.0002859 EE2$

Where, ME = Metabolizable energy, MJ/kg DM; GP = Corrected Net gas production (mL/200 mg DM); CP = Crude protein, g/kg DM; EE = Ether extract, g/kg DM; and TA = Total ash, g/kg DM.

Similarly, *In-vitro* organic matter digestibility (IVOMD) and *In-vitro* dry matter digestibility (IVDMD) were derived using standard equations:

$IVOMD (\%) = 14.88 + 0.889 \times GP + 0.45 \times CP + 0.0651 \times Ash$

$IVDMD (\%) = OM \times IVOMD/100$

Where, GP: Net gas production (mL per 200 mg DM); Ash: Total ash content (% of DM); OM: Organic matter content (% of DM)

All analyses were conducted in triplicate, and data were expressed as mean \pm standard error.

RESULTS AND DISCUSSION

The proximate composition, hourly interval basis *in-vitro* gas production, and *in-vitro* fermentation characteristics of maize and bajra are presented in the respective Tables 1, 2, and 3. The *in-vitro* gas production pattern of different feed samples at hourly incubation intervals is present graphically in Fig. 1.

Table 1: Chemical composition (% on DMB) of different feed-stuffs (n=3)

| Parameter | Maize | Bajra | SBM | CoFS-31 |
|---------------|-------|-------|-------|---------|
| DM | 90.99 | 89.93 | 89.49 | 91.74 |
| OM | 97.33 | 98.10 | 92.11 | 90.95 |
| CP | 8.29 | 8.33 | 46.06 | 4.10 |
| CF | 2.21 | 2.29 | 5.86 | 33.87 |
| EE | 3.99 | 3.78 | 1.90 | 1.90 |
| NFE | 82.84 | 83.70 | 38.29 | 51.08 |
| TA | 2.67 | 1.90 | 7.89 | 9.05 |
| AIA | 0.43 | 0.35 | 0.99 | 5.34 |
| NDF | 12.32 | 22.33 | 16.86 | 59.73 |
| ADF | 4.62 | 8.74 | 5.80 | 38.15 |
| ADL | 1.41 | 2.38 | 2.91 | 7.73 |
| Hemicellulose | 7.70 | 13.58 | 11.07 | 34.29 |
| Cellulose | 3.22 | 6.36 | 2.89 | 30.42 |

Maize and Bajra

The proximate composition of maize revealed a DM content of 90.99% and OM content of 97.33%, while the bajra DM and OM contents were 89.93% and 98.10%, respectively. Maize exhibited a higher dry matter content compared to bajra, while the organic matter (OM) content was slightly higher in bajra than in maize. The CP contents were comparable and at par in maize and bajra (Table 1), falling within the reported ranges of 7.4-9.5% for maize (Sharma *et al.*, 2022; Langyan *et al.*, 2022) and for bajra (Kishore *et al.*, 1993). The slightly higher CP values reported by other authors (9.35-12.33%) are likely influenced by soil fertility and fertilizer practices (Abiose and Ikujenioia, 2014; Ndukwe *et al.*, 2015).

The fibre fraction of maize and bajra analysis indicated NDF, ADF, and ADL contents of 12.32% and 22.33%, 4.62% and 8.74% and 1.41% and 2.91%, respectively, while hemicellulose

Table 2: *In-Vitro* gas production (mL/200 mg DM) values on an hourly interval basis of Maize, Bajra, SBM, and CoFS-31 dry fodder

| Sample | Period of fermentation and gas production | | | | | | |
|--------------------|---|------------------|------------------|------------------|------------------|------------------|------------------|
| | 2 h | 4 h | 6 h | 8 h | 12 h | 16 h | 24 h |
| Maize | 5.46 \pm 0.11 | 11.60 \pm 0.23 | 22.60 \pm 0.20 | 40.09 \pm 0.98 | 51.93 \pm 0.79 | 58.16 \pm 1.00 | 64.99 \pm 0.81 |
| Bajra | 5.44 \pm 0.10 | 10.95 \pm 0.22 | 21.15 \pm 0.03 | 36.85 \pm 0.15 | 46.79 \pm 0.13 | 55.01 \pm 0.47 | 62.31 \pm 0.48 |
| SBM | 6.64 \pm 0.23 | 15.74 \pm 0.11 | 22.05 \pm 0.04 | 29.36 \pm 0.18 | 36.60 \pm 0.16 | 43.25 \pm 1.08 | 48.61 \pm 0.41 |
| CoFS-31 Dry Fodder | 3.93 \pm 0.04 | 8.74 \pm 0.11 | 13.11 \pm 0.16 | 17.99 \pm 0.13 | 25.07 \pm 0.22 | 31.01 \pm 0.30 | 34.50 \pm 0.38 |

