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Replacing groundnut cake with gluten meals of rice and maize in diets for growing Sahiwal cattle

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Objective: This experiment investigated the effect of isonitrogenous replacement of groundnut cake (GNC) by rice gluten meal (RGM) and maize gluten meal (MGM) at 75% level on nutrient intake, apparent digestibility, growth performance and related blood constituents in growing Sahiwal cattle.
Methods: Eighteen Sahiwal calves were divided into three groups, based on average body weight (87.24 kg) and age (6 to 12 mo), and treatments were assigned to the different groups randomly. The first group (GP-I) was kept as control and received GNC-based concentrate mixture. In second (GP-II) and third (GP-III) groups, 750 g/kg nitrogen (N) of GNC was substituted by RGM and MGM respectively, with similar forage:concentrate ratio (56:44).
Results: The 90 days of experimental feeding revealed that intake of dry matter, crude protein and digestibility coefficients for all nutrients did not differ among groups. Furthermore, although N balance was greater ($p \leq 0.05$) for GP-III than GP-I and GP-II, average daily gain was similar between GP-I and GP-II but greater ($p \leq 0.05$) for GP-III. In addition, feed efficiency and related haematological variables did not differ due to treatments.
Conclusion: Nutritional worth of GNC and RGM was highly comparable in terms of intake, digestibility and growth in growing calves. However, MGM was found to be more efficacious in improving growth rate than RGM at 75% replacement level of GNC protein.

Keywords: By-products; Gluten Meals; Nitrogen Metabolism; Nutrient Utilisation; Protein Feeding; Zebu Cattle

INTRODUCTION

A diverse category of abundantly available agro-industrial residues are the valuable animal feedstuffs, owing to their utilisable nutrient profiles. As concentrate feed resources for ruminants are limited in India to the extent of 47% [1] and concurrently, the export of as high as 5 million tonnes of protein-rich oilseed meals [2] further exacerbate nation's feed balance. Therefore, only viable proposition to rescue livestock farmers from overcoming increasing feed cost and nutritional crisis is to initiate search on new and non-traditional feed resources. Such ingredients, if produced as by (co)-products in agro-industrial activities with no or little human food value would be desirable [3]. In this endeavour, the value of rice gluten meal (RGM), a by-product of rice wet-milling industry was found to be interesting. It could replace up to 750 g/kg N of groundnut cake (GNC) without any negative influence on intake, nutrient utilisation and growth rate of crossbred calves [4]. Moreover, RGM contains favourably good amino acid profile with relatively higher methionine than GNC [4]. No further details on RGM appear to be available hitherto in literature. A similar by-product, maize gluten meal (MGM) has been studied much explicitly in ruminant nutrition. It is a source of rumen undegradable protein with the highest known metabolisable protein value among plant proteins [5]. Previous studies have compared MGM with soybean meal (SBM) and other feeds for small ruminants [6,7], growing cattle [8], lactating dairy cows

[9,10] and buffaloes [11]. While MGM is rich in xanthophylls making it yellowish; RGM is brownish in appearance and both have powdery consistency [4,5]. No prior attempt has been made to compare the nutritional value of RGM and MGM after replacing traditional protein ingredient GNC in growing calves. Considering this background, the present study was designed to investigate the effect of isonitrogenous replacement of GNC by RGM and MGM on nutrient intake, apparent digestibility, growth performance and related blood constituents in growing Sahiwal cattle.

MATERIALS AND METHODS

Animals, diets and management

The present feeding trial was performed at Livestock Research Centre, ICAR – National Dairy Research Institute, Karnal, India located at 29°42″20′ N (latitude) and 76°58″52.5′ E (longitude). The weather in the region is characterised by an annual rainfall of 700 mm with temperature ranging from near freezing point in winter to 45°C in summer. Ethical clearance from Institutional Animal Ethics Committee was obtained before commencing the experiment.

