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Evaluation of *kharif* Forage Crops for Biomass Production and Nutritional Parameters in Indo-Gangetic Plains of India

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ABSTRACT

A field experiment was conducted during *Kharif*, 2017 at Research Farm of Agronomy Section, ICAR- National Dairy Research Institute, Karnal. The experiment was laid out in randomized complete block design with eight treatments and three replications. Among eight treatments, two perennial forage crops *viz.,* NBH and guinea grass cultivated sole as well as intercropped with cowpea and four seasonal fodder crops (cowpea, sorghum, baby corn and maize) were tested. Among different fodder crops, the highest DM content was recorded in guinea grass intercropped with cowpea in the 2:3 row ratio (25.1%) followed by sole guinea grass (24.9%) and cowpea (16.9%). The yields of protein (14.46 q/ha), ether extract (3.28 q/ha) and total ash (13.07 q/ha) were higher (P<0.05) in NBH intercropped with cowpea. The higher ADF content was observed in the sole sorghum (41.6%) followed by sole guinea (40.1%) and sole maize (35.3%). The higher value of NDF was recorded in the sole guinea grass (71.16%) as compared to other treatments. The ADL was found to be the highest in the sole cowpea (8.68%) crop. The NBH intercropped with cowpea in 2: 3 row ratio produced higher DM yield. The crude protein, ether extract and ash yield were also higher in the same combination of crop.

Key words: Chemical Composition, Fibre fractions, Forage and nutrient yield, Kharif crops

INTRODUCTION

Livestock plays an important role in Indian economy and about 20.5 million people depend upon livestock rearing for their livelihood. Livestock contributed 16% to the income of small farm households as against an average of 14% for all rural households (DAHD & F, 2012). India has vast livestock resources and contributes 4.1% of GDP and 25.6% of total agriculture GDP (GOI, 2017). At present, India is having 5.4% of the cultivated area under fodder crops which has resulted in a severe deficit of green fodder (36%), dry crop residues (11%) and concentrate feed ingredients (44%) as per IGFRI (2016) report. Due to shortage of feed and fodders, animals are not getting sufficient amount of quality feed and fodder resulting in adverse effect on animal's productivity. The two main attempts to fill this gap between fodder requirement and availability are either to increase the area under fodder production or to boost the productivity per unit area per unit time. Increase in area under fodder crops does not appear to be feasible. Therefore, second approach *i.e.* to boost productivity per unit area per unit time, remains the possible alternative.

Napier hybrid bajra and guinea grass are important forage grasses of the tropics known for good biomass production, palatability, persistence and fodder quality. The intercropping of legumes (cowpea) with guinea/napier grass will also ensure the availability of quality fodder in the existing cropping pattern. Halli *et al.* (2018) revealed that grasses grown with legume (cowpea) sustained the soil health and improved the feed quality which resulted in increase in milk production of cattle. The low CP content of these grasses can be enhanced through intercropping with forage legumes to maintain the desirable quality. Maize (*Zea mays* L.) is one of the most important and ideal forages. Sorghum (*Sorghum bicolor* L. Moench.) is most widely grown fodder under rainfed conditions owing to its low water requirement. In India, area under fodder sorghum is around 2.6 m ha (ICAR, 2012) which meets over 2/3rd of the fodder demand during *kharif* in western Haryana, U.P., Punjab, Delhi and Rajasthan. Thus, evaluation of different *kharif* forage crops alongwith perennial forage grasses and their fodder quality of all these crops at single site has not been done. Hence, a field experiment was conducted to evaluate the quality

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aspect of different *kharif* forage crops.

MATERIALS AND METHODS

The field experiment was conducted at the Agronomy Research Farm of ICAR- National Dairy Research Institute, Karnal, Haryana during *kharif*-2017. Karnal is situated in sub-tropical zone with annual rainfall of 1066 mm with bimodal distribution, 70% of which occurs during the main rainy season (June to September).

Soil of the experimental field was clay loam in texture, low in available nitrogen (196 kg/ha), medium in available phosphorus (20.80 kg/ha), high in available potassium (289.30 kg/ha) and neutral to alkaline in reaction (pH 7.18). The experiment was laid out in randomized complete block design (RCBD) with two perennial fodder crops NBH (variety NBH-37), guinea grass (Bundel guinea-1) intercropping combination with cowpea (C-152) and four annual crops cowpea, sorghum, baby corn and maize varieties (C-152, Sudan chari, HM-4 and J-1006, respectively) in the eight treatments with three replications using a total of 24 numbers of plots.

