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Author Name : Claudio A. Pozo [1] *

Username : claudioapozo@gmail.com, **Email :** claudioapozo@gmail.com, **Status :** Published

Author Name : Gilberto Vilmar Kozloski [2]

Username : gilberto.kozloski@ufsm.br, **Email :** gilberto.kozloski@ufsm.br, **Status :** Published

Author Name : Henrique Ribeiro-Filho [3]

Username : henrique.ribeiro@udesc.br, **Email :** henrique.ribeiro@udesc.br, **Status :** Published

Author Name : Vicente Celestino Pires Silveira [4]

Username : vcpsilveira@gmail.com, **Email :** vcpsilveira@gmail.com, **Status :** Published

Author Name : Jean F. TOURRAND [5]

Username : tourrand@aol.com, **Email :** tourrand@aol.com, **Status :** Published

Predicting forage intake by sheep through the Pampa Corte model or NRC

Pozo, C.A.[*†]; Kozloski, G.V.[*]; Ribeiro Filho, H.M.N.[‡]; Tourrand, J.F.[*§]; Silveira, V.C.P.[*]

*Universidade Federal de Santa Maria, Santa Maria, RS, Brazil; †Universidad Nacional de Formosa, Formosa, Argentina; ‡Universidade do Estado de Santa Catarina, Lages, SC, Brazil; §Centre de Coopération Internationale en Recherche Agronomique pour le Développement, Montpellier, France

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Abstract
The aim of the present study was to evaluate the precision and accuracy of the Pampa Corte and National Research Council (2007; NRC) models for predicting forage intake (FI) by sheep. Individual data (n = 213) of observed FI, body weight and chemical composition of consumed diet were taken from fifteen indoor digestibility trials conducted with male sheep housed in metabolic cages and fed only forage *ad libitum*. The diets were composed of tropical grasses, temperate grasses and legumes. Individual observations of FI were averaged by treatment (n = 32) into each experiment which were then compared to FI values predicted by Pampa Corte model or NRC using concordance correlation coefficient (CCC) and regression analysis. The average value of observed FI was 847 (± 241) whereas those predicted by Pampa Corte model and NRC were, respectively, 826 (± 230) and 987 (± 208) g DM/day. Observed values of FI were linearly related ($P < 0.01$) to those predicted through either Pampa Corte or NRC. However, the Pampa Corte resulted in higher CCC than NRC. Also, through the Pampa Corte model, the linear regression presented a slope not different from 1 and an intercept not different from 0. The NRC model, however, resulted in a slope of the linear regression lower than 1 despite the intercept was not different from 0. The Pampa Corte model was more precise and accurate in predicting FI by sheep fed only forage than NRC.

Introduction
Forage intake (FI) is the main factor affecting performance of grazing ruminants (Mertens and Grant 2020). However, FI cannot be measured directly and its determination in grazing situations still remains a challenge. Traditional nutritional systems, as NRC predicts the FI by sheep using empirical static equations which adjust satisfactorily to the conditions in which they were developed, but usually have limited precision and accuracy in grazing conditions (Hackmann and Spain 2010; Tedeschi et al. 2019). Pampa Corte (Silveira 2002) is a mechanistic dynamic model which predicts the intake, nutrients supply and productive performance of grazing ruminants based on rumen capacity and/or physical constraints of intake. The validity of this model on estimating the productive performance of beef and sheep have been previously evaluated (Trevisan et al. 2009; Silveira et al. 2011; Silveira et al. 2012). However, the precision and accuracy of this model on predicting FI was still not consistently validated with data from controlled trials. Therefore, the aim of the present study was to evaluate the precision and accuracy of either model Pampa Corte or NRC for estimating FI by sheep fed only forage in digestibility trials.

Methods and Study Site
A data set of individual observations was compiled from fifteen independent digestibility trials with sheep (n = 213), housed in metabolic cages, and fed only forage *ad libitum*. Trials were conducted at the Universidade Federal de Santa Maria, Santa Maria, RS and at the Universidade do Estado de Santa Catarina, Lages, SC, both in southern Brazil (29°4′S, 53°4′W). General description of the animals and diet variables used as inputs in the model are presented in Table 1. Experimental periods varied between 15 to 21 days, with 10 to14 days for adaptation and 5 to 7 days for data and sample collection.