Table 3: *In-vitro* values of Maize, Bajra, SBM, and CoFS-31 dry fodder

| Feed sample | GP-24 (mL/g DM) | RIVGP24, (mL/200mg DM) | ME (MJ/kg DM) | IVDMD (%) | IVOMD (%) |
|--------------------|-------------------|------------------------|------------------|-----------|-----------|
| Maize | 324.95 \pm 0.81 | 64.99 \pm 0.81 | 12.62 \pm 0.13 | 74.52 | 76.56 |
| Bajra | 311.55 \pm 0.48 | 62.31 \pm 0.48 | 12.22 \pm 0.08 | 72.74 | 74.15 |
| SBM | 243.05 \pm 0.41 | 48.61 \pm 0.41 | 12.34 \pm 0.06 | 73.08 | 79.33 |
| CoFS-31 Dry Fodder | 152.10 \pm 0.38 | 34.50 \pm 0.38 | 7.19 \pm 0.05 | 43.48 | 47.80 |

GP-24: Net gas production after 24 hrs of incubation, ME: Calculated using GP-24 value, IVDMD: *In-vitro* dry matter digestibility, IVOMD: *In-vitro* organic matter digestibility.



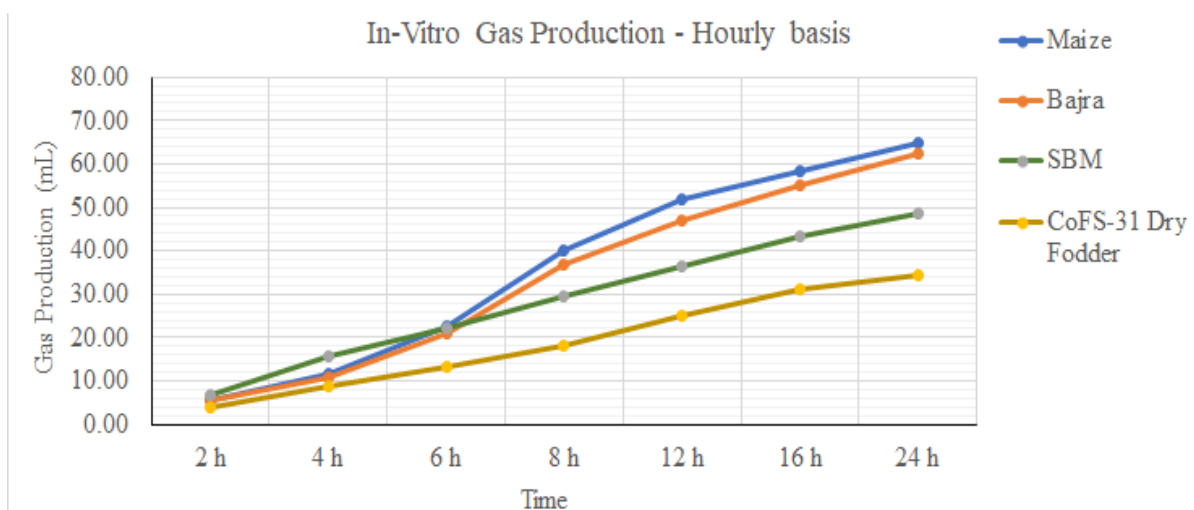


Fig. 1: *In-vitro* gas production pattern of different feed samples at hourly incubation intervals.

and cellulose were 7.70%: 13.59%, and 3.21%: 5.83%. Maize also had lower fibre content (NDF, ADF, and ADL) than bajra. Hemicellulose and cellulose followed a similar trend, indicating that bajra is slightly more fibrous. This is consistent with previous reports (Kumar *et al.*, 2012) and is likely due to differences in genotype, agro-climatic conditions, maturity stage, and analytical methods (Langyan *et al.*, 2022).

Maize exhibited a gradual and consistent increase in *in-vitro* gas production (Table 2) throughout the incubation period, reflecting its high fermentability and readily available carbohydrate content. The gas volume rose from 5.46 ± 0.11 mL/200 mg DM at 2 h and 11.60 ± 0.23 mL at 4 h, indicating active microbial fermentation initiation. The maximum gas production between intervals was observed at period 6 h (22.60 ± 0.20 mL) and 12 h (51.93 ± 0.79 mL), thereafter declining trend was observed. The maximum gas production recorded at 24 h was 64.99 ± 0.81 mL/200 mg DM. The *in-vitro* gas production of bajra followed a similar trend to maize, though with slightly lower values at all incubation intervals. The gas production increased from 5.44 ± 0.10 mL at 2 h to 10.95 ± 0.22 mL at 4 h, indicating a comparable rate of initial fermentation. Subsequently, the maximum gas production amongst time intervals was recorded between 6 h (21.15 ± 0.03 mL) to 12 h (46.79 ± 0.13 mL), and reaching a maximum of 62.31 ± 0.48 mL/200 mg DM at 24 h.

The net gas production at 24 h (Table 3) of incubation of maize was 324.95 mL/g DM with a corresponding relative *in-vitro* gas production (RIVGP24) of 64.99 mL/200 mg DM. The ME content was 12.62 MJ/kg DM, and IVDMD and IVOMD were 74.52% and 76.56%, respectively. Whereas the bajra recorded the net gas production after 24 h as 311.55 mL/g DM with an RIVGP24, of 62.31 mL/200 mg DM. The corresponding ME value of Bajra was 12.22 MJ/kg DM. The IVDMD and IVOMD were 72.74% and 74.15%, respectively. *In-vitro* gas production at 24 h was higher in maize than in bajra. Correspondingly, ME was slightly higher in maize than in bajra, while IVDMD and IVOMD also followed the same trend.

