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Review article

Voluntary feed intake and digestibility of four domestic ruminant species as influenced by dietary constituents: A meta-analysis

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This meta-analysis was performed to evaluate whether voluntary feed intake and digestibility of forage-based diets differ between four domestic ruminant species, i.e. sheep, goats, cattle and buffaloes, and secondly, whether dietary constituents, i.e. protein and fibre influence the respective variables. A dataset on voluntary feed intake, digestibility and composition of basal diets and supplements of the respective domestic ruminant species was compiled by pooling data from previously published studies. A total of 45 studies were found to meet the required criteria. Data were analysed by mixed model regression methodology. Discrete (domestic ruminant species) and continuous predictor variables (chemical composition of diet) were treated as fixed effects, while different studies were considered as random effects. Significant linear relationships were observed between log-transformed boy weight and log-transformed dry matter intake (DMI) for all ruminant species ($P < 0.05$). Within species, this scaling factor was lower for sheep and goats than for cattle and buffalo. Crude protein (CP) concentration affected DMI of ruminants positively with variations among the species; buffaloes were more responsive to CP, followed by sheep, goats and cattle. In contrast, acid detergent fibre (ADF) negatively influenced DMI across all species except buffaloes, and had a much stronger effect on DMI of sheep and cattle than on DMI of goats. The impact of CP on DM digestibility (DMD) was similar to its influence on DMI. The strongest effect was observed in cattle and was only significant in cattle and buffaloes ($P < 0.05$). Neutral detergent fibre reduced DMD only in cattle, while sheep were positively influenced and goats tended to be positively affected. The ADF lowered DMD in sheep, goats and cattle with significant effect for sheep and goats.

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1. Introduction

Numerous studies have compared feed intake and digestibility of various nutrients between sheep and goats (e.g. Abidi et al., 2009; Molina Alcaide et al., 2000; Yañez-Ruiz and Molina Alcaide, 2008) and between sheep and cattle (e.g. Kawashima et al., 2007; Mulligan et al., 2001; Südekum et al., 1995). Fewer studies have made comparisons between cattle and buffaloes (e.g. Ichinohe et al., 2004; Lapitan et al., 2008; Pearson and Archibald, 1990). Also relatively few published studies are available for comparison of feed intake and digestibility among more than two ruminant species (e.g. Burns et al., 2005; Sharma and Murdia, 1974; Sharma and Rajora, 1977). Therefore, we assumed that it may be a useful and informative addition to the limited literature to investigate the influence of different dietary factors on voluntary intake and digestibility of more than two domestic ruminant species simultaneously.

For comparisons of voluntary feed intake across ruminant species of varying body weights (BW), a reference scaling unit is needed to achieve comparability, because large ruminants will usually eat less relative to BW than small ones. Thus, different scaling factors have been applied to compare feed intake among ruminants of various sizes. Traditionally, for sheep and cattle feed intake comparisons in Europe, metabolic body size (MBS, i.e. $BW^{0.75}$; Kleiber, 1961) is used as a scaling factor and researchers in North America usually express dry matter (DM) intake (DMI) related to $BW^{1.0}$ (Mertens, 1994). Researchers in Australia and New Zealand frequently use the reference unit of $BW^{0.90}$ based on the recommendations of Graham (1972) for feed intake comparisons. The scaling unit of $BW^{0.90}$ has been verified by several other researchers, supporting its use for feed intake comparisons among different livestock species (Hackmann and Spain, 2010; Minson and Whiteman, 1989; Reid et al., 1990). These different scaling factors have also been found in datasets comparing mammalian herbivores beyond ruminants. Across all available species ranging from small rodents to elephants, dry matter intake scales more or less to MBS (reviewed in Clauss et al. (2007) and Meyer et al. (2010)). If, in contrast, only large species with a BW above 10 kg are considered, the scaling exponent is higher at $BW^{0.84}$ (Müller et al., 2013). The relevance of these different scaling exponents lies in their use when comparing data on DMI between animals of different BW within and between species. If for example a lower scaling exponent (e.g. $BW^{0.75}$) is used for comparisons than the actual one (e.g. $BW^{0.84}$), then the relative intake of the larger animals (expressed per unit $BW^{0.75}$ in this example) will be artificially increased compared to that of the smaller animals. For the same reason, it is important to know whether the same scaling exponents can be used in inter- and intraspecific comparisons.

