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Impact of NDF content and digestibility of diets based on corn silage and alfalfa on intake and milk yield of dairy cows

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ABSTRACT - A meta analysis (22 studies, 83 dietary treatments) evaluated the impact of neutral detergent fiber (NDF) content and whole tract NDF digestibility (NDFD) on dry matter intake (DMI) and milk yield (MY) in high producing dairy cows fed corn silage and alfalfa based diets. Experimental diets were ingested at high levels to support high MY (24.1 and 37.3 kg/d, respectively of DM and MY). The average NDFD was of 42.9% (range: 20.0-68.0 %; within study standard error: ±4.0 %). DMI was negatively related with the dietary NDF (e.g. ±1.0 % of NDF caused ±160 g/d of DMI; r^2=0.51; P<0.01), while NDFD and NDF were positively related (r^2=0.74; P<0.01; ±1.0 % of NDF caused approximately ±1.0 % of NDFD). MY was not influenced by dietary NDF. Considering a subset of 5 studies, the regression between NDFD and corn silage:alfalfa ratio in the diet (r^2=0.84; P<0.01) allowed to estimate the NDFD of diets containing only alfalfa hay (55%) or corn silage (44%). In conclusion, the dietary NDF concentration influences the NDFD and this has implications both for DMI and MY of cows. Diets based on alfalfa hay have higher NDFD than those based on corn silage.

Key words: NDF, Digestibility, Dairy cow.

Introduction – The dietary NDF content is a major factor affecting intake in ruminants (Mertens, 1987) and a high rumen degradation of NDF (NDFD) is a key factor to increase the DMI of dairy cows (Oba and Allen, 1999). Infact, when fibrous materials are quickly degraded in the rumen, further intake is promoted by a reduction in rumen fill. In addition, fibre degradation supplies cows with nutrients and substrates for milk synthesis, which can further improve milk yield. Corn silage and alfalfa hay are often the base forages in dairy cows diets, and their NDFD values measured in high lactating cows may be useful for the ration improving and to a better prediction of dairy cow performances. The objectives of the present work are to study the impact of NDF content and *in vivo* NDFD of diets based on corn silage and alfalfa on intake and milk yield in high producing dairy cows and to estimate the *in vivo* NDFD of alfalfa and corn silage.

Material and methods – Published experiments with lactating dairy cows reporting whole total tract NDF digestibility (NDFD) of total mixed rations (TMR) were selected for meta-analysis on the basis of the publication date (i.e., not more than 10 years old) and type of dietary forages (i.e., corn silage and/or alfalfa hay as the only forages in the diet). A total of 22 experiments, for a sum of 83 dietary treatments, were identified from the following 20 papers being: Bal *et al.* (2000a and 2000b), Benchaar *et al.* (2007), Benefield *et al.* (2006), Bernard *et al.* (2004), Brito and Broderick (2006), Cooke and Bernard (2005), Dhiman *et al.* (2000), Kowsar *et al.* (2008), Moreira et al (1999), Nennich *et al.* (2003), Neylon and Kung (2003), Oba and Allen (2000, 2003), Qiu at al. (2003), Ruppert *et al.* (2003), Schwab *et al.* (2002), Taylor and Allen (2005) and Weiss and Wyatt (2000, 2002). Studies were published in the Journal of Dairy Science, with the exception of Moreira *et al.*, (1999), which was made

available to the author. Four recent experiments were not included in the inventory because they used the indigestible NDF as internal marker. Each study provided means of DMI, diet chemical composition and NDFD. Eighteen studies (68 dietary treatments) reported milk data and only 13 studies (49 dietary treatments) reported data on the acetate and propionate concentrations of rumen liquid. Milk energy was calculated by fat and protein contents and MY was expressed as milk having 680 Kcal/kg. The linear regression analysis were evaluated with a linear mixed model (St-Pierre, 2001) as:
$Y_{ij}=B_0+B_1X_{ij}+s_i+e_{ij}$ where: B_0 is the overall intercept across trials (fixed effect), B_1 is the across trials, overall regression coefficient for the linear effect of X (fixed effects), X_{ij} is the dependent variable for the i^{th} treatment of the j^{th} trial, (i = 1, n_j; j=1, 22 (or 18, or 13)), s_i is the random effect of trial i, approximately normal (0, σ^2_s), and e_{ij} is the residual error, approximately normal (0, σ^2_e).

Results and conclusions – The diets in the studies selected for evaluation had nutrient compositions typical for lactating cows (Table 1) and were ingested at high levels (24.1±1.0 kg DM/d) to produce high milk yields of 37.3±1.1 kg/d. Average NDFD (measured at 106±44 days in milk), was 42.9 % with a wide range among dietary treatments (20.0-68.0 %) and a coefficient of variation within studies of ±10%. This high variability is also probably due to different NDFD measurements, which used several markers (i.e., acid insoluble ash, chromium, rare earths) or total faecal collection. The average *in vivo* values of present survey are about 25% lower than those obtained *in vitro* after 48h of incubation for dairy cows TMR samples (55.8±6.4 %, Mentink *et al.*, 2006; 58.7±6.4 %, Hoffman, 2008). This suggests that a reduction of the *in vitro* incubation times (i.e. from 48 to 30h) probably allows more accurate NDF digestion data for high producing cows.

