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ANIMAL RESEARCH PAPER

Faecal index to estimate intake and digestibility in grazing sheep

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SUMMARY

The current research was carried out to evaluate the use of crude protein and fibre components in faeces for estimating intake and digestibility in sheep fed with pearl millet (*Pennisetum americanum* (L.) Leeke). The equations were developed from four trials in metabolism cages with 16 sheep in each trial. Each animal received a different quantity of millet leaves in the diet: 0·015, 0·020 and 0·025 dry matter (DM) as a proportion of live weight (LW) and *ad libitum* with at least 0·2 of daily feed refusals. Organic matter intake (OMI, g/day) was measured, through the difference between offer and refusals; total faeces were collected for 5 days, which was used to determine faecal crude protein (CPf, g/day and g/kg of organic matter (OM)), faecal neutral detergent fibre (NDFf, g/day and g/kg OM), faecal acid detergent fibre (ADFf, g/day and g/kg OM) and OM digestibility (OMD). Linear regression equations were calculated to determine the relationship between OMI and CPf ($P<0·001$, $R^2=0·90$, relative prediction error (RPE = 14·02%). A multiple linear equation was generated for OMI including CPf and NDFf ($P<0·001$, $R^2=0·94$; RPE = 9·25%). Hyperbolic (single and multiple) and exponential models were tested to estimate OMD, where the hyperbolic multiple model including CPf and NDFf showed lower RPE (3·90%). These equations for estimating OMI and OMD were evaluated on sheep grazing *P. americanum* fertilized with increasing levels of nitrogen (N) (50, 100, 200 and 400 kg N/ha), comparing measured and estimated OMI. The intake estimated by multiple regression (CP and NDFf) showed a higher R^2 (0·98) and lower RPE (5·25%) than the simple (CPf only) linear equation ($R^2=0·94$; RPE = 20·45%). The results demonstrated the feasibility of using the faecal index generated in metabolism cages for estimating intake and digestibility in sheep grazing *P. americanum*.

INTRODUCTION

Knowledge of intake and quality of the diet of grazing animals is essential to undertake appropriate interventions in livestock management. However, the inability to estimate these with ease and accuracy are serious limitations in the definition of management goals (Boval *et al.* 2003).

The quality of the diet, particularly energetic value, can be characterized by organic matter digestibility (OMD). However, under grazing conditions, its value cannot be determined directly by quantitative measures of forage intake and faecal excretion, thus requiring indirect measures for its estimation. Among the various indirect methods (*in vitro* techniques, internal and external markers), faecal indices have some attractive features, such as the lack of need to simulate the diet of the animal, allowing for individual animal estimates, and the need for only simple chemical analyses of samples.

The faecal indices technique is based on the assumption that the amount of crude protein (CP) excreted in faeces per unit of ingested organic matter (OM) is constant (Lancaster 1949). In this case, when the digestibility of OM in the diet decreases, the concentration of faecal endogenous CP in OM is

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diluted by the increasing amount of faecal OM and is, therefore, an indicator of digestibility (Lukas *et al.* 2005). Thus, this relationship also allows faecal CP (CPf) to be used for intake estimations. Instead of using the concentration of CP in faeces, it uses the total excretion of CP.

Carvalho *et al.* (2007) pointed out that the main criticism of the use of this method to estimate digestibility is the high individual variability in the results and the need to obtain an equation for each grazing situation (grass species, level of nitrogen (N) fertilization, growing season and geographic location, among others) as a function of variations in CP ingestion. Results may vary in proportion to the level of indigestible OM intake (OMI). Previous studies using CP as an indicator of faecal digestibility have shown that this relationship is most accurate when prediction equations are built specifically for particular plant species, rather than seeking to cover a wide range of forages (Coates & Penning 2000).

