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REGULAR ARTICLES

Rice gluten meal as an alternative by-product feed for growing dairy calves

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Abstract This experiment aimed at studying the nutritional characteristics and feeding value of rice gluten meal (RGM, a wet-milling by-product of rice) in growing dairy calves. RGM contained 464 g/kg of crude protein with 821 and 196 g/kg nitrogen (N) of borate-phosphate insoluble N and acid detergent insoluble N, respectively, which were higher ($P < 0.05$) than groundnut cake (GNC). In vitro gas production, organic matter digestibility and energy values were comparable between RGM and GNC. For in vivo trial, 18 Karan-Fries calves (6–12 months) were randomly assigned into three groups based on comparable body weight and age. The first group (GP-I) was fed concentrate mixture containing mainly GNC as protein source, whilst it was replaced by RGM up to 50 and 75 % on N basis, in second (GP-II) and third (GP-III) groups, respectively. Thus, RGM constituted 140 and 210 g/kg of concentrate mixture of GP-II and GP-III, respectively. In addition, all animals were offered chopped green maize and wheat straw for the whole experimental period of 90 days. Results revealed that there was no difference in intake and digestibility of nutrients, N balance, average daily gain (ADG) and feed efficiency among three groups. Nevertheless, RGM-based diets produced cost-effective ADG than GP-I. Furthermore, experimental calves did not differ in haematological variables like glucose, blood urea N, plasma proteins and non-esterified fatty acids. This study demonstrated that RGM could be incorporated successfully in the concentrate mixture, replacing 75 % of GNC without any discernable compromise in the performance of growing calves.

Keywords Concentrate mixture · Digestibility · Groundnut cake · Protein nutrition · Rice gluten meal · Unconventional feed

Introduction

Exploring locally available by-product feeds has been suggested for sustainable livestock production throughout the world (Eisler et al. 2014). In this context, rice gluten meal (RGM), a by-product of wet-milling of rice, is relatively a new feedstuff having brownish coloured coarse powdery texture, which is available in appreciable amounts in northern India. Commercial traders categorise RGM as a high crude protein (CP) (40–55 %) and high-energy (75 % total digestible nutrients, TDN) ingredient, which is currently priced equivalent to GNC and is recommended for feeding ruminants and poultry (www.innovativesoch.com/rice-gluten-meal/). In comparison with most of the traditionally used oilseed cakes/meals, gluten meals differ, at least in palatability, consistency and are generally high protein feeds. For instance, corn gluten meal (CGM, CP > 60 %) has been studied as a source of undegradable protein for various classes of ruminants (Heuzé et al. 2015). With respect to RGM (19.2 % CP), Deif et al. (1968) estimated a biological value (BV) of 0.81–1.0 in adult rams and no further scientific study appears to have been conducted especially for cattle feeding.

It was believed that biological responses to RGM may not be the same as that of conventional protein sources, and therefore, we hypothesised that its dietary inclusion benefits performance of growing cattle. The main objectives were to evaluate RGM as a partial replacement of GNC on intake, diet digestibility, nitrogen (N) retention, growth and blood variables in growing dairy calves.

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Materials and methods

Animals, feeding and management

Eighteen Karan-Fries (Tharparkar × Holstein-Friesian) female calves aged 6–12 months were selected from the Livestock Research Centre, ICAR-National Dairy Research Institute, Karnal, India. Six animals were assigned randomly to each of three treatments based on comparable body weight: GP-I, 88.3 ± 6.2 kg GP-II, 89.3 ± 6.2 kg and GP-III, 88.8 ± 6.9 kg. Animals were housed in well-ventilated stalls, individually tethered using nylon ropes, and subjected to managerial practices approved by the Institutional Animal Ethics Committee. Ad libitum clean drinking water was provided thrice daily. Antiseptic solution (phenyl) was applied weekly to the floors, ensuring good hygiene. Animals were allowed to exercise in a paddock for 1 h, twice weekly. During the adaptation period of 10 days, animals were dewormed using Ivermectin (Hitek®, 0.2 mg/kg body weight, S/C) and freed of external parasites with Deltamethrin (Butox®, 3 mL/L of water).