The crop was supplied with well decomposed farm yard manure (FYM) @ 10 t/ha three weeks prior to sowing of the crop. Half dose of nitrogen and full dose of phosphorus and potassium were applied in the form of urea, DAP and MOP, respectively as basal application and remaining half dose of nitrogen was supplied in split dose through broadcasting. In NBH and guinea grass, 25 kg/ha N was top dressed after each cutting. All standard agronomic and required plant protection measures were followed. The 1st cut was taken at 60 (DAP and DAS, respectively) in NBH, guinea grass and cowpea, sorghum and maize while baby corn was harvested at 65 DAS, 2nd cut at 30 days after 1st cutting was taken in the NBH, guinea grass and multicut sorghum. Samples taken from each plot were dried in shade followed by overnight drying in hot air oven at 70^{o}C for DM estimation. The DM, CP, EE and total ash (AOAC, 2005) and cell wall constituent's *viz.,* NDF, ADF, hemicellulose and ADL (Van Soest *et al.,* 1991) were determined. The data were analysed following ANOVA technique (Gomez and Gomez, 1984) in randomizes block design using SAS 9.3 software (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Among different forage crops, the highest DM content was recorded in the intercropped guinea grass (25.1%) with cowpea in the 2:3 row ratio followed by sole guinea grass (24.9%) which was statistically at par with each other (Table 1). The higher DM content was observed in guinea grass because presence of more fibre content than sorghum (21.9%) and maize (21.51%). While, the lowest DM content was recorded in cowpea (16.93%). It might be due to more succulent shoots of cowpea fodder which led to reduction in DM content of

Table 1. DM content, dry fodder yield (DFY), CP content and crude protein yield (CPY) of different fodder crops

Treatment	DM (%)	DFY (t/ha)	CP (%)	CPY (q/ha)
NBH sole	19.27^{d}	11.68^{a}	9.78^{b}	11.43^{b}
Guinea sole	24.9^{a}	10.95^{a}	8.30^{d}	9.08^{c}
NBH + cowpea*	19.57^{d}	11.95^{a}	9.97^{b}	14.46^{a}
Guinea grass + cowpea*	25.1^{a}	10.59^{a}	8.50^{d}	11.67^{b}
Cowpea sole	16.93^{e}	5.68^{c}	17.10^{a}	7.93^{d}
Sorghum sole	21.96^{b}	9.91^{b}	8.01^{e}	9.72^{c}
Baby corn sole	19.57^{d}	6.50^{c}	8.94^{d}	5.84^{e}
Maize sole	21.51^{c}	9.99^{b}	9.45^{e}	9.43^{c}
SEm±	0.14	0.55	0.14	0.57
LSD (P= 0.05)	0.43	1.61	0.42	1.69

^{a,b,c,d,e} Values bearing different superscripts in a column differ significantly (P<0.05) fodder cowpea plant. The present results are similar to those reported by Babasup *et al.* (2011).

Among different fodder crops, the highest dry fodder yield was recorded in the intercropping (2:3) row ratio of NBH + cowpea (11.95 t/ha) followed by sole NBH (11.68 t/ha). Sole NBH value was statistically at par with that of NBH + cowpea intercropping (Table 1). Mean relative yields of all intercropping treatments were greater (P<0.05) than sole fodder crops which indicated the advantages of intercropping over sole production. Higher dry fodder yield might be because these fodders showed the vigour and inherent growth performance. Nitrogen fixation ability of cowpea provided nitrogen carried over to NBH which enhanced the growth performance and production potentials by producing higher number of tillers and leaves/clumps and fast accumulation of sink component of photosynthesis. The lower dry fodder yield was noticed in the sole fodder cowpea due to higher moister content and lower fibre content. Anita *et al.* (2015) revealed that NBH and guinea grass intercropped with cowpea enhanced the total green fodder yield. The results of present investigation are in conformity with the findings of Aulakh *et al.* (2012).