However, other authors (Boval *et al.* 2003; Lukas *et al.* 2005) argue that establishing specific equations can limit the use of this methodology. Suggestions have been made to overcome this, including the formation of equations from diets with a wide range of digestibility; the inclusion of other faecal components in the equation and the use of nonlinear models to create relationships with CPf digestibility (Wang *et al.* 2009; Peripolli *et al.* 2011).

The aim of the current study was to test the use of the faecal index to generate equations for intake and digestibility in sheep fed with pearl millet (*Pennisetum americanum* (L.) Leeke) in metabolism cages, as well as to test the accuracy of these equations when applied under grazing conditions.

MATERIALS AND METHODS

Location and experimental design

The experiments were conducted at the Agronomic Experimental Station, located in Eldorado do Sul (30°05′S, 51°40′W) belonging to the Federal University of Rio Grande do Sul, Brazil. The experiment was divided into two phases: the construction of equations for estimating the intake and digestibility of pearl millet through indoor trials with sheep kept in metabolic cages in a completely randomized experimental design with four replicates (animals) and four treatments (forage allowance); the equations were then evaluated with sheep grazing *P. americanum* in a randomized block design with three replications (paddock) and four treatments (levels of N fertilization). Humane animal care and handling procedures followed the guidelines of the Federal University of Rio Grande do Sul.

Indoor trials

Four trials were performed in 2010 and 2011, using sheep fed with *P. americanum* leaves in metabolism cages. The trials were developed to represent the plant phenological cycle, including growth and reproductive stages, both stages repeated in the 2 years. This procedure was adopted to study the necessity of constructing specific equations for OMD and OMI in each phenological cycle. Each trial followed the same experimental design and sampling schedule, with 16 male sheep (all *c.* 1 year old, average live weight (LW) of 30·04 ± 5·52 kg) allocated randomly to four treatments, representing four levels of herbage allowance (kg dry matter (DM)/100 kg LW): 0·015, 0·020 and 0·025 DM as a proportion of LW and *ad libitum*. In the *ad libitum* treatment the goal was obtaining at least 0·2 of daily feed refusals. Two animals that showed low levels of feed intake (less than half of the average amount for the group) were removed from the study, leaving a total of 62 sheep.

Considering ruminant ingestive behaviour, which is normally grazing the upper 0·50 of the sward (Lemaire *et al.* 2009), the vertical heterogeneity of tropical pastures (Sollenberger & Burns 2001) and the fact that the *P. americanum* plant has very distinct stem and leaf blade characteristics, it was decided to sample only the upper half of leaf blades to simulate the material that would naturally be selected by grazing lambs. For this, the *P. americanum* offered to the sheep in metabolism cages was clipped with a hand sickle, just before feeding, in the morning (09:00 h) and afternoon (18:00 h) from a pasture fertilized with 150 kg N/ha. Representative samples of the harvested forage were taken daily to determine DM content by oven drying. One pooled sample from the test period was sent for chemical analysis. Forage properties are shown in Table 1.

Intake and digestibility measurements in indoor trials

The digestibility trials were conducted in metabolic cages using an adaptation phase of 10 days, followed by 5 days for collection of faeces and intake measures according to Rymer (2000). The amounts of forage

Table 1. *Chemical composition of the forage* P. americanum *fed to sheep in indoor trials*

Parameters	Mean	Range	CV	SE	Phenological cycle (Pr > F)
Dry matter (g/kg)	128	119–136	7·69	4·9	0·45
OM (g/kg DM)	890	876–901	0·86	3·8	0·73
CP (g/kg OM)	229	217–241	5·18	6·0	0·94
NDFacp (g/kg OM)	548	500–596	0·02	0·05	0·002
ADFacp (g/kg OM)	290	251–330	8·56	12·4	0·97
NDIN (g/kg N)	329	321–369	4·77	7·9	0·30
ADIN (g/kg N)	73	62–87	17·16	6·3	0·80

CV, coefficient of variation; SE, standard error; DM, dry matter; OM, organic matter; CP, crude protein; NDFacp, neutral detergent fibre corrected to ash and crude protein; ADFacp, acid detergent fibre corrected to ash and crude protein; NDIN, neutral detergent insoluble nitrogen; ADIN, acid detergent insoluble nitrogen.

offered, refusals and the faeces excreted by each lamb were weighed and sampled daily. Intake was considered as the difference between herbage offered and that refused. Digestibility was calculated as the difference between forage intake and faeces excreted, divided by forage intake.