Inconsistencies between the outcomes of individual studies may result from differences in the specific experimental conditions, the diets used and their chemical composition. Combining data from various reports into a meta-analysis can be a useful tool to deal with the inconsistencies exhibited across a variety of experimental conditions of different studies (Charbonneau et al., 2006; Sauvant et al., 2008). Therefore, we performed a meta-analysis of various studies to determine whether there is a common scaling exponent for DMI among domestic ruminant species or if this exponent is species specific, and to investigate the influence of dietary nutrient composition on DMI and digestibility.

2. Materials and methods

2.1. Description of database

A dataset summarizing voluntary feed intake, digestibility, and composition of basal diets and supplements of forage-based diets fed to domestic sheep, cattle, goats and buffaloes was compiled by pooling data from scientific literature (references listed in Appendix). The total number of studies meeting the inclusion criteria was 45, which were divided into 3 main categories that comprised comparisons between sheep and cattle ($n=10$), sheep and goats ($n=25$), and cattle and buffaloes ($n=10$). The corresponding numbers of individual observations for sheep, goats, cattle and buffaloes were 139, 78, 91 and 30, respectively. Detailed composition of diets evaluated in the present study can be obtained from the corresponding author upon request. The prerequisites for a study to be included in the dataset was that DM digestibility (DMD, in g/kg), BW of animals (individual BW (kg)) of animals used in an experiment or mean value of a group of animals given for a certain trial, and feed intake (expressed as DMI, g/day) of any two or more of the above mentioned domestic ruminant species was reported for ad libitum feeding conditions. Chemical characteristics of the diets (i.e. neutral detergent fibre (NDF), acid detergent fibre (ADF) and/or crude protein (CP)) were included as available. Feed intake data given as kg/day, % of BW or g/kg $BW^{1.0}$, g/kg $BW^{0.90}$ or g/kg $BW^{0.75}$ were converted to g/day.

An allometric relationship between DMI and BW was constructed according to the following model:

$$DMI = aBW^b,$$

where a is a constant and b is the scaling factor. The respective model was transformed into its logarithmic equation to obtain a linear relationship between DMI and BW, where the scaling factor is the slope of the equation:

$$\log DMI = \log a + b \log BW$$

In a first step, scaling factors were estimated for each ruminant species separately. The scaling factor was then used to obtain species-specific MBS, i.e. $BW^{\text{scaling factor}}$ for each species. Feed intake was then expressed as g DMI per unit of species-specific MBS. To know whether there is a common scaling factor for all four ruminant species or not (i.e. each species has its specific scaling factor), interaction between species and log BW on log DMI was statistically tested.

2.2. Statistical analyses

Data were analysed using mixed model regression methodology (St-Pierre, 2001; Sauvant et al., 2008). Models with either discrete a predictor variable (domestic ruminant species) or continuous predictor variables (chemical composition of diets: CP, NDF or ADF) were assessed individually. The respective predictor variables were considered as fixed effects. Different studies were considered as random effects. The model statistics used for this study was Akaike's information criterion (AIC). The AIC was applied in model selection to measure the relative goodness of fit of a statistical model. In this study, AIC was used to select whether a model is quadratic or linear (lower AIC is better model), together with the P-value (explained below). Accordingly, for the continuous predictor variable (chemical composition of diet), the following model was used:

$$Y_{ij} = B_0 + B_1X_{ij} + B_2X_{ij}^2 + s_i + b_iX_{ij} + e_{ij},$$

where Y_{ij}=the dependent variable, B_0=overall inter-study intercept (fixed effect), B_1=the overall linear regression coefficient Y on X (fixed effect), B_2=the overall quadratic regression coefficient Y on X (fixed effect), X_{ij}=the value of the continuous predictor variable, s_i=the random effect of the ith study, b_i=the random effect of study on the regression coefficient of Y on X, and e_{ij}=the residual error. When a quadratic model did not significantly explain the relationship between independent and dependent variables, the model was modified into a linear model by taking out the $B_2X_{ij}^2$ term. For the discrete predictor variable (domestic ruminant species), the following model was applied:

$$Y_{ijk} = \mu + s_i + \tau_j + s\tau_{ij} + e_{ijk},$$

where Y_{ijk}=the dependent variable, μ=overall mean, s_i=the random effect of the ith study, τ_j=the fixed effect of the jth level of factor τ, $s\tau_{ij}$=the random interaction between the ith study and the jth level of factor τ, e_{ijk}=the residual error.

Data were weighted by the number of animals in each study. Tukey's test was applied as a post hoc test to compare the differences among means in the case of discrete predictor variables.

3. Results

In some studies not all the variables of interest were reported, therefore, the number of observations across variables was not uniform (Table 1). There were large differences between minimum and maximum values in the database for dietary constituents (NDF, ADF and CP) between buffaloes and the other three species; for these three species, however, the nutrient ranges of the diets were relatively similar.

Table 1
Statistical description of the dietary and response variables in the database.

Species	Variables[a]	n[b]	Mean	SD[c]	Minimum	Maximum
Sheep						
	Body weight, kg	139	41.6	17.3	10.2	82.6
	Feed nutrients, g/kg DM					
	NDF	69	520	168	134	768
	ADF	53	364	154	94	870
	CP	126	124	68	16	422
	DMI, g/kg MBS	139	898	435	139	2530
	DMD, g/kg DM	92	580	95	243	815
Goats						
	Body weight, kg	78	26.0	15.0	7.0	67.8
	Feed nutrients, g/kg DM					
	NDF	35	457	184	134	764
	ADF	25	347	164	94	870
	CP	78	121	75	25	422
	DMI, g/kg MBS	78	600	300	150	1520
	DMD, g/kg DM	45	611	102	312	869
Cattle						
	Body weight, kg	91	391.0	136.5	103.0	674.0
	Feed nutrients, g/kg DM					
	NDF	38	603	83	406	768
	ADF	43	403	128	221	661
	CP	68	114	66	16	313
	DMI, g/kg MBS	91	6857	3166	1680	19870
	DMD, g/kg DM	67	555	87	366	717
Buffaloes						
	Body weight, kg	30	329.0	137.8	150.0	722.0
	Feed nutrients, g/kg DM					
	NDF	5	606	54	510	632
	ADF	15	450	65	350	578
	CP	26	76	66	22	255
	DMI, g/kg MBS	30	5539	2055	2390	11200
	DMD, g/kg DM	15	478	79	366	610

References used to construct the data base are given as a separate list at the end of the article before the reference section.

[a] NDF=neutral detergent fibre; ADF=acid detergent fibre; CP=crude protein; DM=dry matter, DMI=DM intake; DMD=DM digestibility; MBS=Metabolic body size.

[b] n=Number of data used.

[c] SD=Standard deviation.

Significant linear relationships were observed between log-transformed BW and log-transformed DMI of all domestic ruminant species in this study (Fig. 1). Individual regression equations for each ruminant species as shown in the footnote of Fig. 1 demonstrated that the scaling exponent for relative DMI (rDMI; intake expressed in relation to BW) is lower in small ruminants than in large ruminants. The differences for scaling factors among species were significant for each individual factor as shown by the significant interaction between species and log BW ($P<0.01$).