A total of 18 Sahiwal heifers were divided into three groups, based on live body weight (BW: 87.24 kg) and age (6 to 12 mo). The first group (GP-I) served the control and received hand-mixed total mixed ration (TMR) containing green maize (*Zea mays*, African tall variety chopped to 2 to 3 cm), wheat straw (*Triticum aestivum*, threshed to 1 to 2 cm) and GNC-based concentrate mixture (coarse mash) in proportions of 50%, 6%, and 44% (dry basis), respectively. Groups second (GP-II) and third (GP-III) were offered a TMR in which 75% of GNC proteins in the concentrate mixture were replaced isonitrogenously by RGM and MGM, respectively. Thus, three major protein meals i.e., GNC, RGM, and MGM constituted 300, 227, and 175 g/kg of concentrate mixture of GP-I, II, and III, respectively.

Before beginning the trial, a ten-days adaptation was given, during which all animals were dosed with anthelmintic (Fenbendazole) orally and poured with acaricidal preparation (Deltamethrin) externally, ensuring parasite-free healthy condition. Each animal was individually tied with nylon rope, housed in a well-ventilated stall (min. floor space: 2 m×2 m per animal), provided with asbestos roof and cement floored-house having adequate sunlight and amenities for individual feeding. All animals were given 1 h exercise in an open paddock twice weekly. The body of animals and floor was cleaned daily with moderate pressure water and floor was disinfected with diluted phenyl solution periodically. *Ad libitum* water was made available for drinking thrice daily. Empty BW was noted on electronic scale for two consecutive days before commencing experimental feeding and thereafter, every fortnightly. Calculated quantity of feed required by each animal was accurately weighed using spring balance and constituted TMR, on individual animal basis, and offered at 09:30 h, meeting complete nutrient requirements [12] throughout 90 days of experiment. The TMR was mixed frequently in a day within manger to avoid heat production, and promoting satisfactory intake. Feed refusals were noted every next morning to ascertain actual dry matter intake (DMI) by the animals. Diets were adjusted fortnightly to account for the changes in BW.

Metabolism trial and sampling protocol

Towards the end of feeding trial, a metabolism trial was conducted by shifting all animals into metabolism cages. After two-days of acclimatisation, the amount of daily TMR ingested and total quantitative excretion of faeces and urine was collected separately, for next seven-days. Daily aliquots of urine (1/100th) and faeces (1/80th) were preserved for N estimation in the clean plastic bottles previously containing 300 mL/L of sulphuric acid to prevent volatile losses of ammonia compounds. About 1/30th of total wet faeces were sampled for immediate determination of dry matter (DM) content. Properly mixed and pooled samples of faeces (5 g) and urine (10 mL) were subjected for determining N by Kjeldahl method (Kel Plus, Pelican, Chennai, India).

Laboratory analyses

Chemical composition, cell wall fractionation and calculation of apparent digestibilities of nutrients: Representative samples of feeds offered, left-over residues and faeces were dried (65°C for 48 h) in hot-air oven (Labco, Delhi, India) till constant weight and ground (Wiley mill) to pass through 1 mm sieve and kept in air-tight zip lock polythene bags awaiting further analyses. Standard methods of AOAC [13] were followed for determining DM (ID: 934.01), crude protein (CP; N×6.25; ID: 984.13), ether extract (EE; ID: 920.39), and total ash (ID: 942.05). Fibre fractions like neutral detergent fibre (NDF) and acid detergent fibre (ADF) were assayed [14] and heat stable α-amylase (Sigma Aldrich, St. Louis, MO, USA) was used in the former for concentrate ingredients only. Acid detergent lignin was recovered from ADF by solubilising cellulose with 72% (w/w) sulphuric acid [14]. All analyses were done, at least, in triplicate.

Apparent coefficient of digestibility was computed on the basis of intake and faecal excretion of particular nutrient. Energy value of the diets was expressed in terms of metabolisable energy (ME), calculated with the relationship of 1 kg total digestible nutrients = 15 MJ of ME [15,16].