The lambs were harnessed with faecal bags. These were emptied once a day and sample faeces from each animal were obtained by pooling 0·20 of each daily defecation. After 72 h oven drying, the faeces and the herbage samples were analysed as described below.

Chemical analysis

Analyses of samples of feed offered, forage refused and faeces included: DM by drying at 105 °C for 12 h (Easley *et al.* 1965), OM by heating in an oven at 550 °C (AOAC method no. 22.010 and 7010, 1975), N content by the Kjeldahl method (AOAC method no. 2036, 1960 and no. 2049, 1975), and total CP content was obtained as N multiplied by 6·25 (N × 6·25). Acid detergent fibre (ADF) was analysed excluding the ash content and neutral detergent fibre (NDF) without the use of amylase. The fibre analysis was performed according to Van Soest & Robertson (1985). The determination of total N, NDF and ADF excreted in the faeces were carried out by multiplying the measured content in the faecal sample by the daily faecal production. Those measures relative to concentration (g/kg) of faecal NDF and CP were used in the OMD predictions, while those relative to daily excretion (g/day) of faecal NDF and CP refer to OMI predictions.

Statistical analyses of indoor trials

To test the effects of phenological cycle and forage level an analysis of variance, linear regression of OMI (g/day) on faecal crude protein (CPf, g DM/day) was determined and total faecal ADF (ADFf) and faecal neutral detergent fibre (NDFf) (g DM/day) were included with faecal CP (CPf) in a multiple regression using the REG procedure with stepwise option from SAS version 9.2 (SAS Institute Inc., Cary, NC, USA). Observed CPf values were used in the equations generated to obtain estimated values of OMI. These data were compared with measured values of OMI, calculating the residual between the estimated and measured value, to obtain the mean square prediction error (MSEP) according to Fuentes-Pila *et al.* (1996). The accuracy of these equations was evaluated by the relative error of prediction (RPE) defined as the ratio between the positive square root of the MSEP and the average of observed values, expressed in percentage (Fuentes-Pila *et al.* 2003).

Regression equations between the OMD and CPf (g/kg OM) were estimated, using hyperbolic and exponential models, to evaluate CPf as a marker to estimate digestibility. The inclusion of NDFf and ADFf in the faeces were also evaluated using a multiple hyperbolic equation with CPf. Observed CPf was used in the equations generated to obtain estimated values for OMD.

Grazing trial

The relevance of the prediction regressions for OMI and OMD determined in metabolism cages

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Table 2. *Organic matter intake (OMI), digestibility (OMD) and chemical composition of the faeces from sheep fed with levels of* P. americanum *in indoor trials*

Parameters	Mean	Range	CV	SE	Forage level (Pr > F)
OMI (proportion of LW)	0·0167	0·009–0·040	13·54	0·0003	< 0·01
OMD	0·74	0·60–0·82	3·25	0·003	< 0·01
CPf (g/kg OM)	242	212–277	4·59	1·4	0·73
NDFf (g/kg OM)	606	516–659	4·60	3·5	0·01
ADFf (g/kg OM)	332	283–381	5·24	2·2	0·06

CV, coefficient of variation; SE, standard error; LW, live weight; OM, organic matter; CPf, faecal crude protein; NDFf, faecal neutral detergent fibre; ADFf, faecal acid detergent fibre.

using a faecal index was tested in lambs grazing *P. americanum* pastures.

