Zoo-technical responses of growing cattle fed sun-dried brewers’ spent grain at 20% of dietary inclusion

Padam Veer Singh1,2, M. K. Ghosh1, M. S. Mahesh3* and A. Chatterjee1

Abstract

Background: Agro-industrial by-products are gaining immense significance in animal feeding as a plausible solution to curtail ever-increasing prices of traditional feedstuffs, which may in turn stave off the skewed profit margin in dairy production. To this end, the present experiment sought to evaluate the effect of sun-dried brewers’ spent grain (BSG)—a by-product of distillery industry—as a dietary component on the performance outcome in cattle. Ten growing male Jersey crossbred cattle were stratified into two groups of control (T1) and treatment (T2) based on comparable body weight (BW: 59.3 ± 5.9 kg). Animals in group T1 were fed a basal diet comprising of approximately 15% green oats, 45% paddy straw and 40% concentrate mixture, whilst that of T2 contained 20% (w/w) sun-dried BSG, equally substituting concentrate mixture with the proportion of forage components similar to that of T1 on dry basis.

Results: 105 days of experimental feeding revealed that the intake and apparent digestibility of nutrients did not differ between two groups. However, animals in group T2 exhibited a greater ($P < 0.05$) average daily gain in BW along with an improvement ($P < 0.05$) in feed conversion ratio over group T1. Additionally, diet offered to group T2 relatively proved 20% more economical than T1. Furthermore, on comparing cost/kg crude protein furnished by a range of conventional ingredients, BSG appeared third in the rank, only next to mustard (rapeseed) de-oiled cake and de-oiled rice bran.

Conclusion: Based on these results, it is concluded that sun-dried BSG could be incorporated at 20% in the diet for leveraging a greater growth performance in cattle, while also realising a distinct reduction in feed outlay.

Keywords: Alternative feedstuffs, Brewers’ spent grain, Cattle, Economics, Growth performance, Nutrient utilisation, Sun drying

Background

Amidst depletion of naturally available feed resources, raising cost of traditional ingredients and a simultaneous upsurge in demand for dairy, there has been a growing interest among ruminant producers worldwide to explore locally available agro-industrial by-products as optional feedstuffs. Consequently, owing to their poor human-edible value and availability at a reasonably cheaper price, by-product-based feeding strategy may beneficially contribute to global food security as well as sustainable dairying (Heuzé et al. 2017; Mahesh and Thakur 2018; Naik et al. 2018; Ramirez et al. 2021).

Brewers’ spent grain (BSG) is a by-product of beer brewing industry, primarily consisting of solid residue emanating from the germinated grains (malt), husk pericarp and seed coat, etc., after mashing and lautering processes (Bradford and Mullins 2012; Ikram et al. 2017). Being accounted for about 85% of all by-products of brewing (Lao et al. 2020), yield of BSG equates to 21–22%
of total beer brewed (Bianco et al. 2020). As it is a concentrate of protein and fibre, it is particularly suitable for ruminant feeding (Heuzé et al. 2017). Notwithstanding, fresh BSG in wet form is highly perishable, bulky, and it is logistic-unfriendly for long haul, besides posing storage difficulty (Dhiman et al. 2003; Kavalopoulos et al. 2021). Whereas, if dumped as landfill, it results into a serious environmental pollution as each tonne of BSG could generate as much as 513 kg CO₂ equivalent of greenhouse gases and thus increasing carbon footprint (Kavalopoulos et al. 2021). Hence, for animal feeding, processes such as ensiling and different forms of drying have been attempted with varying degrees of success (NRC 2001; Heuzé et al. 2017; NASEM 2021). The dried BSG could contribute a dietary level of 5–60% under different feeding scenarios in cattle (Lopez-Guisa and Satter 1991; Belibasakis and Tsirgogianni 1996; Dhiman et al. 2003; Inthapanya et al. 2016; Faccenda et al. 2018; Parmenter et al. 2018; Hatungimana et al. 2020), buffaloes (Ban-Tokuda et al. 2007) and small ruminants (Aguilera-Soto et al. 2008). Additionally, the prior experiments have also investigated BSG as an alternate for forage fibre (Lopez-Guisa and Satter 1991; Bradford and Mullins 2012) as well as soya bean meal (SBM; Faccenda et al. 2018). It is uncommon to employ BSG as a standalone ingredient, but used complementary to concentrate feed. As the latter is becoming increasingly expensive in the recent times globally, it would be more meaningful to substitute it partially by BSG from an economic viewpoint. Since feed alone represents over 65% of the recurring expenses, the nutritional interventions impacting farm bottom-line either by reduction in input cost or augmenting performance or both would be interesting. And, effective utilisation of by-product feeds has been a recommended strategy globally to achieving waste-to-profit transformation through a holistic circular economy approach (Ramírez et al. 2021).