For a period of 90 days, animals were individually fed a total-mixed ration (TMR) containing green maize (*Zea mays*, African Tall variety harvested at mid-bloom stage, chopped to 2–3 cm), wheat straw (threshed to 1–2 cm) and isonitrogenous concentrate mixture (mash), maintaining an approximate forage/concentrate ratio of 55:45 to meet nutritional requirements (ICAR 2013a). Animals in GP-I were offered concentrate mixture containing mainly GNC, whilst in GP-II and GP-III, 50 and 75 % of GNC was replaced (on N basis) by RGM, respectively. Body weights (BW) were recorded on an electronic scale in the morning before feeding and watering for two consecutive days at the start of the experiment and thereafter every fortnightly. Calculated quantity of feed for each animal was weighed accurately using a spring balance before constituting TMR, and the orts, if any, were noted the next morning to ascertain actual dry matter intake (DMI). Commensurate with average daily gain (ADG), the feeding regimen was adjusted every fortnightly.

Metabolism trial and sampling protocol

A seven-day metabolism trial was conducted towards the end of feeding trial, during which daily DMI and total excretion of faeces and urine were recorded. For N determination, faecal samples (1/100th of the daily voids) were preserved in 250 mL/L of sulphuric acid to make a pooled sample for 7 days for each animal. Separate aliquots of fresh urine (1/80th of total voids) were stored in polypropylene bottles previously containing 100 mL/L of sulphuric acid for total N estimation. About 5-g faeces and 5-mL urine were processed for N estimation. TDN was computed using intake of nutrients and their corresponding digestibility coefficients, which was converted to metabolisable energy (ME) (NRC 2001). Feed efficiency

Table 1 Ingredient and chemical composition of concentrate mixtures, major protein sources and forages ($n = 3$)

Attribute	GP-I	GP-II	GP-III	Rice gluten meal	Groundnut cake	Green maize	Wheat straw
Ingredient composition (g/kg dry matter)							
Maize	330	330	330				
Groundnut cake	300	150	75				
Rice-gluten meal	–	140	210				
De-oiled rice bran	180	190	195				
Wheat bran	160	160	160				
Mineral mixture[a]	20	20	20				
Salt as NaCl	10	10	10				
Chemical composition (g/kg dry matter)							
Organic matter	930	938	940	950	901	897	875
Crude protein	230	232	235	464	446	78.8	32.9
Ether extract	47.0	45.9	44.2	34.4	68.9	17.3	9.5
Ash	70	62	60	50	99	103	125
Neutral detergent fibre[b]	279	289	294	404	286	676	813
Acid detergent fibre[b]	157	168	170	173	167	456	532
Hemicellulose	122	121	124	231	119	220	281
Acid detergent lignin	39.6	57.6	56.9	38.4	49.8	46.8	87.9

GP-I concentrate mixture without rice gluten meal (RGM), *GP-II* concentrate mixture containing 50 % replacement of groundnut cake (GNC) protein by RGM, *GP-III* concentrate mixture containing 75 % replacement of GNC protein by RGM

[a] Percentual composition of commercial mineral mixture: Ca 20, P 12, Mg 5, I 0.026, Co 0.00120, Fe 0.4, Mn 0.12, Zn 0.8, S 1.8 and Cu 0.1

[b] Expressed inclusive of residual ash

Table 2 Nitrogen (N) fractions and energy values of major protein meals used in concentrate mixtures ($n = 3$)

Attribute	Rice gluten meal	Groundnut cake
N fractions (g/kg of total N)		
Borate-phosphate buffer insoluble N	821 ± 2.5[a]	368 ± 3.3[b]
Acid detergent insoluble N	196 ± 3.9[a]	27.7 ± 3.0[b]
Non-protein N[a]	115 ± 1.9	102 ± 2.1
Energy values		
$GP_{24\ h}$ (mL/g dry matter)	183 ± 1.0	192 ± 1.1
Organic matter digestibility (g/kg)	737 ± 1.9	751 ± 2.1
Metabolisable energy (MJ/kg)	13.2 ± 0.03	13.6 ± 0.03
Net energy for maintenance (MJ/kg)	8.98 ± 0.02	9.32 ± 0.02
Net energy for gain (MJ/kg)	6.16 ± 0.01	6.44 ± 0.01

Means bearing different superscripts (a, b) in a same row differ ($P < 0.05$)

$GP_{24\ h}$ net gas production after 24 h of incubation in buffered rumen fluid. Presented value is an average of three readings taken over two separate runs

[a] Estimated as 1000-Trichloroacetic acid precipitable nitrogen (g/kg N)

was calculated as the ratio of ADG in BW to DMI. Ratio of N retention to that of N digested gave apparent BV (%) of diets.