The higher CP content was recorded in cowpea crop. The comparable values of CP content were also observed in cowpea (17.19 and 17.12%) intercropped with guinea and NBH grass, respectively in (2: 3) row ratio (Table 1). Among different non-leguminous fodder crops, higher CP content was recorded in NBH (9.97%) intercropped with cowpea followed by sole NBH (9.78%) while the lowest level was recorded in sole sorghum (8.01%). The highest total CP yield (14.46 q/ha) was recorded in NBH + cowpea intercropping followed by guinea + cowpea (11.67 q/ha) intercropping. The lowest value of total CP yield was recorded in sole baby corn (5.84 q/ha). This might be due to its lower DM yield as well as CP content while the highest CP yield in NBH + cowpea intercropping could be due to higher dry matter yield. These findings are in conformity with those of Kushwaha *et al.* (2018). Cowpea is usually intercropped with cereal fodders and grasses to improve the nutritive value of the herbage and similar results have been reported by Strydhorst *et al.* (2008). Sengul (2003) noticed that intercropping system provided better micro-environment that favoured higher protein content than those obtained from sole legume or grass stands.

The EE content was the highest in fodder cowpea (3.0%) intercropped with NBH followed by cowpea (2.95%) intercropped with guinea grass. It was comparatively higher than the rest of fodder crops. Among others crops, the lowest value of EE was observed in sole baby corn (1.54%). Ayub *et al.* (2002) also reported that EE content was positively correlated with nitrogen application. Total ether EE yield was the highest in intercropping of NBH + cowpea fodder (3.28 q/ha) followed by sole crop of NBH (3.03 q/ha) (Table

Table 2. Ether extract, ether yield, ash content, ash yield and NFE content of different fodder crops

Treatment	EE (%)	EE yield (q/ha)	Ash (%)	Ash yield (q/ha)	NFE (%)
NBH sole	2.60^{b}	3.03^{a}	10.81^{b}	12.63^{a}	47.11^{b}
Guinea sole	1.64^{d}	1.80^{c}	11.72^{a}	12.83^{a}	45.27^{c}
NBH + Cowpea*	2.65^{a}	3.28^{a}	10.85^{b}	13.07^{a}	47.66^{b}
Guinea grass + Cowpea*	1.67^{c}	2.21^{b}	11.88^{a}	12.31^{a}	45.39^{c}
Cowpea sole	2.85^{a}	1.62^{c}	10.88^{b}	6.19^{c}	42.9^{d}
Sorghum sole	1.88^{c}	1.85^{c}	9.60^{c}	9.51^{b}	50.43^{a}
Baby corn sole	1.54^{d}	1.00^{d}	8.53^{e}	5.55^{c}	50.77^{a}
Maize sole	1.63^{d}	1.63^{c}	9.15^{d}	9.14^{b}	50.92^{a}
SEm±	0.07	0.11	0.1	0.56	0.39
LSD (P= 0.05)	0.22	0.35	0.31	1.65	1.17

[a,b,c,d,e] Values bearing different superscripts in a column differ significantly (P<0.05)

2). The total ash content was the highest in guinea grass (11.88%) intercropped with cowpea followed by guinea sole (11.72%). It was higher than other treatments. The lowest ash content was recorded in baby corn (8.53%) compared to other treatments which might be due to the higher DM content in guinea grass compared to other forage crops. The total ash yield (q/ha) was the highest in combination of NBH intercropping (13.07 q/ha) with cowpea in 2: 3 row ratio followed by sole guinea grass (12.83 q/ha) while the lowest total ash yield was obtained in the baby corn (5.55 q/ha). Similar findings were also reported by Rathore *et al.* (2015).

Among different forage crops, NFE content (Table 2.) was the highest in sole maize (50.92%), baby corn (50.77%) and sorghum (50.43%). Cereal forage crops showed higher NFE content compared to those of leguminous crops. The lowest NFE content was recorded in cowpea intercropped with grasses. The N application rate was inversely proportional to NFE content (Glamoclija *et al.,* 2011).