The main objective of this research was to determine the response of growing cattle fed sun-dried BSG at 20% of the diet, replacing customary concentrate mixture on intake, digestion, body weight (BW) changes, feed conversion ratio (FCR) as well as feeding economics. In addition, it was also tested whether sun-dried BSG offers an opportunity to use as an economical crude protein (CP) source in practical diet formulations.

**Methods**

**Collection and processing of wet BSG**

The wet BSG of barley origin was procured at regular intervals from a local brewery (M/s United Breweries Limited, Kalyani, West Bengal, India). The collected wet BSG was dried by spreading over a tarpaulin sheet for 3–4 days under sunlight with at least three manual rotations a day. The initial moisture content of the wet BSG was ~75%. Following sun drying, the moisture level was brought down to approximately 10% and the same was stored in plastic bags for subsequent use during feeding trial.

For chemical characterisation (described in the later sections), the sun-dried BSG samples of different batches were pooled and oven-dried for 24 h, ground and stored in airtight plastic containers awaiting analyses.

**Animals, diets, housing and general management**

Ten apparently healthy male Jersey crossbred growing cattle aged 4–9 months were selected from the herd maintained at the Eastern Regional Station of ICAR—National Dairy Research Institute, Kalyani, India. All the animals were vaccinated, dewormed and treated for ectoparasites. The initial BW of each animal was noted before the start of the experiment. Following this, animals were randomly stratified into two experimental groups of control (T1) and treatment (T2) of five animals each in such a way that both had an average comparable live BW of 59.3±5.9 kg. Animals in group T1 were fed with a diet containing approximately 15% chopped green oats (*Avena sativa*; harvested at 9 weeks) and 45% paddy (*Oryza sativa*) straw along with 40% commercial concentrate mixture. The diets for animals in group T2 were similar to that of T1, except 20% (w/w) of the diet (i.e., 50% of concentrate mixture) was substituted by equal proportion of sun-dried BSG. Thus, both the experimental diets had similar forage-to-concentrate ratio of 60:40, offered in a typical component-fed system. Animals were fed individually in a specially built mangers, whereby they had no access to feed/forage allocated to the neighbouring animal. All animals had ad libitum provision to drinking water throughout the experiment spanning 105 days. Feeding management was done to fulfil the nutrient requirements of growing cattle as recommended by the NRC (2001) feeding standard.

All animals were housed in an experimental shed having amenities for individual care and management. The cement-floored house was well ventilated and received sufficient sunshine. Periodically, the floor was disinfected with antiseptic solution to observe high hygienic standards. On a weekly basis, all animals were given bath with plain water. Feeding and all other protocols relating to handling and management of experimental animals were performed in compliance with the Institutional Animal Ethics Committee rules laid out by CPCSEA, New Delhi, Government of India.

The amount of offered feedstuffs and the residues from individual animal was weighed daily using spring balance and sampled at weekly intervals for determining dry matter (DM), to calculate average DM intake (DMI) as below:

\[ DMI (kg/d) = \text{DM offered (kg/d)} - \text{DM in the residue (kg/d)} \]
Before commencing morning feeding and watering, BW of each animal was recorded on an electronic platform scale, at weekly interval to estimate BW changes, and the diets were adjusted accordingly to commensurate with change in BW. Using the data of DMI and average daily gain (ADG), FCR was computed. Similarly, ratio of intakes of energy and protein to that of ADG yielded the respective conversion ratios. Based on feed cost per unit growth in group T2, relative to that of T1, termed as relative feed cost was calculated as exemplified by Mahesh (2022).