Chemical analyses

Representative samples (feeds, orts and faecal samples) were dried at 65 °C for 48 h and ground to pass through a 1-mm screen using Wiley mill for subsequent chemical analyses (AOAC 2005) like ether extract (EE, # 920.39), total ash (# 942.05), Kjeldahl N (# 984.13), neutral detergent fibre (NDF, # 2002.04), acid detergent fibre (ADF, # 973.18) and acid detergent lignin (# 973.18). Hemicellulose was calculated as NDF-ADF. N fractions were estimated as delineated by Licitra et al. (1996). For in vitro gas production ($GP_{24\ h}$), prediction of organic matter digestibility (OMD) and ME, Hohenheim gas method (Krishnamoorthy et al. 1995) was followed. Net energy for maintenance (NE_m) and gain (NE_g) was calculated from the equations exemplified in NRC (2001). Amino acid analysis was done using HPLC (Waters India Pvt. Ltd., New Delhi) in accordance with AOAC (2005).

Blood analyses

Blood samples of each animal were collected from the jugular vein at the beginning of trial and thereafter at monthly intervals and metabolites like glucose, non-esterified fatty acids (NEFA), blood urea nitrogen (BUN) and total proteins were estimated in plasma by similar procedures as explained previously (Gami et al. 2015).

Statistical analysis

The data were expressed as mean ± standard error and subjected to one-way analysis of variance using Statistical Analysis System (SAS Inst. Inc., Cary, NC, USA) software, fitting the following linear model:

$$Y_i = \mu + T_i + \varepsilon_i$$

Table 3 Amino acid profile of major protein meals used in the concentrate mixtures

AA (% CP)	Rice gluten meal	Groundnut cake
Arg	6.50	10.97
His	1.81	2.41
Ile	5.23	3.48
Leu	6.33	6.39
Lys	3.19	3.29
Met	2.08	1.17
Phe	5.90	4.77
Thr	3.16	2.59
Val	5.40	3.97
EAA	39.6	39.0
Ala	6.29	4.00
Asp	7.25	10.2
Cys	0.81	1.03
Glu	16.6	15.8
Gly	4.17	4.92
Pro	4.32	4.28
Ser	4.00	3.93
Tyr	3.34	2.71
NEAA	46.8	46.9
BCAA	17.0	13.8
Total AA	86.4	85.9
Lys, % EAA	8.06	8.43
Met, % EAA	5.25	3.00

EAA essential AA (Sum of Arg, His, Ile, Leu, Lys, Met, Phe, Thr and Val), *NEAA* non-essential AA (Sum of Ala, Asp, Cys, Glu, Gly, Pro, Ser and Tyr), *BCAA* branched-chain AA (Sum of Ile, Leu and Val), *Total AA* EAA + NEAA where Y_i is the dependent variable, μ is the general mean, T_i is the effect of ith treatment and ε_i is the residual error of ith observation.

The differences among means were considered statistically significant at 5 % level of probability ($P \leq 0.05$).

Results

Chemical composition of feeds and forages

Chemical composition of ingredients of basal diet and major protein sources (GNC and RGM) is presented in Table 1. RGM contained slightly higher crude protein (CP) than GNC; however, NDF content was much higher (404 g/kg) than that of GNC (286 g/kg). Table 2 illustrates that a substantial ($P < 0.05$) proportion of N in RGM was in the form of borate-phosphate insoluble N (BIN). In addition, acid detergent insoluble N (ADIN) fraction was considerably ($P < 0.05$) higher in RGM than GNC. Other in vitro measures like $GP_{24\ h}$, OMD and energy values (ME, NE_m and NE_g) were almost comparable between RGM and GNC (Table 2). AA make-up of protein sources depicted that both RGM and GNC contained almost all essential amino acids (EAA). While GNC was rich in arginine, RGM had relatively higher content of methionine, phenylalanine, valine and alanine. Although lysine content in total EAA was comparable, methionine was higher in RGM than GNC (Table 3).

Nutrient intake and apparent digestibility, N balance and growth performance

As evidenced in Table 4, intake of DM, CP and ME was similar among three groups. A similar trend was also observed for the apparent digestibility of all nutrients. Moreover, three groups of animals did not differ in N balance, apparent BV and ADG (Tables 4 and 5 and Fig. 1). Although feed efficiency was comparable, feed cost/kg gain was reduced to the extent of 5.1 and 10 % in GP-II and GP-III, respectively (Table 4).

Blood metabolites

Concentrations of analysed blood metabolites are furnished in Table 5. It was observed that levels of glucose, BUN, total protein and NEFA were unchanged across all treatments and none was significant.