Among different cereals forage crops, the highest NDF content (Table 3) was obtained in sole guinea grass (71.16%) followed by sole sorghum (70.62%) and guinea grass intercropped with cowpea (70.57%). These were statistically at par with sole guinea grass. The lowest NDF content was noticed in the sole maize (62.67%). However, in cowpea, NDF content was lower (P<0.05) than all cereal forage crops which might be due to the fact that more rapidly synthesized carbohydrates are converted into proteins and protoplasm and only smaller portion is available for cell wall material. The results are in close conformity with the findings of Ayub *et al.* (2002) in sorghum.

The ADF content (Table 3) in sole sorghum (41.61%), sole guinea (40.07%), guinea intercropped (39.37%), sole NHB (38.84%), intercropped NBH (38.33%) were statistically at par with sole sorghum forage. The lowest ADF content was noticed in sole maize (35.3%) and it was lower than sole sorghum fodder crop. However, in cowpea, the ADF content (30.81%) was lower compared to all cereal forage crops. It is observed that legume fodder crops are more digestible than cereal fodder crops. Similar values of proximate principles and fibre fractions have been reported by Chander Datt *et al.* (2009).

The hemicellulose content was the highest in the guinea grass (31.2%) intercropped with cowpea in 2: 3 row ratio and sole guinea grass (31.09%) with cowpea. Cereal forage crops had higher hemicellulose content compared to legume fodder crops. The lowest hemicellulose content was observed in sole cowpea (16%). Hemicellulose content in plants possessed inverse relation with nitrogen uptake and CP content. Iqbal *et al.* (2012) reported that to get better CF yield, cereal fodder should be intercropped with legumes fodder preferably cowpea. The highest acid detergent lignin (ADL) content was recorded in the sole cowpea fodder crop (8.68%) followed by intercropping of

Table 3. Fibre fractions (% DM basis) in different treatments

Treatment	NDF (%)	ADF (%)	Hemicellulose (%)	ADL (%)
NBH sole	68.04[b]	38.84[a]	29.20[a]	3.49[c]
Guinea sole	71.16[a]	40.07[a]	31.09[a]	3.25[c]
NBH + cowpea*	67.63[b]	38.33[a]	29.3[a]	3.28[c]
Guinea grass + cowpea*	70.57[a]	39.37[a]	31.2[a]	3.27[c]
cowpea Sole	46.81[d]	30.81[c]	16.00[b]	8.68[a]
Sorghum sole	70.62[a]	41.61[a]	29.01[a]	4.82[b]
Baby corn sole	63.06[c]	35.94[b]	27.12[a]	4.85[b]
Maize sole	62.67[c]	35.30[b]	27.37[a]	4.99[b]
SEm±	0.55	1.66	1.75	0.18
LSD (P= 0.05)	1.64	4.88	5.15	0.53

[a,b,c,d] Values bearing different superscripts in a column differ significantly (P<0.05)

cowpea (8.15%) with guinea grass. While the lowest ADL content was obtained in the sole guinea grass (3.25%) as also reported by Das *et al.* (2015).

CONCLUSION

The intercropping of NBH with cowpea in 2: 3 row ratio produced higher dry matter yield. The crude protein, ether extract and ash yield were also recorded higher in the same combination of crops. These all parameters are indicative of its good quality fodder production.

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Bioavailability of Major Minerals from Commonly Used Ruminants Feeds Using Dialyzability Technique

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ABSTRACT

Four feeds namely maize (*Zea mays*) grain, deoiled rice (*Oryza sativa*) bran, groundnut (*Arachis hypogaea*) cake and mustard (*Brassica campestris*) cake were used to assess the bioavailability of calcium, phosphorous, magnesium, sodium and potassium by dialyzability technique under *in vitro* conditions. For this, three Karan Fries calves kept on roughage based diet were used for collection of rumen liquor through stomach tube. *In vitro* dry matter digestibility (IVDMD) of different samples was estimated at three stages *i.e.* simulating ruminal, abomasal and intestinal conditions followed by determination of bioavailability of major minerals in the soluble fraction of intestinal stage sample through a 12 kD dialyzable membrane. Maize grain (69.91±1.11) possessed the highest ($P<0.05$) IVDMD value followed by mustard cake (68.51±1.087), groundnut cake (63.59±2.07) and deoiled rice bran (51.22±1.05) at the intestinal stage of digestion. Similarly, the highest ($P<0.05$) bioavailability of Ca, P and Mg (71.76±1.66, 87.57±0.37 and 85.05±0.12%, respectively) was found for maize grain followed by mustard cake, groundnut cake and deoiled rice bran, however, Na bioavailability was higher (98.10±0.10%) in case of groundnut cake and numerically similar values were obtained for K. Results suggested that *in vitro* method could be used for prediction of bioavailable minerals fraction from feeds, however, validation by actual *in vivo* experiment is required before accepting the bioavailability values while considering these for dietary mineral requirements.