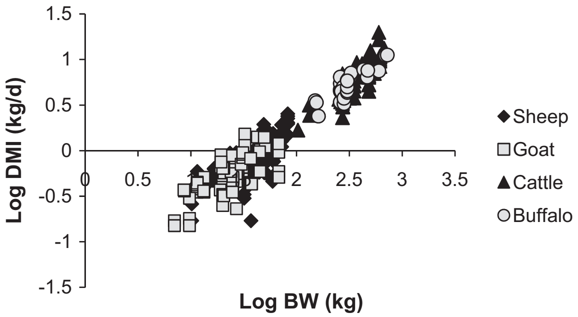

Fig. 1. Relationship between log body weight (BW) and log dry matter intake (DMI). The regression equation for each ruminant species is as follows (mean ± 95% confidence interval): Sheep: log DMI = −1.105 (±0.290)+0.639 (±0.187)log BW; $P<0.001$; $r^2=0.49$. Goat: log DMI = −1.231 (±0.290)+0.714 (±0.212)log BW; $P<0.001$; $r^2=0.55$. Cattle: log DMI = −1.461 (±0.445)+0.883 (±0.175) log BW; $P<0.001$; $r^2=0.71$. Buffalo: log DMI = −1.316 (±0.602)+0.818 (±0.246) log BW; $P<0.001$; $r^2=0.75$. *P*-values: species, $P<0.01$; log BW, $P<0.001$; species × log BW, $P<0.01$.

The regression analysis showed that CP concentration impacted positively on DMI of ruminants with variations among the species (Table 2). Quite large differences were found for slope values of regression equations among all four ruminant species. The impact of feed constituents on DMI of these four ruminant species is also shown in Fig. 2. Overall buffaloes were found to be more responsive to CP with slope value of 0.364, followed by sheep, goats and cattle, and this response was significant for all species. In case of NDF, the number of observations for buffaloes was low; therefore, it was not possible to include this continuous predictor variable in the analysis. However, NDF negatively affected DMI of the other three species yet with a significant effect in cattle only. In contrast, ADF negatively influenced DMI of all species except buffaloes, showing the strongest effect on DMI of sheep and cattle with slope values of −0.032 and −0.023, respectively. The DMI of goats was less influenced by ADF with a slope value of −0.005 (Table 2).

The regression analysis for the effect of dietary factors on digestibility of animals showed that CP was positively correlated to DMD across species. The effect was much greater in cattle than the other three ruminant species, and it was significant only for cattle and buffaloes ($P<0.05$; Table 3). The database of buffaloes for NDF and ADF was small. Therefore, only sheep, goat and cattle data could be analysed for these chemical entities. The NDF depressed DMD only in cattle, whereas it positively

Table 2
Equations for linear regression between chemical composition of feeds (independent variable; in g/kg dry matter) and dry matter intake (response variable); g/kg metabolic body size of sheep, goats, cattle and buffaloes.

Independent				Parameter estimates[d]						Model statistics[e]
Variables[a]	Species	Model[b]	*n*[c]	Intercept	95% CI	$P_{Intercept}$	Slope	95% CI	P_{Slope}	AIC
CP	Sheep	Q	126	57.3	14.1	<0.001	0.289	0.161	<0.001	
							−0.0005	0.0004	0.014	1157.1
	Goats	Q	78	43.9	12.3	<0.001	0.211	0.125	0.002	
							−0.0004	0.0003	0.013	680.0
	Cattle	Q	74	22.9	7.0	<0.001	0.199	0.092	<0.001	
							−0.0005	0.0003	<0.001	531.3
	Buffaloes	Q	26	32.1	7.0	<0.001	0.364	0.152	<0.001	
							−0.0012	0.0005	<0.001	190.3
	All	Q	304	42.4	11.4	<0.001	0.266	0.139	<0.001	
							−0.0005	0.0004	0.008	2917.0
NDF	Sheep	L	67	106.5	25.1	<0.001	−0.041	0.045	0.085	612.1
	Goats	L	34	69.3	19.1	<0.001	−0.012	0.032	0.472	287.8
	Cattle	L	38	75.1	21.3	<0.001	−0.060	0.035	0.002	260.9
	Buffaloes	n.d.	5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	All	L	144	95.5	19.4	<0.001	−0.050	0.036	0.008	1406.8
ADF	Sheep	L	53	99.4	23.3	<0.001	−0.032	0.055	0.263	485.0
	Goats	L	25	59.6	16.0	<0.001	−0.005	0.033	0.787	205.1
	Cattle	L	43	46.8	17.7	0.002	−0.023	0.036	0.224	306.9
	Buffaloes	L	15	42.3	22.4	0.034	0.004	0.049	0.868	107.0
	All	L	136	75.8	20.3	<0.001	−0.031	0.048	0.214	1330.4