The forage offered and refusals were weighed, recorded, and sampled throughout the experimental periods and all samples were dried at 55°C for at least 72 h, ground through a 1-mm screen and pooled by animal within each experimental period for analysis. Total dry matter (DM) content in forage samples was determined by oven drying at 105°C for 24h. Forage samples were analyzed for neutral detergent fiber (NDF) (Senger et al. 2008), crude protein (Kjeldahl method; AOAC 1997) and nitrogen fractions (Licitra et al. 1996). Water-insoluble fraction of forage was determined by weighing 5 g of sample in TNT bags (10 x 10 cm), and incubating in distilled water at room temperature and with agitation for 3 h. Following, the samples were washed with distilled water and dried at 55°C for at least 72 h. The water-insoluble DM fraction was them incubated in an *in vitro* gas production test (Theodorou et al. 1994), and the fractional rate of gas production (kd) was estimated using a simple exponential model (Ørskov and McDonald, 1979).

Forage DM digestibility (DMD) was determined by incubating the samples during 48 hours into the rumen of a cannulated steer grazing a native grassland and receiving supplementation with concentrate feedstuffs. Cell content (CC) was calculated as 100-NDF (%), and digestible cell wall (DCW) as DMD-CC (%) (Silveira 2002).

Individual data of body weight and forage attributes (i.e. CC, CP, CP fractions, DCW, kd, NDF) were averaged by treatment into each experiment (n = 32), and used as inputs in the Pampa Corte model. Predictions of FI through Pampa Corte are based on model described by Illius and Gordon (1991), which consider the rumen capacity and physical constraints of intake (Silveira 2002). In addition, FI was also predicted using the equation proposed by NRC, which considers the BW, a standard reference BW and quality constraint factors based on digestibility and proportion of legumes in the diet.

Mean values of observed FI into each treatment were compared to those predicted by either Pampa Corte model or NRC. The precision and accuracy of the linear relationships were evaluated by CCC analysis and parameters of the regression analysis, using the mixed procedure of the SAS software (SAS Institute Inc., Cary, NC, USA). For regression analysis, the model included trial as random effect. The confidence interval (95%) of the equation parameters was calculated on the basis of standard errors (SE) values (i.e., ± 2SE) and was used to evaluate the deviation of either the slope from 1 or the intercept from 0. Significance was declared at $P \leq 0.05$.

Table 1. Animal variables and diet composition in digestibility trials carried out with sheep

Trial	Diet components	Animal		Diet			
		BW (kg)	FI (g DM/day)	CP (%)	NDF (%)	DMD (%)	kd (%/h)
1	*Avena sativa* haylage	31–46	541–969	21	66	65	2.61
2	*Axonopus catharinensis* fresh cut at different days of regrowth	35–46	620–1323	7–14	63–68	62–73	5.33–6.12
3	*Axonopus catharinensis* fresh plus *Arachis pintoi* fresh	28–44	1052–1659	7–10	44–31	77	6.07
4	*Cynodon dactylon* fresh	23–31	343–849	15	76	55	2.71
5	*Cynodon dactylon* fresh with level of refusal	25–28	507–1047	21–23	63–65	65	4.86
6	*Cynodon dactylon* hay	21–37	753–1054	19	71	76	6.53
7	*Cynodon dactylon* hay	16–25	447–734	6	77	66	2.71
8	*Cynodon dactylon* hay	17–31	388–657	13	75	59	2.82
9	*Cynodon dactylon* hay with or without urea	19–49	437–928	7–12	74	66	2.58
10	*Echinochloa sp.* hay	27–38	533–1085	7	73	55	4.72
11	Native grassland hay	17–18	309–413	7	82	50	3.49
12	Native grassland hay	21–38	545–642	7	78	52	3.56
13	*Pennisetum clandestinum* hay cut at different days of regrowth	32–38	606–1069	12–17	65–67	60–66	5.14–5.22
14	*Pennisetum purpureum* hay plus levels *Arachis pintoi* hay	35–46	824–1542	10–19	49–75	71–75	5.89–6.36
15	*Sorghum sudanense* fresh	26–35	331–810	11	67	69	3.49

BW= body weight; CP= crude protein; DM= dry matter; DMD= *in situ* dry matter digestibility; FI= forage intake; kd= fractional rate of gas production of the water-insoluble DM fraction; NDF= neutral detergent fibre.