**Digestion trial, sampling and processing**

A digestibility trial of 6 days was conducted towards the end of feeding trial in a total faecal collection method. During this trial, samples of offered feeds (green oats, paddy straw, concentrate mixture and BSG), corresponding residues and faeces were collected the next morning separately for each animal. These samples were collected daily and immediately dried in hot-air oven at 60 °C until achieving a constant weight to estimate DM and then ground in a laboratory hammer mill to pass through 1-mm sieve. Samples were pooled for 6 days and then stored in airtight plastic containers for further chemical analysis. On individual animal basis, the suitable aliquots of fresh faeces was sampled daily, preserved in plastic bottles previously containing 25% (v/v) sulphuric acid, and pooled over for 6 days. About 5 g of this wet faeces was properly mixed, and the pooled sample was subjected for nitrogen (N) estimation by kjeldahl method.

**Chemical analysis**

Representative samples of offered feeds, residue left and faeces were subjected to wet chemistry analysis. The DM, ash, CP (as kjeldahl N × 6.25), ether extract (EE) and crude fibre (CF) were estimated as per the standard methods of AOAC (2005). Fibre fractions such as neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (estimated with concentrated sulphuric acid, 720 g/kg) were assayed by the procedures outlined by Van Soest et al. (1991), without using heat-stable amylase and sodium sulphite in the former. Gravimetric procedures were followed to determine calcium (Ca) and phosphorus (P) content in BSG.

**Calculation of digestibility and energy value**

Based on the intake and faecal excretion of a particular nutrient, apparent digestibility co-efficient was computed, as below:

\[
\text{Apparent digestibility (g/kg)} = \frac{\text{Intake (kg)} - \text{faecal excretion (kg)}}{\text{intake (kg)}} \times 1000 \div \text{intake (kg)}
\]

Using the digestibility coefficients of individual nutrients, apparent total digestible nutrients (TDNa) of diet was calculated according to Owens et al. (2010), as follows:

\[
\text{TDNa (g/kg)} = [d\text{CP intake (kg)} + d\text{CF intake (kg)} + d\text{NFE intake (kg)} \times 2.25] \times 1000 \div \text{DMI (kg)}
\]

where \(d\) = co-efficient of apparent digestibility (g/kg) and NFE = nitrogen-free extract.

Metabolisable energy (ME) value of diets was calculated from TDNa by multiplying the latter with 0.15 (1 kg TDNa = 15.13 MJ of ME; NRC 2001).

**In vitro gas measure**

Hohenheim in vitro gas production method of Menke and Steingass (1988) was used to measure net gas production (GP) after 24 h of incubation of 0.2 g BSG, as below:

\[
\text{GP (mL/g DM)} = \frac{[(\text{Syringe reading at 24 h} - \text{initial syringe reading}) - (\text{blank reading at 24 h} - \text{initial blank reading}) \times 0.2 \times 5]}{\text{actual dry weight of sample incubated}}
\]

**Statistical analysis**

The data were expressed as mean±standard error for all parameters. Statistical analysis was performed by applying student’s T test using Statistical Package for the Social Sciences for Windows (SPSS, Chicago, IL, USA) with the below model:

\[
Y_i = \mu + D_i + e_i,
\]

where \(Y_i\) = independent response variable (e.g. DMI, digestibility, FCR, etc.); \(\mu\) = overall mean; \(D_i\) = effect of \(i\)th treatment (\(i\) = T1 and T2), and \(e_i\) = residual error component of \(i\)th observation.

The significance among means of two groups was established at 5% level of probability when the \(P\) value for null hypothesis was ≤0.05. The data on DMI and ADG were analysed on every weekly basis, and since there was no significant interaction found with period, only the main effect of treatment was considered.
Results

Composition and nutritional characteristics
Chemical composition and nutritional attributes of BSG as well as basal feeds and forages are presented in Table 1. The BSG contained CP close to that of concentrate mixture with higher EE. Content of NDF was higher than the concentrate mixture, but close to green oats.

Intake and digestibility of nutrients, and growth performance of cattle
As illustrated in Table 2, intake of DM (Fig. 1), CP and ME was not different in both the groups. A similar trend was true for apparent digestibility of all nutrients and nutritive value expressed as digestible nitrogen, ME and their ratio. However, changes in the BW (Fig. 2) and growth rate calculated as ADG were higher \((P < 0.05)\) with an improved \((P < 0.05)\) FCR observed in animals belonging to group T2 (Table 3). In addition, relative feed cost per kg growth (i.e. gain) was lower by 20% in group T2 than T1.