Key words: Bioavailability, Dialyzability, In *vitro* digestion, IVDMD, Major minerals

INTRODUCTION

There is scanty information on bioavailability of minerals from different feed ingredients. Reliance on simplistic attributes such as solubility of the plant mineral in water or unphysiological extractants (*e.g.* citric acid) produces results having poor correlation with *in vivo* assessments of mineral bioavailability. Now a days, to assess the bioavailability of minerals, *in vitro* methods have gained importance because of accuracy of results, speed of analysis and relatively low costs. Solubility after the sequential simulation of gastric and intestinal digestion can give convincing values for ruminants. The accessibility of minerals to rumen microbes is equally important. Use of such *in vitro* techniques for prediction of availability can be made but account must be taken of possible interactions between feeds and results will always have to be validated *in vivo* (Suttle, 2010). Besides this, minerals in feeds and forages are associated with other compounds or trapped in the indigestible nutrient fractions resulting in slow release or making these unavailable for use. Therefore, mineral content can be determined chemically while bioavailability is difficult to be estimate (Evitayani *et al.,* 2006). Hence, this study was designed to investigate the bioavailability of major minerals (Ca, P, Mg, Na and K) present in mustard cake, groundnut cake, maize grain and deoiled rice bran under *in vitro* conditions.

MATERIALS AND METHODS

The samples of test feed *i.e.* maize grain, groundnut cake, mustard cake and deoiled rice bran were collected from feed mill of ICAR-National Dairy Research Institute, Karnal and dried in hot air oven at 80°C for 48 h and ground to pass through 1 mm sieve using Willey mill and stored in 200 mL capacity plastic bottles. These were analyzed for their proximate principles (AOAC, 2005) and fiber fractions (Van Soest *et al.,* 1991). Residues left after NDF and ADF determination were pooled separately for further analysis of NDF and ADF bound minerals.

Three stage *in vitro* experiment was conducted to determine DM digestibility of different feed ingredients. Ground samples were subjected to a

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simulated ruminal, abomasal and intestinal phase digestion by following the method of Tilley and Terry (1963) with certain modification as described by Calsamiglia and Stern (1995). Rumen liquor was collected from three male Karan Fries calves (Av. age= 12 month; BW=120 kg) using stomach tube. After collection of rumen liquor in pre warmed thermos flask, brought to laboratory and used as a source of rumen microbes. About 0.5 g of ground sample was taken for ruminal digestion to which 10 mL of fresh strained rumen liquor and 40 mL of McDougall buffer (McDougall, 1948) were added, CO_2 was passed through the contents for about 10 sec. and the stoppard flasks were incubated for 24 h at 38ºC with periodic shaking. Ruminal digestion was followed by addition of 2 mL of 6N HCl and 0.1 g pepsin enzyme (from porcine mucosa) and pH was then adjusted to 2.0 with additional HCl. After 24 h of incubation at 38ºC in abomasal followed by intestinal with addition of 0.5 mL of 1N NaOH and 13.5 mL of a pH 7.8 phosphate buffer containing 37.5 mg of pancreatin (pancreatic enzymes from porcine pancreas, P1750, Sigma-Aldrich). The contents were incubated at 38°C for 6 h. After incubation, the flasks were removed and centrifuged at 3000 rpm for 10 min. and supernatant was collected for further analysis.