Blood biochemistry

Approximately 10 mL of blood sample from jugular vein of each animal was collected in heparinised vacutainer tubes (BD Vacutainer, Plymouth, UK) in the morning before offering feed and water at the beginning of trial. Later, blood collection was done at an interval of one month. Immediately following collection, tubes were horizontally rolled between palms, placed in ice box and transported to laboratory. Plasma was separated by centrifuging blood samples at 500×g for 20 min in a thermostable centrifuge (Remi, Mumbai, India). It was frozen at –20°C till analysis. Concentration of glucose, total proteins, plasma urea nitrogen (PUN) was determined using commercial diagnostic kits (Span Diagnostics Limited, Surat, India). Copper soap extraction method [17] was used to estimate the levels of plasma non-esterified fatty acids (NEFA).

Statistical analysis

The data were expressed as mean±standard error and analysed by one-way analysis of variance using SAS software, [18] following simple linear fixed effect model, as follows:

$$Y_{ij} = \mu + T_i + \varepsilon_{ij}$$

Where, Y_{ij} is the dependent response variable, μ is the overall mean common to all observations, T_i is the effect of ith treatment and ε_{ij} is the random residual error distributed as N of ijth observation. Means were separated for statistical significance at 5% level (p≤0.05) using post-hoc comparison by Tukey's Studentised Range Test.

RESULTS

Experimental feeds and their chemical composition are presented in Table 1. The three concentrate mixtures used in the study were isonitrogenous and contained approximately similar levels of organic matter (OM). On DM basis, MGM contained higher CP (58.0%) than RGM (44.7%); however, NDF content of MGM (180 g/kg) was much lower than that of RGM (404 g/kg).

Intake of DM, OM, and CP was comparable among the three groups (Table 2). Coefficients of apparent digestibility for DM, OM, CP, EE, NDF, and ADF in the total digestive tract were also unaffected by treatments, and this resulted in similar nutritive value and plane of nutrition among the three groups (Table 2). Furthermore, MGM-based diets in GP-III showed better (p≤0.05) N balance than that of GNC, which in turn was similar with that of GP-II containing RGM (Table 3). Whereas, predicted microbial N synthesis (MNS) and its efficiency did not vary across diets (Table 3). Nevertheless, average daily gain (ADG) and fortnightly live weight gain (Figure 1) were significantly (p≤0.05) greater in GP-III, leading to a higher total live weight gain. Feed efficiency was comparable among three groups (Table 3).

Mean values of haematological parameters like glucose, PUN, total proteins and NEFA did not vary and were statistically similar among all animals of three groups (Table 4).

DISCUSSION

As sustainable livestock production in recent times focuses on sustainable animal diets [3], the present investigation aimed to know the growth response of cattle fed conventional (GNC and MGM) or alternative (RGM) protein meal-based concentrate mixtures.

Chemical and cell wall composition of feeds and forages used in this study is similar to the table values [19,15]. Chemical composition of RGM and GNC was almost similar with the previously reported data [4], and that of MGM is in agreement with the summarised values [5]. A higher CP in MGM could be due to relatively greater starch extraction during wet milling than that

Table 1. Physical and chemical composition of concentrate mixtures, protein meals and forages (n = 3)