Table 1. Descriptive statistics of DMI of cows, dietary chemical characteristics and MY.

	unit	mean	sd	range
DMI	kg/d	24.1	1.0	17.3-27.7
diet chemical composition:				
crude protein	% DM	16.9	3.0	14.7-18.3
NDF	“	31.5	18.0	22.8-41.8
Ash	“	7.4	4.0	4.9-12.0
ether extract	“	4.3	2.0	2.4-5.5
NDFD	% NDF	42.9	4.0	20.1-68.1
MY	kg/d	37.3	1.1	25.1-45.4

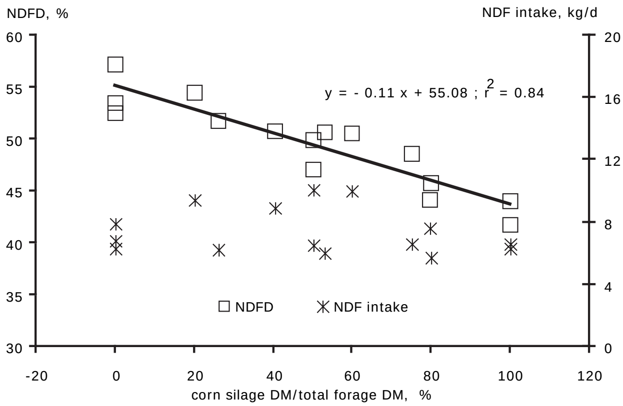
sd: standard deviation within studies.

The regression analysis (Table 2) showed an expected negative relationship (r^2=0.51; P<0.01) between DMI and NDF level of the diet (i.e., ±1% in NDF caused a ±160 g/d DMI variation). However, in intake models which assume a fixed maximum NDF intake capacity of cows (e.g. 7.6 kg NDF/d for cows of 650 kg body weight, Mertens, 1987) a ± 1% change in dietary NDF produces a very wide DMI variation (around ±900 g/d). No relationship occurred between DMI and NDFD (data not shown), while NDFD and NDF were positively related (r^2=0.74; P<0.01; ±1% variation in NDF was associated

Table 2. Regression (adjusted for trial effect) between experimental variables and diet NDF (%DM).

trials	treatments	independent variable	regression parameters				
			intercept	slope	r^2	SE	P
22	83	dry matter intake, kg/d	29.20±1.91	-0.16±0.06	0.51	± 0.879	<0.01
22	83	NDFD, %	13.2±6.8	1.0±0.2	0.74	± 3.09	<0.01
18	68	milk yield, kg/d	40.20±4.16	-0.09±0.12	0.20	± 0.962	ns
13	49	rumen acetate:propionate	0.85±0.60	0.05±0.02	0.63	± 0.236	<0.01

Figure 1. Dietary NDFD and corn silage: alfalfa proportion in the diets.



to approximately ±1% NDFD of diets) and this indicates the favorable rumen conditions for fiber degradation when diets are more concentrated in NDF (e.g. higher pH and slower passage rate in the rumen). This is confirmed by the positive relation between rumen acetate:propionate ratio and dietary NDF (r^2=0.63; P<0.01). Finally, the energy corrected MY was not influenced by dietary NDF. Therefore, the weak fill effect of increasing dietary NDF concentrations on DMI and the absence of negative impacts on milk yield are probably due to the concomitant improvements in NDFD. To estimate the NDFD of alfalfa and corn silage, a subset of 5 studies (15 diet treatments) were selected from the whole dataset to have used diets containing corn silage and alfalfa hay as unique forages and/or with different substitution ratios. The regression between NDFD and corn silage - alfalfa ratio in the diet (expressed as corn silage DM/total forage DM, in g/kg) showed a good fit (r^2=0.84; P<0.01; Figure 1). Estimated NDFD by regression were 55 and 44% for diets containing only alfalfa hay or corn silage, respectively. These data only approximated the specific NDFD of forages, because part of dietary NDF (about 33%) was from non-forage sources. However, data indicated a higher value for alfalfa than corn silage (about 20%), whereas *in vitro* data after 48h of incubation indicate opposite results (Hoffman, 2008). In high producing cows, a possibly shorter rumen retention time favours forages with high rates of degradation, such as legumes, relative to their potential NDF digestion.

In conclusion, the dietary NDF concentration influences the *in vivo* NDFD and this has implications both in terms of fill effect of NDF and energy supply to the cows. Diets based on alfalfa hay have higher *in vivo* NDFD than those based on corn silage.

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