In dialysis procedure, pre treatment of dialyzable membrane (flat width 25 mm, internal diameter 16 mm, molecular weight 12 kD, Sigma-Aldrich) was done by boiling it for 5 min. in Millipore water. The ready to use membranes were kept in 20% ethanol solution in refrigerator at 4ºC and rinsed several times with Millipore water. A known quantity of sample (10 mL) was taken from the supernatant collected in third stage of *in vitro* digestion and was filled in dialyzable membrane and tied with thread. Samples were kept in 1000 mL beaker containing 500 mL Millipore water for 24 h. The contents were continuously shaken using magnetic stirrer (Kaushik, 2013). The bioavailabilty of minerals was the amount of dialyzable mineral expressed as a percentage of total mineral in the feed sample (Hansen, 2008). Bioavailability of minerals was determined by estimating concentration of the mineral in dialysate.

The modified method of closed system of acid digestion of samples (EPA, 2001) was followed for digestion of samples for mineral estimation. The contents of Ca, Mg, Na, and K were analysed using atomic absorption spectrophotometer (Hitachi Model Z – 5000 with Zeeman correction). The P content was estimated by spectrophotometer (AOAC, 2005). The data were statistically analyzed using SPSS (2010).

Table 1. Chemical composition (% DM basis) and mineral profile of the feeds

Parameter	Mustard cake	Groundnut cake	Maize grain	Deoiled rice bran
Dry matter	91.52	91.62	91.76	90.97
Crude protein	37.70	45.45	9.81	16.60
Ether extract	5.90	6.12	4.22	1.10
Crude fibre	8.37	7.61	2.42	13.09
Nitrogen free extract	39.91	34.52	83.56	54.32
Ash	8.12	6.32	1.53	14.90
Neutral detergent fibre	29.50	18.12	11.70	41.10
Acid detergent fibre	20.62	14.32	2.80	25.50
Calcium	0.48	0.32	0.15	0.80
Phosphorous	1.58	0.74	0.41	1.90
Magnesium	0.63	0.51	0.34	1.14
Sodium	0.082	0.05	0.025	0.033
Potassium	1.84	1.25	0.78	1.25

Table 2. Mineral (% of total) found in NDF and ADF fraction of feeds

Parameter	Fibre fraction	Mustard cake	Groundnut cake	Maize grain	Deoiled rice bran
Calcium	NDF	3.63	3.79	3.23	6.52
	ADF	2.69	2.36	1.91	2.79
Phosphorous	NDF	2.135	2.417	2.432	5.52
	ADF	0.76	0.78	0.457	1.751
Magnesium	NDF	2.57	2.72	1.75	3.37
	ADF	1.13	1.19	0.83	1.12
Sodium	NDF	0.718	0.752	0.372	0.775
	ADF	0.274	0.282	0.153	0.313
Potassium	NDF	0.693	0.714	0.412	1.331
	ADF	0.355	0.321	0.166	0.51

(n=6, replicates per feed)

RESULTS AND DISCUSSION

The chemical composition of the four ingredients has been presented in Table 1. Deoiled rice bran had higher NDF (41.10%) followed by mustard cake (29.50%). Lowest values for NDF (11.70%) and ADF (2.30%) were observed in maize grain. The values are in agreement with those reported by ICAR (2013). The highest values for Ca (0.80%), P (1.90%) and Mg (1.14%) were found in DORB. The lowest levels of Ca (0.15%,), P (0.41%), Mg (0.34%), Na (0.025%) and K (0.78%) were found in maize grain. Kumar and Kaur (2007) reported that Ca and P contents in different concentrate ingredients varied from 0.11 to 0.67% and from 0.68 to 1.61%, respectively. The results of present study are comparable with the values given by ICAR (2013).

The maximum association of Ca with NDF and ADF fraction was found in DORB (6.52 and 2.79%). The association of all the minerals with fiber fractions were lowest in case of maize grain among all four feedstuffs (Table 2). Among all minerals, solubility of Ca was quite low. No information is available on minerals associated with NDF and ADF fractions in concentrate ingredients. However, reports are available indicating variation in association of minerals with cell wall constituents in forages. Serra *et al.* (1996) reported 0.7 Ca, 14.3 P, 1.9 Mg and 3.7% K associated with NDF and 0.2 Ca, 4.4 P, 0.7 Mg and 2.8% K with ADF fraction in same forages. Evitayani *et al.* (2006) showed that 27.5 Ca, 8.3 P and 18.1% Mg was associated with NDF and 7.8 Ca, 1.8 P and 2.2% Mg was associated with ADF in grasses.