Attribute	GP-I[1)]	GP-II[1)]	GP-III[1)]	Groundnut cake	Rice gluten meal	Maize gluten meal	Green maize	Wheat straw
Ingredient composition (g/kg, as mixed)								
Maize	330	330	330	-	-	-	-	-
Groundnut cake	300	75	75	-	-	-	-	-
Rice gluten meal	-	227	-	-	-	-	-	-
Maize gluten meal	-	-	175	-	-	-	-	-
De-oiled rice bran	160	160	210	-	-	-	-	-
Wheat bran	180	180	180	-	-	-	-	-
Mineral mixture[2)]	20	20	20	-	-	-	-	-
Salt (as NaCl)	10	10	10	-	-	-	-	-
Chemical composition (g/kg dry matter)								
Organic matter	930	937	935	901	949	975	901	868
Crude protein	216	216	223	450	447	580	89	31
Ether extract	45	45	46	689	34	50	15	9
Neutral detergent fibre[3)]	266	292	286	285	404	180	664	842
Acid detergent fibre[3)]	162	167	166	167	172	117	429	541
Hemicellulose	104	125	120	118	231	63	235	321
Cellulose	116	117	116	117	134	107	283	452
Acid detergent lignin	45	50	49	498	38	10	46	88

[1)] GP-I, groundnut cake (GNC)-based concentrate mixture; GP-II, concentrate mixture containing 75% replacement of groundnut cake (GNC) protein by rice gluten meal; GP-III concentrate mixture containing 75% replacement of GNC protein by maize gluten meal.
[2)] Meeting Bureau of Indian Standard specifications (Composition as g/kg: Ca, 200; P, 120; Mg, 50; I, 0.26; Co, 0.0120; Fe, 4; Mn, 1.2; Zn, 8; S, 18; Cu, 1).
[3)] Inclusive of residual ash.

Table 2. Nutrient intake, apparent digestibility, nutritive value and plane of nutrition in three groups of calves

Attribute	GP-I[1)]	GP-II[1)]	GP-III[1)]
Dry matter intake (kg/d)			
Green maize	1.59±0.08	1.70±0.08	1.85±0.11
Wheat straw	0.18±0.01	0.21±0.01	0.21±0.01
Concentrate mixture	1.39±0.04	1.48±0.06	1.53±0.05
Total	3.17±0.12	3.40±0.12	3.59±0.16
g/kg $W^{0.75}$	83.65±2.14	89.02±3.01	86.61±2.33
Overall average (90 d)	3.07±0.19	3.24±0.20	3.60±0.17
Digestibility (g/kg)	642±7.75	637±6.07	642±4.56
Organic matter			
Intake (kg/d)	2.90±0.11	3.11±0.12	3.29±0.14
Digestibility (g/kg)	657±8.71	667±9.32	670±9.13
Crude protein			
Intake (kg/d)	0.49±0.01	0.52±0.02	0.55±0.02
Digestibility (g/kg)	505±10	499±6.58	518±12
Ether extract			
Intake (kg/d)	0.09±0.01	0.10±0.01	0.10±0.01
Digestibility (g/kg)	753±7.35	737±5.26	746±8.24
Neutral detergent fibre			
Intake (kg/d)	1.59±0.06	1.74±0.06	1.85±0.08
Digestibility (g/kg)	513±7.28	506±3.29	512±7.84
Acid detergent fibre			
Intake (kg/d)	1.02±0.04	1.10±0.04	1.17±0.05
Digestibility (g/kg)	427±5.18	424±3.38	432±6.35
Nutritive value and plane of nutrition			
Nitrogen (g/kg DM)	24.27±0.17	24.49±0.27	24.54±0.26
Metabolisable energy (MJ/kg DM)	8.60±0.04	8.7±0.07	8.92±0.12
Nitrogen: metabolisable energy	2.82±0.01	2.81±0.02	2.75±0.04
Digestible organic matter intake (g/kg $W^{0.75}$)	50.28±1.28	53.15±1.83	54.46±1.42
Digestible energy intake[2)] (MJ/kg $W^{0.75}$)	0.92±0.02	0.92±0.09	0.94±0.02
Metabolisable energy intake (MJ/kg $W^{0.75}$)	0.75±0.02	0.75±0.03	0.77±0.01

DM, dry matter.