Economic feasibility of BSG vis-à-vis other ingredients
Figure 3 revealed the economic feasibility of including BSG as a protein ingredient in formula feeds. Based on CP content and current market price, it was observed among a range of common concentrate feedstuffs that BSG, as an economic CP source (calculated as cost/kg CP), was ranked third (INR 78.3) that is next to mustard (rapeseed) de-oiled cake (INR 75.7) and de-oiled rice bran (INR 71.4).

Discussion
As it is recognised that diets based on inexpensive and underutilised feed resources could be one of the most paying propositions for economic sustainability of ruminant production (Mahesh and Thakur 2018; Ramirez...
Singh et al. 2021), the present experiment utilised BSG with the objective of evaluating its feasibility to minimise overall feeding cost in growing cattle.

The compositional value of BSG sourced from several local distilleries showed an average CP content of 230 g/kg with EE of 71.5 g/kg. This broadly lies within the range reported previously (Aghajanzadeh-Golshani and Maheri-Sis 2010; Heuzé et al. 2017; Ikram et al.
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along with Ca and P (Heuzé et al. 2017). In addition, NDF content is of particular interest in BSG, because it is valued as a non-forage fibre source having a strong positive effect on chewing time (56.6 min/kg DM) by cows, which is far greater than other fibrous feedstuffs (Heuzé et al. 2017). The calculated ME content is close to the table value of 11.25 MJ/kg as published by NRC (2001), and DM digestibility is within the range summarised by Heuzé et al. (2017). Likewise, in vitro GP recorded for BSG is comparable with the earlier results of Aghajanzadeh-Golshani and Maheri-Sis (2010). With this nutritional characterisation per se, it appears that BSG can be comparable with that of conventional concentrate mixture and therefore, partial isonitrogenous and isoenergetic substitution was studied under in vivo system.

The DMI determines the amount of nutrients ingested by the animal for maintenance and production (NRC 2001; NASEM 2021). In the present experiment, on quantitative terms, at 20% of dietary inclusion, the average intake of BSG in group T2 was ~600 g/animal/d. This level had no influence on DMI, implying BSG did not affect palatability and voluntary intake in growing cattle. This result is in general agreement with the past research that incorporated BSG at a dietary inclusion of 7.2% in finishing steers (Parmenter et al. 2018), 15–16% in dairy cows (Belibasakis and Tsirgogianni 1996; Dhiman et al. 2003), 21% in oxen (Faccenda et al. 2018), 30% in growing cattle/buffaloes (Ban-Tokuda et al. 2007) and 60% in feedlot lambs (Aguilera-Soto et al. 2008).

Both the groups of animals displayed similar digestibility pattern for all the nutrients. However, the effect of BSG on digestibility shows a wide disparity in the literature. For instance, while Inthapanya et al. (2016) noted higher DM digestibility at 5% BSG (in ensiled form), Faccenda et al. (2018) found a trend of decreasing DM digestibility with incremental levels (0, 33, 66 and 100%) of BSG, whereas Aguilera-Soto et al. (2009) reported no change in the digestibility of nutrients at 33% inclusion of BSG in cattle. It is probable that a reduction in digestibility could be a consequence of poor quality (microbial spoilage) of wet form of BSG (Heuzé et al. 2017; Faccenda et al. 2018), which was not the case in the present study. Furthermore, BSG has also been known to act as a prebiotic, thereby enhancing digestive comfort in animals (Lao et al. 2020). Overall, it can be deduced from the results that 20% inclusion of sun-dried BSG exerts no deleterious effects on utilisation of nutrients by growing cattle. Furthermore, as expected, a similar nutritive value of diets for energy and protein is coherent with the unaltered responses for both DMI and apparent digestibility, regardless of dietary treatments.