A grazing trial was carried out on pastures fertilized with four levels of N fertilization (50, 100, 200 and 400 kg N/ha). Each N level was replicated three times, giving a total of 12 paddocks, with three lambs grazing on each. Therefore the total number of test animals was 36, each *c*. 5 months old with average LW of 20·05 ± 1·6 kg. The target sward height was 300 mm, as this has been suggested as the optimal height for individual live weight gain and gain per area on *P. americanum* pastures (C. R. C. Castro, personal communication). The sward height was controlled by the use of regulator animals using the put-and-take methodology (Mott & Lucas 1952). Sward height and stocking rate were measured weekly. Approximately 150 height measurements per week were taken with a sward stick, along two diagonal lines throughout the experimental pasture. Herbage mass was estimated via the relationship between sward height and herbage mass. This relationship was determined by cutting of two quadrants (0·50 × 0·50 m) in each paddock, where 15 sward heights and herbage masses were evaluated. Samples of forage were taken by hand-plucking to evaluate pasture quality during this period. The sample was collected in the morning and afternoon by two persons in each block. After collection, samples were oven dried at 60 °C for 72 h and sent for chemical analysis.

Evaluation of OMI and OMD regression in the grazing trial

After 30 days of adaptation to the pasture, intake and digestibility measurements on the lambs began. Faecal output was measured by collecting all faeces excreted by each animal in individual harness bags, over a 5-day measurement period. One animal which had pododermatite (foot rot) infection was excluded, so data from only 35 lambs were used. The total amount of faeces over the 5-day measurement period was weighed, mixed and homogenized. From this a 0·20 subsample was taken to determine chemical composition (DM, OM, CP, NDF and ADF) as described above. The OMI and OMD were estimated for grazing lambs from the chemical constituents of the faecal subsample taken for each animal, using the regression established in metabolism cages.

To test the effects of N level on grazing trial parameters, an analysis of variance was carried out using a Tukey test ($P < 0·05$) to compare means. The best equation for OMI prediction was evaluated by two different equations: linear regression (including only CPf) or multiple linear regression (CPf and NDFf); these equations were compared with the measured OMI, obtained from faecal output and OMD estimated by multiple hyperbolic regression (CPf and NDFf). The equations for OMI were also tested to verify if the intercept was different of 0 and the slope equal to 1.

RESULTS

Indoor organic matter intake and digestibility

Herbage quality showed little variation between phenological stage of the forage and only the NDF fraction was affected ($P < 0·01$; Table 1).

Organic matter intake was affected by forage allowance ($P < 0·001$) ranging from 0·0093 to 0·0396 LW as proposed by the methodology (Table 2). Similarly, OMD was also affected by forage allowance ($P < 0·001$) with a difference between the higher and lower OMD values close to 200 g/kg OM.

Organic matter intake and OMD prediction equations from faecal index

The results demonstrated that there was no significant improvement in the equations constructed specifically

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Table 3. *Relationship between the organic matter intake (OMI, g/day) and faecal crude protein (CPf g/day) and faecal neutral detergent fibre (NDFf, g/day) from sheep fed with levels of* P. americanum *in indoor trials*

Model	Equation (OMI)	R^2	RPE (%)	Pr > F
CPf	OMI = 23·949 + 15·31 × CPf	0·90	14·02	< 0·001
CPf + NDFf	OMI = 16·52 + 29·15 × CPf − 5·38 × NDFf	0·94	9·25	< 0·001

RPE, relative prediction error.

Table 4. *Relationship between the organic matter digestibility (OMD) and concentration of faecal components (faecal crude protein, CPf; neutral detergent fibre, NDFf and acid detergent fibre, ADFf; g/kg of organic matter) from sheep fed with levels of* P. americanum *in indoor trials*

Model	Equation (OMD)	R^2	RPE (%)	Pr > F
Hyperbolic simple	OMD = 1·20838–112·831/CPf	0·53	4·06	< 0·001
Hyperbolic Multiple	OMD = 1·24238–106·421/CPf − 0·000182763 × ADFf	0·54	4·03	< 0·001
	OMD = 1·29325–98·2962/CPf − 0·000239755 × NDFf	0·56	3·90	< 0·001
Exponential	OMD = 1·5313–1·1486exp$^{(-0{\cdot}154 \times CPf/100)}$	0·77	4·40	< 0·001