[a] CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre.
[b] *Q* = quadratic; *L* = linear; n.d. = not determined; number of data for buffaloes was <10.
[c] *n* = Number of data used.
[d] CI = Confidence interval.
[e] AIC = Akaike's information criterion.

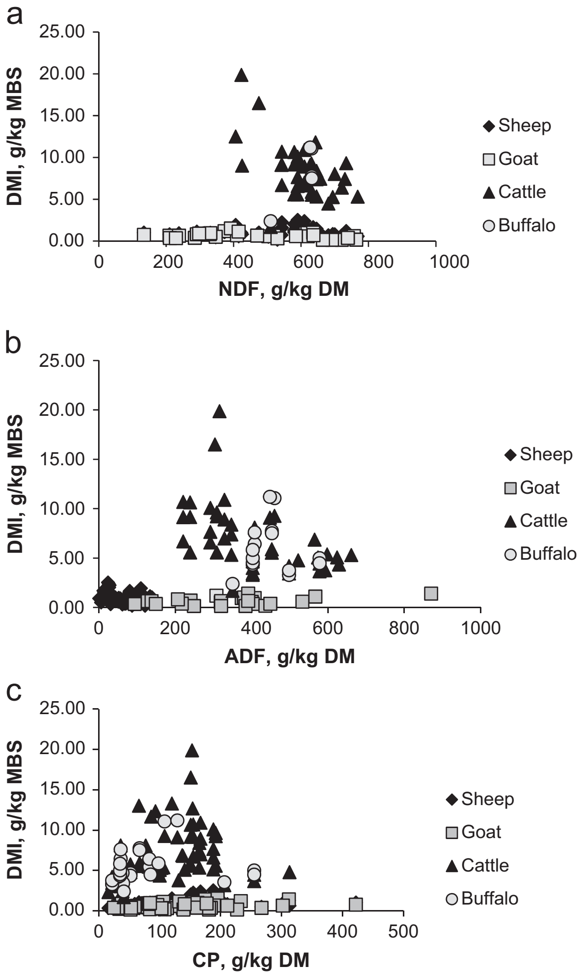

Fig. 2. The influence of various dietary constituents on dry matter intake (DMI) of sheep, goat, cattle and buffalo. MBS, metabolic body size.

influenced DMD in sheep and goats (Table 3; significant effect in sheep only). On the other hand, ADF lowered DMD in sheep, goats and cattle with a significant effect observed for sheep and goats. The species-specific response of DMD to dietary constituents is also highlighted in Fig. 3.

4. Discussion

4.1. Relationship between dry matter intake and body weight of animals

Voluntary feed intake is generally recognized as one of the most important factors influencing performance. Domestic ruminant species have substantially different BW, ranging from about 30–600 kg for matured dwarf female goat and cattle, respectively (Adejumo and Ademosun, 1991). Different opinions with regard to the effect of size on intake may be found in the literature. Kleiber (1961), for instance, stated that feed conversion in herbivores is dependent of body size because intake is directly proportional to maintenance requirement. As with increasing size, maintenance requirements per unit of BW decrease, feed intake relative to BW will decrease to the same extent. On the other hand, Van Soest (1982) argued that gut size of animals acts as a limiting factor, and that, because gut capacity scales linearly with BW, intake of a given diet will be a constant fraction of BW irrespective of species size. In the present study, we obtained an allometric relationship between DMI and BW of animals confirming the findings of other researchers who also described the relationship between feed intake and BW (Peyraud et al., 1996; Faverdin, 1999). The different scaling factors were found species-specific with lower values for small ruminants (sheep, goats) and higher values for large ruminants (cattle, buffalo), supporting previous studies on ruminant and non-ruminant herbivores (Clauss et al. 2007; Meyer et al., 2010).