1) GP-I, groundnut cake (GNC)-based concentrate mixture; GP-II, concentrate mixture containing 75% replacement of groundnut cake (GNC) protein by rice gluten meal; GP-III concentrate mixture containing 75% replacement of GNC protein by maize gluten meal.

2) Digestible energy = Metabolisable energy÷0.82 (NRC [15]).

Table 3. Pattern of nitrogen (N) utilisation and body weight changes in experimental Sahiwal calves

Attribute	GP-I[1)]	GP-II[1)]	GP-III[1)]
N utilisation			
N intake (g/d)	79.64±2.75	83.06±3.01	88.12±3.61
Faecal N excretion (g/d)	36.01±1.28	37.36±0.77	38.22±1.34
Urinary N excretion (g/d)	24.88±1.5	25.59±2.39	28.75±2.46
Total N excretion (g/d)	60.89±2.75	62.95±3.01	66.97±3.67
N balance (g/d)	18.75[a]±0.31	20.11[ab]±0.47	21.15[b]±0.47
Microbial N synthesis[2)] (g/d)	37.81±3.66	38.94±2.81	44.30±3.48
Efficiency of microbial N synthesis (g/kg DOMI)	19.80±0.77	18.90±0.64	20.14±0.71
Body weight (BW) changes during the experiment			
Initial BW (kg)	87.15±11.8	87.25±9.1	87.33±7.8
Final BW (kg)	135.93±11.2	138.79±11.6	150.00±10.9
Total gain (kg)	48.78[a]±1.3	52.54[a]±1.4	62.58[b]±1.6
Average daily gain (g/d)	542.0[a]±29.3	573.1[a]±32.9	695.3[b]±45.7
Feed efficiency	0.18±0.01	0.18±0.01	0.20±0.02

DOMI, digestible organic matter intake.

1) GP-I, groundnut cake (GNC)-based concentrate mixture; GP-II, concentrate mixture containing 75% replacement of groundnut cake (GNC) protein by rice gluten meal; GP-III concentrate mixture containing 75% replacement of GNC protein by maize gluten meal.

2) Predicted value (NRC [15]).

ab Mean values bearing different superscript letters in the same row differ significantly at $p \leq 0.05$.

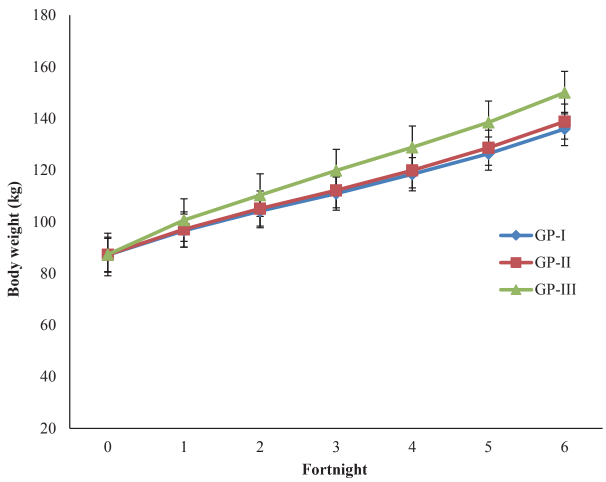

Figure 1. Fortnightly changes in the body weights (kg) among experimental calves fed different protein meals. GP-I, groundnut cake (GNC)-based concentrate mixture; GP-II, concentrate mixture containing 75% replacement of GNC protein by rice gluten meal; GP-III, concentrate mixture containing 75% replacement of GNC protein by maize gluten meal.

of RGM. This might have led to relatively lower carbohydrate content (345 vs 468 g/kg) in the former.

A lack of effect on DM and other nutrient intakes reveals that DMI is not governed primarily by the type of protein source in growing cattle diets. It is consistent with previous findings [4]. Others [20,21] also found a lack of influence of source and levels of dietary protein on DMI in growing cattle/buffaloes. Yet, the actual intake of DM and CP in the present study fulfilled the nutrient requirements of calves [12].