Growth is a function of tissue accretion in young animals, and a rapid ADG is an economical trait in animal agriculture. The BSG-based diet in group T2 led to a better ADG in growing cattle of group T2. It is an interesting finding because at 7.2% of dietary inclusion, there was no influence on growth performance in fattening cattle (Parmenter et al. 2018). The FCR and feed cost/kg gain over 105 days of experiment were found more favourable for group T2, implying that BSG-based diets could be utilised as efficiently as conventional diets for growth. Although lysine could be limiting in BSG-based diets, at 20% inclusion, such effects were not evident when compared with conventional diet, as also been reported previously for up to 40% dietary incorporation (Heuzé et al. 2017). Furthermore, it is even clear from the results that
animals in group T2 consumed 15% less DM than T1 to yield unit growth rate. This, indeed, translates to an additional beneficial implication (i.e. relative feed cost) over farm bottom-line to the extent of 20% in group T2. Akin to our data, Hatungimana et al. (2020) obtained satisfactory zoo-technical responses in Holstein heifers when wet BSG substituted 20% SBM- and corn-based concentrates. Largely, it can be inferred that 20% BSG helps improve BW gain, feed conversion with a practically attractive economics and thus favourably culminating in the cost-effective raising of growing cattle.

Since CP is the most cost-consuming nutrient input in any feed formulation, the practical value of BSG as a source of CP was compared with other conventional ingredients. Using cost per unit CP as a sole criterion, BSG could be ranked third among a range of common agro-industrial by-product feedstuffs. Despite de-oiled rice bran was found most economical—at 9% lower price than BSG—it is generally regarded as a filler material in compound feed formulations. Although mustard/rapeseed (Brassica juncea Coss.) cake was found second economical ingredient, which is a very widely used CP source in the practical formulations by feed industry in India, it does contain antinutritional factor like glucosinolates that may interfere with feed palatability and nutrient utilisation (Mahesh et al. 2019). Whereas BSG, on the other hand, besides having a readily acceptable palatability, has also been recognised as a valuable source of readily fermentable non-forage fibre (Bradford and Mullins 2012; NASEM 2021) due to its utilisable structural carbohydrate (cellulose and hemicellulose) composition (Ikrar et al. 2017). Moreover, rumen bypass protein of BSG (Belibasakis and Tsirgogianni 1996; NRC 2001; Heuzé et al. 2017; NASEM 2021) has a reasonable replacement value of corn gluten meal (Lopez-Guisa and Satter 1991) that may further underpin its worth in high-merit dairy cows fed on relatively high concentrate diets. Indeed, Naik et al. (2018) showed 20% additional net income on using BSG after replacing rice bran for milking cows.

**Conclusions**

It was concluded from the present experiment that sun drying proves to be an effective way to utilise BSG in cattle diets. In agreement with our hypothesis, a modest incorporation of BSG at 20% of the diet, the growing cattle performed equivalent with that of conventional diet while also achieving faster growth rate with a distinct reduction in feed outlay. In totality, wherever available, it is worthwhile to use human-inedible by-product like BSG that could partly minimise the competition between human food and ruminant feed associated with edible conventional concentrates.

**Abbreviations**

ADF: Acid detergent fibre; ADG: Average daily gain; BSG: Brewers’ spent grain; BW: Body weight; Ca: Calcium; CF: Crude fibre; CP: Crude protein; DM: Dry matter; DMI: Dry matter intake; EE: Ether extract; FCR: Feed conversion ratio; GP: Gas production; ME: Metabolisable energy; N: Nitrogen; NFE: Nitrogen-free extract; P: Phosphorus; SBM: Soya bean meal; TDNa: Apparent total digestible nutrients.

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**Author contributions**

MKG and PVS designed the study. PVS performed the trial and generated the data. AC assisted in data analysis and interpretation. MSM wrote the paper, tabulated the data and drew figures. All authors have read and approved the final manuscript.

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**Availability of data and materials**

All the major data have been presented in the tables and figures of this paper. The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

**Declarations**

**Ethics approval and consent to participate**

Institutional Animal Ethics Committee approved the study, and the rules of CPCSEA, New Delhi, Government of India were duly followed during this experiment. All authors have participated in the research.

**Consent for publication**

Not applicable.

**Competing interests**

The authors declare that they have no known competing financial or other interests and/or personal relationships that could have appeared to influence the work reported in this paper.

**Author details**

1. ICAR – National Dairy Research Institute (Deemed University), Eastern Regional Station, Kalyani, West Bengal 741235, India. 2. Present Address: Animal Nutrition Group, National Dairy Development Board, Salt Lake City, Kolkata, West Bengal 700091, India. 3. Livestock Farm Complex, Faculty of Veterinary and Animal Sciences, Banaras Hindu University, Mirzapur, Uttar Pradesh 231001, India.

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