RPE, relative prediction error; CPf, faecal crude protein; NDFf, faecal neutral detergent fibre; ADFf, faecal acid detergent fibre; RPE, relative prediction error.

for single stage of the phenological cycle. So equations were developed independent of phenological stage, and all trial data were considered in the equation construction. A linear regression ($P < 0{\cdot}001$) between OMI and CPf was found: OMI = 23·949 + 15·31 × CPf, with a coefficient of determination (R^2) of 0·90 and RPE = 14·02% (Table 3). The inclusion of NDFf and/or ADFf in the estimated intake equation showed a significant effect ($P < 0{\cdot}001$). Nevertheless, only NDFf was used to compose the multiple regression model to estimate OMI, since the inclusion of both parameters did not lead to significant improvement in equation prediction. The multiple regression model including CPf and NDFf reduced the RPE by 4·77% and increased R^2 by 4%. For digestibility, the hyperbolic model taking into account only CPf resulted in an RPE of 4·06%, close to that found for the exponential model (RPE = 4·40%). An exponential model was also tested and all equations showed RPE of <10%. However, the multiple hyperbolic model with inclusion of CPf and NDFf achieved the lowest RPE (3·90%, Table 4).

Sward characteristics, chemical composition and forage intake by grazing lambs

As proposed by the methodology, the sward height did not differ ($P > 0{\cdot}05$) between treatments (Table 5). For the chemical composition of pasture, only CP was affected ($P < 0{\cdot}01$) by N fertilization, ranging from 233 to 321 g/kg OM. The effects on chemical composition of pasture caused no significant differences in OMI and OMD between N fertilizations, with average values of 3·83% LW and 836 g/kg OM, respectively.

The OMI estimated by multiple regression (CPf and NDFf) showed a higher R^2 (0·98) and lower RPE (5·25%) than the simple linear (CPf only) equation created to estimate OMI ($R^2 = 0{\cdot}94$/ RPE = 20·45%; Fig. 1).

DISCUSSION

Indoor OMI and OMD

The results for chemical evaluation of forage are in accordance with previously cited findings (C. R. C. Castro, personal communication) for pearl millet. However, most chemical parameters did not differ between phenological stages. This may be attributed to the way in which herbage was harvested (0·50 upper sward level and selection for leaves only), as the stem characteristics usually contribute most to changes in chemical composition of forages in different phenological stages. Because of this, no significant differences were detected for OMD in different phenological stages. However, differences observed in OMD as a response to herbage allowance show a modification in efficiency of herbage use due to intake changes.

Table 5. *Sward characteristics, faeces composition and forage intake by lambs grazing* P. americanum *pastures fertilized with nitrogen levels*

Parameters	Mean	Range	CV	SE	Nitrogen level (Pr>F)
Sward characteristics					
Sward height (mm)	280	241–318	5·68	4·8	0·34
Herbage mass (kg/ha)	1971	1731–2248	7·91	47·0	0·36
Measures from hand plucking sample					
Organic matter (g/kg DM)	890	876–911	0·75	2·0	0·27
Crude protein (g/kg OM)	282	233–321	3·85	3·3	<0·01
NDFash (g/kg OM)	599	543–697	5·36	9·7	0·26
ADFash (g/kg OM)	286	249–375	8·68	7·5	0·22
Measures from faeces					
Faecal production (g of OM/day)	148	96–190	12·06	5·1	0·14
Crude protein (g/kg OM)	297	270–314	5·02	4·3	0·76
NDF (g/kg OM)	551	500–605	5·61	8·9	0·94
Measures from grazing lambs					
OMI (proportion of LW)	0·04	0·03–0·05	9·10	0·001	0·83
OMD (g/kg OM)	836	784–851	2·89	7·2	0·85

CV, coefficient of variation; SE, standard error; OM, organic matter; NDF, neutral detergent fibre; NDFash, neutral detergent fibre corrected for ash; ADFash, acid detergent fibre corrected for ash.