Discussion

Composition of feeds and forages used in the study, except RGM, is comparable with the table values (ICAR 2013b) for Indian feedstuffs. A low N solubility of RGM in borate-

Table 4 Nutrient intake, apparent digestibility and body weight changes in experimental crossbred calves

Attribute	GP-I	GP-II	GP-III
Nutrient intake			
Dry matter (kg/day)	3.86 ± 0.07	3.73 ± 0.03	3.83 ± 0.02
Crude protein (g/kg $W^{0.75}$)	15.0 ± 0.1	14.7 ± 0.2	14.7 ± 0.2
Total digestible nutrients (g/kg $W^{0.75}$)	62.1 ± 1.5	57.1 ± 1.0	60.8 ± 0.9
Metabolisable energy (MJ/day)	32.4 ± 1.2	30.5 ± 1.1	32.3 ± 0.8
Apparent digestibility (g/kg)			
Dry matter	633 ± 7.6	638 ± 15	641 ± 11
Organic matter	654 ± 19	669 ± 19	674 ± 19
Crude protein	546 ± 21	567 ± 14	541 ± 26
Ether extract	773 ± 32	749 ± 24	753 ± 22
Neutral detergent fibre	500 ± 11	503 ± 26	533 ± 19
Acid detergent fibre	416 ± 9.0	438 ± 40	405 ± 39
Body weight (BW) changes during the experiment			
Initial BW (kg)	88.3 ± 6.2	89.3 ± 6.2	88.8 ± 6.9
Final BW (kg)	130 ± 8.9	134 ± 9.3	136 ± 7.7
Total gain (kg)	41.4 ± 3.6	44.6 ± 3.7	47.2 ± 1.9
Average daily gain (g/day)	460 ± 2.2	497 ± 2.9	524 ± 2.7
Feed efficiency	0.12 ± 0.01	0.13 ± 0.01	0.14 ± 0.01
Feed cost (US$)/kg live weight gain	2.19	2.06	1.97

GP-I concentrate mixture without rice gluten meal (RGM), *GP-II* concentrate mixture containing 50 % replacement of groundnut cake (GNC) protein by RGM, *GP-III* concentrate mixture containing 75 % replacement of GNC protein by RGM

Table 5 Nitrogen (N) metabolism and haematological variables of experimental calves fed on rice gluten meal-based rations

Attribute	GP-I	GP-II	GP-III
N metabolism			
N intake (g/day)	90.9 ± 4.9	93.4 ± 5.3	91.0 ± 3.8
Faecal N loss (g/day)	41.3 ± 3.1	40.6 ± 3.0	41.8 ± 6.1
Urinary N loss (g/day)	34.4 ± 3.3	36.3 ± 1.9	32.0 ± 3.4
Total N loss (g/day)	75.6 ± 5.6	76.9 ± 4.6	73.8 ± 3.9
N balance (g/day)	15.3 ± 1.3	16.5 ± 1.6	17.3 ± 1.7
Biological value (%)	31.5 ± 3.4	31.0 ± 1.9	35.2 ± 0.7
Haematological variables			
Glucose (mg/dL)	64.4 ± 1.7	67.0 ± 2.1	66.9 ± 2.4
Non-esterified fatty acids (μmoL/L)	101 ± 1.5	99.3 ± 1.7	99.0 ± 1.5
Total protein (mg/dL)	7.14 ± 0.1	7.21 ± 0.1	7.29 ± 0.1
Blood urea nitrogen (mg/dL)	15.1 ± 0.6	14.9 ± 0.6	15.0 ± 0.7

GP-I concentrate mixture without rice gluten meal (RGM), *GP-II* concentrate mixture containing 50 % replacement of groundnut cake (GNC) protein by RGM, *GP-III* concentrate mixture containing 75 % replacement of GNC protein by RGM

phosphate buffer reflects its resistance to ruminal degradation. Concurrently, a high rumen escape potential of gluten proteins has already been documented previously for CGM (Heuzé et al. 2015), and Wadhwa et al. (2012) accounted it for the presence of cereal storage proteins (prolamins and glutelins) in gluten meals that strongly resist ruminal proteolysis. Higher ADIN found in RGM could be ascribed to heat treatment applied during processing, as has been reported for similar feed CGM (NRC 2001). Although ADIN has been generally believed to be completely indigestible, some researchers observed a considerable proportion of N that is available from heat-treated feedstuffs irrespective of ADIN level (Klopfenstein 1996; NRC 2001; Cabrita et al. 2011). $GP_{24\ h}$, OMD and ME found in the present study for GNC agree closely with the previous estimates of Krishnamoorthy et al. (1995), and the similar values obtained for the test ingredient RGM surmises that it compares favourably with GNC. Furthermore, the present results substantiated that the $GP_{24\ h}$ reflects OMD and in turn energetic feed value for ruminants (Krishnamoorthy et al. 1995).