More recently, Müller et al. (2013) suggested that the scaling of DMI is higher in larger as compared to smaller ($<$ 10 kg BW) mammalian herbivores. Given the finding of the present study that the scaling factor was lower in goats and sheep than in cattle and buffaloes, it may be reasonable to suggest that potentially there even are differences in the intake scaling among the larger herbivores ($>$ 10 kg BW) themselves.

When comparisons are intended to compare across different domestic ruminant species, various scaling factors are suggested by different researchers. For example, the use of 0.90 as scaling exponent for interspecies comparisons was suggested by Graham (1972), which has later been endorsed by other scientists (Minson and Whiteman, 1989; Reid et al., 1990; Hackmann and Spain, 2010). In contrast, if comparisons are to be made within species, other scaling factors may be more appropriate, which is supported by the results of the present study with lower scaling factors for small ruminants (sheep and goats) and greater exponents for large ruminants (cattle and buffalo).

The relevance of the magnitude of the scaling exponent was explained by Hackmann and Spain (2010) and Müller et al. (2013): The fact that rDMI scaling in large herbivores is higher than the scaling of energy requirements (which scale to about 0.75, e.g. Müller et al., 2012) suggests that larger herbivores cannot compensate for the poorer diet quality they have to accept in the wild by increasing digestive efficiency, but by increasing intake.

4.2. Dependency of voluntary dry matter intake of ruminants on dietary constituents

The CP concentration had a positive effect on DMI, whereas, fibre fractions of diets depressed DMI of the animals. This trend is consistent with previous studies (Molina Alcaide et al., 2000; Kawashima et al., 2007; Abidi et al., 2009). Overall, buffaloes appeared to be more responsive to CP content of diets at a given CP level than the other three ruminant species. The low quality diets with very low content of CP fed to the buffaloes used in the present study may be responsible, resulting in the positive response to increasing CP concentration. However, it is difficult to draw a concrete conclusion as the data size is small. The other three ruminant species responded similarly to an increase of CP concentration which has also

Table 3
Equations for linear regression between chemical composition of feeds (independent variable; g/kg dry matter) and dry matter digestibility (response variable; g/kg dry matter) of sheep, goats, cattle and buffaloes.

Independent				Parameter estimate[d]						Model statistics[e]
Variables[a]	Species	Model[b]	N[c]	Intercept	95% CI	$P_{Intercept}$	Slope	95% CI	P_{Slope}	AIC
CP	Sheep	L	82	545	47	< 0.001	0.21	0.21	0.059	943.6
	Goats	L	45	553	59	< 0.001	0.31	0.32	0.065	531.1
	Cattle	Q	53	374	66	< 0.001	2.34	0.87	< 0.001	
							−0.0052	0.0026	< 0.001	615.2
	Buffaloes	L	15	400	51	< 0.001	0.83	0.63	0.030	159.9
	All	Q	195	478	48	< 0.001	1.01	0.46	< 0.001	
							−0.0019	0.0011	0.001	2239.1
NDF	Sheep	Q	51	413	203	0.002	0.90	0.80	0.035	
							−0.0011	0.0008	0.008	587.2
	Goats	Q	23	437	236	0.007	0.94	1.02	0.094	
							−0.0012	0.0010	0.0041	276.7
	Cattle	L	32	590	321	0.037	−0.02	0.52	0.946	363.5
	Buffaloes	n.d.	4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	All	Q	110	414	155	< 0.001	0.92	0.60	0.004	
							−0.0011	0.0006	< 0.001	1257.9
ADF	Sheep	L	44	709	95	< 0.001	−0.36	0.21	0.002	484.3
	Goats	L	18	752	118	< 0.001	−0.49	0.31	0.012	199.9
	Cattle	L	34	656	225	0.011	−0.25	0.46	0.288	396.0
	Buffaloes	n.d.	8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	All		104	726	82	< 0.001	−0.44	0.17	< 0.001	1173.4