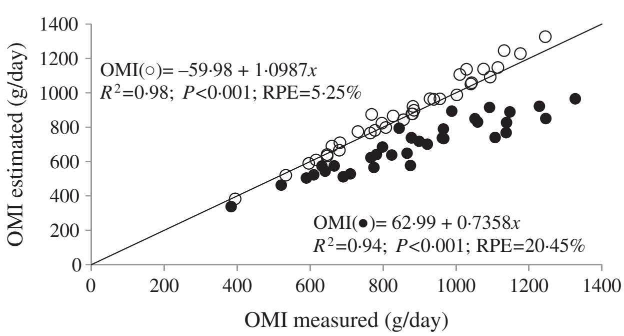

Fig. 1. Relationship between organic matter intake (OMI, g/day) estimated by the intake equation multiple (CPf and NDFf; ○) or using simple linear regression (CPf; ●), with that measured by faecal output and hyperbolic multiple equation (OMD = 1·29325–98·2962/CPf – 0·000239755 × NDFf) for organic matter digestibility on sheep grazing *P. americanum*. The solid line represent the equation when $y = x$.

Organic matter intake and OMD predictions from faecal index

The significant linear relationship between OMI and CPf found in the current study was consistent with observations made by other authors (Boval *et al.* 1996; Azevedo 2011; Peripolli *et al.* 2011). Peripolli *et al.* (2011) compiled data from 58 metabolism experiments with 28 species of herbage (mixed or pure), and also observed a positive linear relationship between OMI and faecal N ($R^2 = 0·71$). This is supported by the theoretical foundation of the relationship between intake and faecal N, which is based on a constant rate of endogenous N excretion per unit of OMI (Lancaster 1949). Nevertheless, the inclusion of NDFf as well as CPf improved estimates of OM intake. L. Oliveira (personal communication), working with temperate (ryegrass) and tropical forages (*Cynodon*), also found significant linear relationships between OMI and faecal N for ryegrass ($R^2 = 0·69$) and *Cynodon* ($R^2 = 0·52$). However, improvements were obtained with the inclusion of ADFf ($R^2 = 0·85$ and 0·55, respectively).

According to Fuentes-Pila *et al.* (2003), values <10% for RPE can be regarded as satisfactory for OMD prediction. In the present study, values below this level were reached with both the simple hyperbolic as well as exponential models, even when including only CPf in the equation. The relationship between CPf and OMD is not constant and linear as it is with OMI (Peripolli *et al.* 2011). This occurs because the excretion of metabolic faecal protein (shedding of digestive epithelium cells, digestive secretions and microbial protein) is constant for each 100 g OMI, but this is not the case for indigestible feed protein, which may vary for the same OMI, depending on the nature of the diet (Boval *et al.* 2003). Moreover, because grazing animals select their food, their diets can be outside the range of feed protein intake established in indoor trials and the CPf may be beyond the maximum of the curve. Therefore, nonlinear models appear to be more appropriate than linear or quadratic models (Boval *et al.* 2003; Lukas *et al.* 2005). Other authors have also reported success in estimating digestibility of faecal protein using hyperbolic (Boval *et al.* 1996, 2003) and exponential models (Wang *et al.* 2009; Peripolli *et al.* 2011).