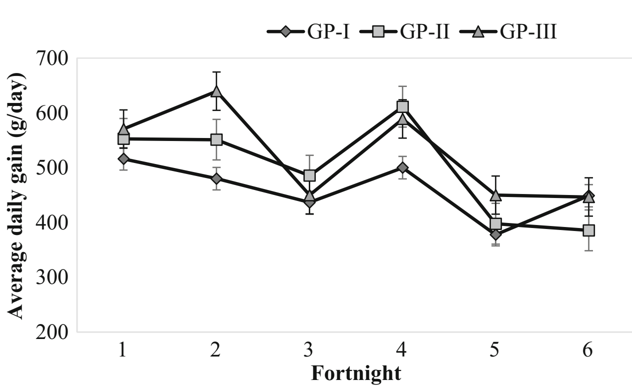

Fig. 1 Fortnightly average daily gain (g/day) in crossbred calves fed rice gluten meal replacing groundnut cake in concentrate mixtures

AA profiling revealed that RGM contained a good balance of AA compared with GNC. Dietary AA comprising of both EAA and nutritionally non-essential AA are crucial for growth, development, gene expression and cellular metabolism in animals (Wu 2014). Proportionally higher arginine concentration obtained for GNC is in close conformity with previous report (Li et al. 2011). It is noteworthy here that RGM is a cereal by-product, while GNC is of legume origin, and therefore, it is obvious that they differ in AA composition. Moreover, Heuzé et al. (2015) reported that CGM is richer in methionine content, which is similar to that of RGM used in the present study. Overall, quantitative AA profile of RGM showed its potential to be incorporated as protein source in dairy cattle nutrition, albeit their extent of metabolic utilisation may need further investigation.

DMI is an important determinant of various nutrients that are available for maintenance and production (NRC 2001). Isonitrogenous replacement of GNC by RGM did not affect DMI, confirming RGM-based diets were well acceptable by growing calves. Since there was no difference in DMI, intake of CP and ME was also similar among three groups.

Digestibility pattern observed for all nutrients showed the same trend, which did not differ among three groups, implying that RGM-based rations could be utilised by growing cattle as good as conventional protein sources like GNC. It is also plausible that a lack of influence on DMI might have resulted in similar digestibility pattern among three groups, as variation in DMI has been attributed to cause altered feed passage kinetics and thus nutrient digestibility (Santos et al. 2016).

Although statistically non-significant, ADG was almost 37 and 64 g higher in GP-II and GP-III, respectively. It is interesting to note similar N retention in GP-II and GP-III, if we assign only 5 % digestibility to ADIN fraction (NRC 2001), as RGM contained much higher ADIN level (19.56 %).

Therefore, it is reasonable that high escape proteins (BIN) might have compensated the effects of ADIN in lowering protein quality. There is also evidence that CGM has a high N digestibility of 97.4 % (Heuzé et al. 2015), which is also a wet-milling by-product. Supportively, Klopfenstein (1996) also registered a higher ADG and protein efficiency in growing calves fed high ADIN (28.8 % of N) dried distillers grains plus solubles (DDGS) than low ADIN counterparts, concluding that ADIN of DDGS did not impair protein utilisation by calves. We presume that such a phenomenon might have occurred in the present study with GP-II and GP-III, explaining the N balance and ADG close to, or slightly better than that of GP-I. Likewise, a similar BV obtained for all three diets suggests that digested proteins of RGM could be retained and utilised for growth almost equally as that of GNC. In addition, diets of GP-II and GP-III were found to be more economical per unit gain, which may have positive connotation on economic raising of dairy calves.

Glucose and NEFA, being energy biomarkers, did not differ due to treatments, which could be due to the similar chemical composition and approximate energy values of experimental diets. Similarly, concentrations of total protein and BUN remained within normal range for growing calves, although the latter is affected by the level and degradability of CP in the diet (Gami et al. 2015). In the present study, as 50 and 75 % replacement of GNC by RGM did not elicit any significant changes in analysed blood metabolites (glucose, NEFA, total protein and BUN) beyond their physiological limits once again substantiates safe incorporation of RGM for growing cattle rations.

It was concluded that RGM could replace GNC in the concentrate mixture of growing calves up to 75 % level without any discernable adverse effect on intake, digestibility, growth rate and blood profiles. With increasing availability, RGM may be used as an alternative to GNC for economic raising of dairy calves. Therefore, results of the present study hold practical implications for utilising RGM by the feed (compound) industry and farming community, which in turn may partially reduce reliance on conventional protein meals.

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Compliance with ethical standards

Conflict of interest None

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