[a] CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre.
[b] Q = quadratic; L = linear; n.d. = not determined; number of data for buffaloes was < 10.
[c] n = Number of data used.
[d] CI = confidence interval.
[e] AIC = Akaike's information criterion.

been reported previously. For example, Quick and Dehority (1986) observed only small differences between feed intake of sheep and goats. However, the authors also mentioned that there would probably be selectivity differences if the animals were kept under natural grazing conditions. Similarly, Molina Alcaide et al. (2000) found equal response of these species when fed medium to good quality diets in the absence of feed selection.

Goats appeared less responsive to increases in fibre fractions (NDF and ADF) than the other species such that these feed fractions had a less negative impact on their DMI. Huston et al. (1988) mentioned that sheep and goats were similar in terms of DMI when higher quality diets were fed; inconsistencies mostly occurred when low quality feeds were given with higher intake shown by goats and this observation is in agreement with the findings of the present study. In a review, Brown and Johnson (1984) indicated that intake was higher in sheep than in goats in most studies, with relatively greater intake by goats fed high fibre diets.

4.3. Dependency of digestibility on dietary constituents

Dietary CP had a positive influence on digestibility. The effect of CP on DMD in cattle was significant and higher than for the other species which may be partly be due to the structure of the data set which encompassed not only a range of diets but also different breeds within species which may also play vital role in feed selection of animals (Huston, 1978). Of the other three species, DMD of buffaloes responded stronger to an increase of CP, however, this observation should be interpreted cautiously as the available dataset for buffaloes was small. The CP influenced DMD in sheep and goats almost in the same manner though non-significantly showing no large differences between the slope values of these species which is in contradiction to the generally accepted theory that goats are able to digest poor quality diets with high cell and low CP content better than other domestic ruminant species (Adebowale, 1988; Domingue et al., 1991; Gihad, 1976). McCabe and Barry (1988) suggested that goats are vastly superior to sheep in utilizing highly lignified diets. Similarly, Al Jassim et al. (1991) and Domingue et al. (1991) found that goats showed superiority over sheep when fed on low quality diets. The better utilization of fibrous diets by goats than other ruminant species may be due to higher fermentation rate (El Hag, 1976), higher rate of salivary excretion (Seth et al., 1976), or higher activity of cellulolytic bacteria (Gihad et al., 1980). Also Doyle et al. (1984) suggested that a greater ability of goats compared with sheep to digest low quality forages resulted from longer ruminal digesta retention times and possibly a higher capacity to recycle and conserve N within the body.

The content of NDF negatively influenced digestibility only in cattle, whereas sheep and goats responded positively with almost the same magnitude to this feed constituent. This finding is in contradiction to the generally accepted idea of reduced digestibility of high-fibre compared with low-fibre diets (Poppi et al., 1980; Woods et al., 1999). Our observations on the effect of NDF on DMD should be interpreted carefully, since data selection can have an impact – data was collected across different