The use of CPf as an index for OMD is considered appropriate only when prediction equations are constructed specifically for the exact feed being tested, since the effects of animal, diet and environment have been suggested as likely limitations for a single equation (Coates & Penning 2000). However, when applying the CPf data from the current study in digestibility equations proposed by Wang *et al.* (2009): $\text{OMD} = 0{\cdot}899\text{–}0{\cdot}644\ \exp^{(-0{\cdot}5774 \times \text{CPf}/100)}$ or the equation proposed by Peripolli *et al.* (2011): $\text{OMD} = 0{\cdot}7326\text{–}0{\cdot}3598\ \exp^{(-0{\cdot}9052 \times \text{CPf}/100)}$, similar RPEs were found (4·87 and 8·34%, respectively) when compared with those observed by the digestibility equations constructed specifically for *P. americanum* in the current study (3·90–4·40%), showing that general equations may be accurate. Furthermore, no major improvements were seen by using the equation developed by Peripolli *et al.* (2011) for the use of local southern Brazilian forages (including one similar to that used here) when compared with the equation developed by Wang *et al.* (2009) with forages from the region of Mongolia, suggesting that this relationship is independent of the region where the equations are generated. However, these comments refer only to a single grass species, and further validation should be conducted with new types of diets.

Organic matter intake and OMD at grazing

Sward structure is an important factor of variation affecting grazing intake (Hodgson 2004). For this reason, a similar target height was defined for all treatments (300 mm), which was close to the mean value reached (280 mm) during the grazing trial. Considering this as the height at which better combined gain per area and per animal for pearl millet is obtained (Castro 2002), it is probable that the ingestive behaviour was not limited by sward structure. This may explain the high values obtained for OMI and OMD, which were close to the highest values observed on the indoor trials.

At pasture, two limitations for the use of CPf to estimate OMD are frequently mentioned: (i) the diet selection of grazing animals can be distinct from that offered in the metabolism cage used to obtain the prediction equations; and (ii) the concentration and forms of feed protein in forages fertilized with different levels of N can diverge from that harvested for indoor trials and used to generate prediction equations (Carvalho *et al.* 2007). In both cases, the effects could be either over- or under-estimation of OMD/OMI.

Based on these considerations, the indoor intake and digestibility equations were tested using animals fed on fertilized pastures with increasing levels of CP by grazing sheep. The results showed high accuracy for OMI when both CPf and NDFf were taken into consideration (Fig. 1). The improvement in intake prediction when NDFf was used was probably due to a different origin than that of CPf. While the CPf is of endogenous origin, the NDFf has exogenous origin, in this case the diet. Furthermore, the relationship between dietary NDF and concentration of NDFf, as demonstrated by Fanchone *et al.* (2007), supports the additive effect of a multiple equation for OMI prediction. However, more detailed studies of intake are needed to clarify/confirm these observations and elucidate the importance of NDFf for intake prediction in other forages.

Regarding the different concentrations of N observed in forage sampled at different fertilization levels, the possible effects of this on the prediction of OMD and OMI could not be applied to the current study. This lack of effect of plant N over the OMD and OMI prediction was probably due to the fact that, on average, most of the CPf originated from endogenous CP and not from the undegraded feed N. Therefore, it is probable that the relationship between intake and CPf would only be modified by great changes in the CP level of the diet. Another possible explanation could be attributed to prediction equations that include the NDFf, which could minimize the effects that the plant N might have over the OMI/OMD predictions.

The relationship between OMI obtained directly from the multiple equation for intake ($\text{OMI} = 16{\cdot}52 + 29{\cdot}15 \times \text{CPf} - 5{\cdot}38 \times \text{NDFf}$) and the estimated intake obtained by measured faecal production and OMD from the multiple hyperbolic equation ($\text{OMD} = 1{\cdot}29325\text{–}98{\cdot}2962/\text{CPf} - 0{\cdot}000239755 \times \text{NDFf}$) confirms the validity of using multiple regression equations for intake, and suggests that both methods may be used to estimate OM intake.

CONCLUSION

Faecal crude protein is suitable for estimating intake of sheep grazing *P. americanum* (L.) Leeke, and prediction accuracy is improved when using multiple regression with the inclusion of NDFf. Similarly, the multiple hyperbolic model was the most accurate for estimating the digestibility, using CPf and NDFf, with grazing animals.

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