There was increasing trend in digestibility (Table 3) when incubation proceeded from ruminal to intestinal stage in all feeds and a similar trends was also reported by Gupta *et al.* (2016) and Parihar *et al.* (2017). Significantly ($P<0.05$) higher IVDMD values were found in maize grain (66.52-72.10%) and lowest in deoiled rice bran (42.90-57.27%). The highest digestibility was 69.91% in maize grain. Digestibility of

Table 3. *In vitro* DM digestibility (%) estimated by three stage digestion technique

Feed	Ruminal stage	Up to abomasal stage	Up to intestinal stage
Mustard cake	$65.59^{Ca}\pm0.7$	$68.74^{Cab}\pm0.6$	$71.19^{Bb}\pm1.04$
Groundnut cake	$57.44^{Ba}\pm1.8$	$65.32^{Bb}\pm0.51$	$68.04^{Bb}\pm2.1$
Maize grain	$66.52^{Ca}\pm0.9$	$71.12^{Db}\pm0.7$	$72.10^{Cb}\pm0.03$
Deoiled rice bran	$42.90^{Aa}\pm0.64$	$53.49^{Ab}\pm0.24$	$57.27^{Ab}\pm1.7$

Figures with different superscripts in a row^{a,b} and in a column$^{A, B,C, D}$ differ significantly ($P<0.05$): (n= 9 replicate per feed)

Table 4. Bioavailability (%) of various major minerals from different feeds using dialyzability technique

Parameter	Mustard cake	Groundnut cake	Maize grain	Deoiled rice bran
Calcium	65.28^{ab}±0.69	61.88^{a}±1.23	71.76^{c}±1.66	66.70^{b}±1.03
Phosphorous	81.20^{a}±0.13	82.73^{b}±0.27	87.57^{c}±0.37	81.22^{a}±0.25
Magnesium	82.42^{a}±0.06	84.34^{b}±0.09	85.05^{c}±0.12	82.49^{a}±0.15
Sodium	97.99^{b}±0.35	98.10^{b}±0.10	95.55^{a}±0.50	96.04^{a}±0.36
Potassium	95.89±0.61	94.33±0.75	96.06±0.11	95.88±0.25

^{a,b,c}Values with different superscripts in a row differ significantly ($P<0.05$); (n= 9 per feed)

mustard cake at ruminal, abomasal and intestinal stage of incubation was found to be 65.59±0.7, 68.74±0.6, 71.19±1.04% and the corresponding values were 57.44±1.8, 65.32±0.51, 68.04±2.1% for groundnut cake. Mondal *et al.* (2010) reported comparable values of DM digestibility in mustard cake (69.63%) and groundnut cake (60.88%) but it was lower for maize grain (50.3%).

The Ca bioavailability (%) was 61.88±1.23 for groundnut cake and 65.28±0.69 for mustard cake. Kumar *et al.* (2015) reported slightly lower values than the present values. Maize grain had higher ($P<0.05$) bioavailability values for Ca (71.76±1.66), P (87.57±0.37) and Mg (85.05±0.12%), respectively than those from mustard cake, groundnut cake and de oiled rice bran which might be due to the lower fibre content, lower association of these minerals with NDF, ADF and higher degradability of maize grain. Values for Na and K were quite high (94.33 to 98.10%) though significantly higher values were found for Na release for both the cakes but considering the extent of release these values seemed be of no practical relevance. Brown *et al.* (2004) reported similar pattern of ruminal release of K from corn and cotton seed meal and reported values of more than 80%. Ceresnakova *et al.* (2007) conducted *in sacco* study on some grasses such as hybrid rila, hybrid niva, grass silage and reported the disappearance of K up to 98 to 99%. Trinacty *et al.* (2000) observed total tract release of K to be 98.4% from lucerne hay using nylon capsule method. Bamikole (2009) studied the macro-mineral bioavailability in goats fed forages of nitrogen fertilized guinea grass and guinea grass verano stylo mixture and observed that K all forages was well utilized with no significant variations.

CONCLUSIONS

Though, *in vitro* method could be used for prediction of bioavailable minerals fraction from feeds, however, validation by actual feeding trial is required before accepting the bioavailability values while formulating rations as the present bioavailability values were much higher than those reported by NRC (2001) under practical situations.

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