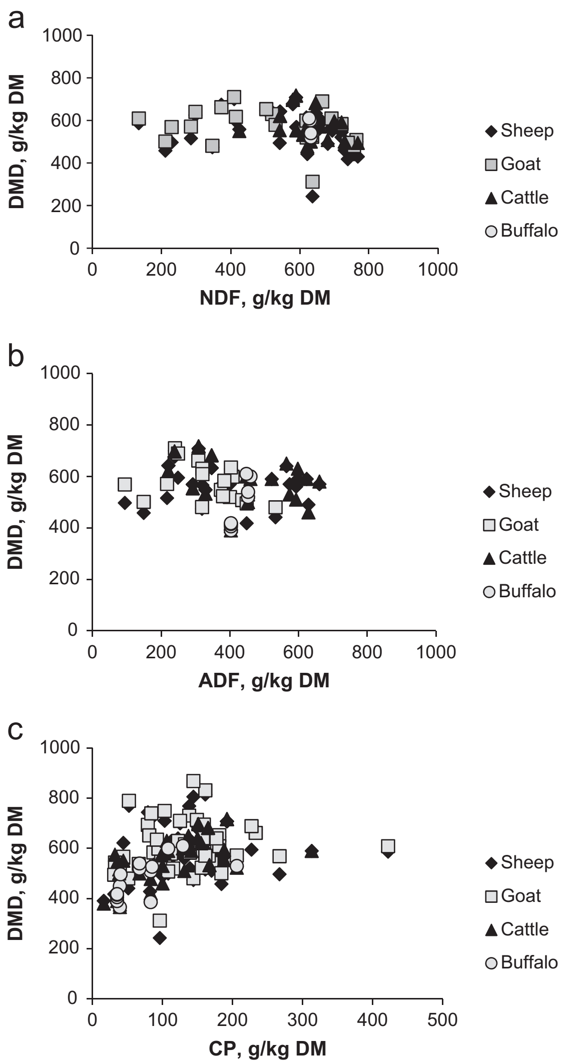

Fig. 3. The influence of various dietary constituents on dry matter digestibility (DMD) in sheep, goat, cattle and buffalo.

studies conducted in different parts of the world with large variations of environmental conditions, animal breeds and feeds.

The ADF negatively influenced DMD. This effect was most pronounced in goats followed by sheep and cattle. Usually goats are considered more robust to digest low quality diets with high fibre concentrations. Nonetheless, several authors have stated that digestibility of high quality diets is either similar among domestic ruminant species or goats are even superior to other domestic ruminant species. Jones et al. (1972) reported that goats digested CP better than dairy steers. Huston (1978) suggested that, in contrast to the general assumption of greater digestibility of low quality forages by goats, that goats would be less efficient in digesting low quality forages because of differences in the dynamics of the gastrointestinal systems between goats and sheep. This author proposed that this occurs because goats have a relatively smaller reticulo-rumen and shorter ruminal retention times, and therefore, satisfy their nutrient requirements by higher daily forage DMI. Brown and Johnson (1985) found that digestibility of NDF and ADF was higher in sheep than in goats and suggested that goats can better exploit their potential on higher quality feeds. Again, the deviation of the outcome of the present data evaluation from the general trend – goats digesting fibrous diets better than other ruminants – may be due to data structure which encompassed different goat breeds; digestive efficiency of goats varies considerably with breed and strain (Huston, 1978).

For the other two species, cattle appeared to digest fibrous diets better than sheep. There are other studies which are in agreement with this finding. Prigge et al. (1984) reported that sheep showed a tendency to consume greater percentage of dietary CP which, vice versa, indicates that cattle do better on low quality diets which are typically low in CP. Similarly, Südekum et al. (1995) reported that cattle digested DM, NDF and ADF better than sheep. Also Woods et al. (1999) revealed that cattle digest fibre better than sheep. The ability of cattle to digest low quality rations better can be linked to the observation that they retain digesta longer in their rumen which may result in a greater digestive efficiency compared with sheep (Poppi et al., 1980).

5. Conclusions

Feed intake of ruminants is dependent upon their BW. Distinguishable, i.e. species-specific, scaling factors for the relationship between DMI and BW were estimated, and the difference was pronounced between small and large ruminants with lower exponents for sheep and goats and higher for cattle and buffaloes. Across all ruminant species, CP had a positive influence on intake and digestibility while fibre fractions influenced DMI negatively except for buffaloes who responded positively to ADF. Digestibility was also negatively influenced by ADF in all species, whereas NDF had a negative effect in cattle only. However, the magnitude of the response of feed intake and digestibility to varying concentrations of dietary constituents differed among the ruminant species.

Conflicts of interest statement

The authors declare that they have no conflict of interest.

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Appendix. List of references used to construct the data base

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