Results

The average value of observed FI was 847 (± 241) whereas those predicted by Pampa Corte model and NRC were, respectively, 826 (± 230) and 987 (± 208) g DM/day. Observed values of FI were linearly related ($P < 0.01$) to those predicted through either model Pampa Corte or NRC (Figure 1). However, the Pampa Corte model resulted in higher CCC than NRC. Also, through the Pampa Corte model, the linear regression presented a slope not different from 1 and an intercept not different from 0. The NRC model, however, resulted in a slope of the linear regression lower than 1 despite the intercept was not different from 0.

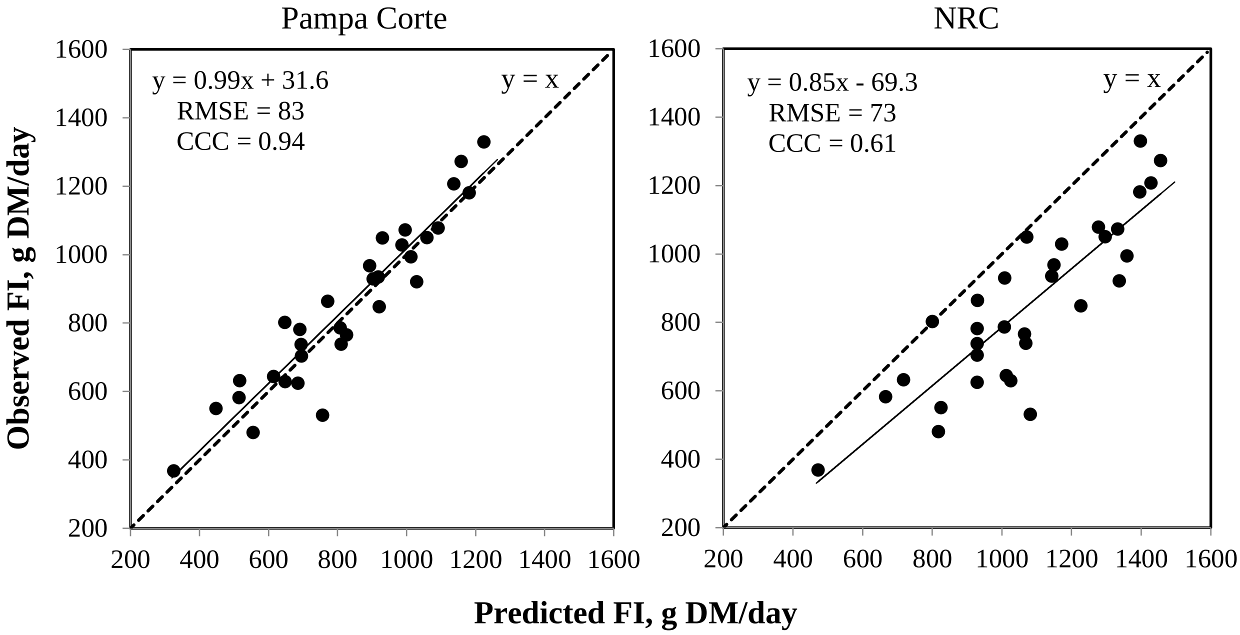

Figure 1. Relationship between forage intake observed and predicted (FI) by the Pampa Corte model or NRC.

Discussion

The Pampa Corte model was more precise and accurate than NRC in predicting observed FI by sheep fed only forage in controlled trials. The NRC which predicts the FI by sheep using empirical static equations over predicted the FI in 94 % of the observations. In fact, empirical models account for fewer variables and are simpler than mechanistic models (Cannas et al. 2019), and usually present low accuracy and precision in the prediction of FI (Pulina et al. 2013; Bateki and Dickhoefer 2019; Tedeschi et al. 2019). In contrast, the Pampa Corte which is a mechanistic dynamic model predicts the FI based on rumen capacity and physical constraints of intake. Also, this model take account the kinetics of fermentation and passage rate of digesta from the rumen, which are related to voluntary FI (Illius et al. 2000).

Conclusions

The Pampa Corte model was more precise and accurate in predicting FI by sheep than the empirical model proposed by the NRC.

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