Overall, both maize and bajra are suitable energy sources for sheep, with maize providing more digestible energy and bajra offering higher fibre, making them valuable for balancing rations in stall-fed sheep production systems. Integrating both grains judiciously in feed formulations could enhance nutritional balance, cost-effectiveness, and regional sustainability in animal nutrition programs.

Soybean Meal

The proximate composition of SBM (Table 1) in the present study was consistent with reported literature values, with CP (46.06%) aligning well with the 45-48% range documented by ICAR (2013), Zagorakis *et al.* (2015), and Janocha *et al.* (2022). Minor variations in CP were attributed to differences in soybean variety, dehulling, and oil extraction processes (Lagos and Stein, 2017). EE and CF values were within standard ranges (EE 1.5-2.0%, CF 4-6%) and closely matched previous findings, though some studies reported slightly lower EE. The fibre fractions NDF, ADF, and ADL were 16.86%, 5.80%, and 2.95%, respectively, while hemicellulose and cellulose contents were 11.06% and 2.85%. Fibre fractions were also in agreement with ICAR (2013) and Zagorakis *et al.* (2015).

Soybean meal showed a distinct fermentation pattern (Table 2) characterized by relatively high initial gas production, indicating rapid microbial utilization of its soluble protein and carbohydrate fractions. The gas volume increased from 6.64 ± 0.23 mL/200 mg DM at 2 h to 15.74 ± 0.11 mL at 4 h, followed by 22.05 ± 0.04 mL at 6 h and 29.36 ± 0.18 mL at 8 h. Gas production continued to rise and reached a maximum of 48.61 ± 0.41 mL/200mg DM at 24 h.

Net gas production (Table 3) after 24 h was 243.05 mL/g DM, with an ME of 12.34 MJ/kg DM. IVDMD and IVOMD were 73.08% and 79.33%, respectively, slightly higher than values reported by Lagos and Stein (2017). Overall, variations in nutrient composition reflect differences in

variety, processing, and origin, and the present results confirm SBM as a rich protein source with moderate fibre content, suitable for ruminant feeding (McDonald *et al.*, 2011; ICAR, 2013).

CoFS-31

The proximate composition of CoFS-31 dry fodder (Table 1) in this study was consistent with reported ranges for multi-cut sorghum varieties (Dombar *et al.*, 2023; Patil *et al.*, 2022). CoFS-31 dry fodder exhibited DM and OM contents of 91.74% and 90.95%, respectively. It contained 4.10% CP, 33.87% CF, 2.94% EE, 9.05% TA, and 43.04% NFE. The NDF, ADF, and ADL fractions were 59.73%, 38.15%, and 7.73%, respectively, while hemicellulose and cellulose were 21.58% and 30.42%. Although its CP (4.10%) was lower than previously reported values (7-9.5%; ICAR, 2013; Ramesh *et al.*, 2017), likely due to harvest stage and environmental factors, its crude fiber (CF), total ash (TA), and fiber fractions were in line with earlier findings (ICAR, 2013; Verma *et al.*, 2016; Hayavadana *et al.*, 2024). The CoFS-31 dry fodder recorded the lowest gas production values among the tested feedstuffs, consistent with its higher fibre content and lower availability of fermentable carbohydrates. This is indicative of slow fermentation and limited degradability, typical of fibrous fodders rich in lignocellulosic components. The gas production (Table 2) increased gradually from 3.93 ± 0.04 mL at 2 h to 8.74 ± 0.11 mL at 4 h, 13.11 ± 0.16 mL at 6 h, and 17.99 ± 0.13 mL at 8 h. Further increments were observed, and maximum production was 34.50 ± 0.38 mL/200 mg DM at 24 h.

The net gas production after 24 h (Table 3) was 152.10 mL/g DM, with an RIVGP24, of 34.50 mL/200 mg DM. The corresponding ME value was 7.19 MJ/kg DM. The IVDMD and IVOMD were 43.48% and 47.80%, respectively. As a dry fodder, CoFS-31 plays a crucial role in sheep rations by providing structural fiber that supports rumen function, ensures effective chewing and saliva production, and maintains gut health. Despite variations in nutrient content across studies, CoFS-31 remains dependable fibrous basal roughage, forming the backbone of stall-fed and semi-intensive sheep feeding systems.

CONCLUSION

The findings of the present study demonstrate that maize and bajra serve as efficient and readily digestible sources of energy, while soybean meal provides high-quality protein, and CoFS-31 contributes essential fibrous structural roughage. The analysis of proximate composition, fiber fractions, and *in-vitro* fermentation characteristics suggests that a strategic combination of these feed ingredients can yield a nutritionally balanced, cost-efficient, and regionally locally adoptable feeding strategy for small ruminant production systems in northern Karnataka.

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