The 75% level of substitution of GNC by either RGM or MGM did not elicit any major changes on nutrient digestibility. Our data is in line with previous reports [4], where no change in digestibility pattern was noted when RGM replaced GNC up to 75% in concentrate mixture fed to dairy calves. Similarly, diets for Comisana lambs, [7] showed that replacing SBM with MGM did not affect nutrient digestibility. It is also reasonable that a similar DMI might have contributed to unaltered nutrient digestion owing to uniform ruminal kinetics and feed passage rate. Many other researchers also deduced similar results when MGM replaced other protein meals for ruminants [6,9-11]. Although not studied in the present experiment, few researchers attributed low utilisation of gluten proteins on account of relatively high heat-damaged acid detergent insoluble N (ADIN) fraction, despite some workers concluded that ADIN level and CP indigestibility is not a one-to-one relationship [22]. We presume such a mechanism might also have resulted in non-significant digestibility of CP in both the gluten meal-fed groups.

The N metabolism differed among three groups, as animals fed MGM-based diets retained slight but significantly higher N than other two groups. Furthermore, a better amino acid profile like methionine in MGM [5] coupled with improved utilisation might have resulted in increased tissue accretion in MGM-based diets than either GNC or RGM diets. In addition, MGM supplies the highest metabolisable protein that is absorbed from intestines in ruminants [5]. It is interesting to note that three different protein meals had very less influence on MNS and its efficiency, as predicted from intake and digestibility of OM [15] (i.e., 0.13 of total digestible nutrients), showing no limitations of either N or fermentable energy for microbial growth in rumen. The present values of microbial efficiency are towards lower side of typical broad range of 18 to 47 g/kg digestible organic matter intake [23] for cattle; nonetheless, these concur with the previous findings, indicating MNS of 40 g/d in growing Sahiwal cattle fed a balanced TMR [20]. As observed in the current trial, no change in ADG was registered when RGM replaced GNC at 50% and 75% for growing crossbred calves [4].

On comparing blood constituents of experimental calves, it can be inferred that protein meals did not exhibit any significant alteration in any of the measured parameters [4,16]. In particular, as ME content of ration was almost similar, the energy biomarkers (glucose and NEFA) did not vary. Similarly, total plasma proteins and PUN, reflecting protein status also did not vary. Overall, it can be stated that incorporation of different protein meals with similar plane of nutrition had no influence on blood energy levels and protein biomarkers in growing Sahiwal calves.

The results allowed us to conclude that dietary inclusion of GNC, RGM, and MGM impacted performance of Sahiwal calves differently, and among these 75% replacement of GNC by MGM was found to be more efficacious in improving growth rate because of higher N retention. Furthermore, under the experimental conditions of this trial, the nutritional worth of GNC and RGM was highly comparable in terms of intake, digestibility and growth. Therefore, the outcome of this research is expected to add new knowledge to Indian feed industry in wisely selecting ingredients for commercial compound feed formulations for growing cattle, thus contributing towards sustainable livestock production.

Table 4. Haematological variables of experimental calves fed on various protein meal-based rations

Attribute	GP-I[1)]	GP-II[1)]	GP-III[1)]
Glucose (mg/dL)	64.78±0.55	65.38±0.50	65.15±0.36
Plasma urea nitrogen (mg/dL)	14.92±0.15	14.97±0.13	15.05±0.21
Total protein (mg/dL)	7.14±0.11	7.18±0.08	7.09±0.05
Non-esterified fatty acids (μmol/L)	100.03±0.32	99.83±0.34	99.96±0.22

[1)] GP-I, groundnut cake (GNC)-based concentrate mixture; GP-II, concentrate mixture containing 75% replacement of groundnut cake (GNC) protein by rice gluten meal; GP-III concentrate mixture containing 75% replacement of GNC protein by maize gluten meal.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organisation regarding the material discussed in the manuscript.

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