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Screening for diets that reduce urinary nitrogen excretion and methane emissions while maintaining or increasing production by dairy cows

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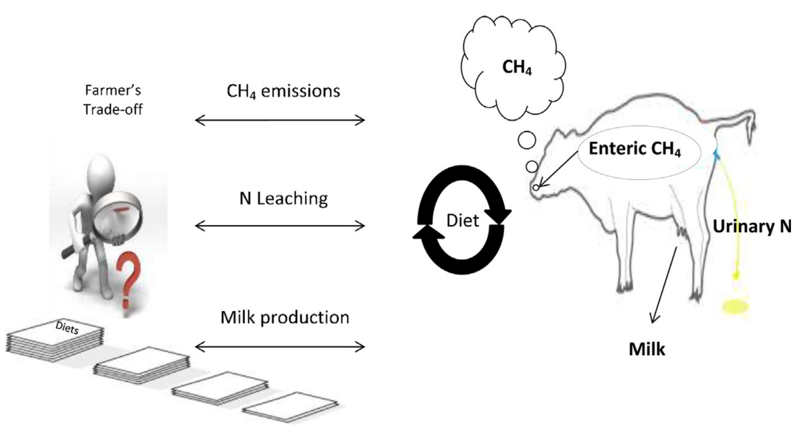
HIGHLIGHTS

- Several factors affect N leaching and urinary N excretion contributes it.
- Some feeding practices help reducing cattle urinary N excretion.
- Reducing cattle urinary N can raise CH_4 emission, i.e. pollution swapping.
- There are simple dietary options to off-set pollution swapping.
- It is up to the farmers and their farming context to choose the best options.

GRAPHICAL ABSTRACT



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ABSTRACT

Farmers face complex decisions at the time to feed animals, trying to achieve production goals while contemplating social and environmental constraints. Our purpose was to facilitate such decision making for pastoral dairy farmers, aiming to reduce urinary N (UN) and methane emissions (CH_4), while maintaining or increasing milk production (MP). There is a number of feeds the farmers can choose from and combine. We used 50 feeds (forages and grains) combined systematically in different proportions producing 11,526 binary diets. Diets were screened, using an a posteriori approach and a Pareto front (PF) analysis of model (Molly) outputs. The objective was to identify combinations with the best possible compromise (i.e. frontier) between UN, CH_4, and MP. Using high MP and low UN as objective functions, PF included 10, 14, 12 and 50 diets, for non-lactating, early-, mid- and late-lactation periods, with cereals and beets featuring strongly. Using the same objective functions, but including ryegrass as dietary base PF included 2, 4, 8 and 4 diets for those periods. Therefore, from a wide range of diets, farmers could choose from few feeds combined into binary diets to reduce UN while maintaining or increasing MP. If the intention is maintaining pasture-based systems, there are fewer suitable options. Reducing UN will simply require dilution of N supplied by pasture by supplementing low N conserved forages. The results also evidence the risk of pollution swapping, reaching the frontier means arriving at a point where trade-off decisions need to be made. Any further reduction in UN implies an increment in CH_4, or reduction in CH_4 emissions increases UN. There is no perfect diet to optimize all objectives simultaneously; but if the current diet is not in the frontier some options can offset pollution swapping. The choice is with the farmers and conditioned by their context.

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1. Introduction

Feeds are not equal in their capacity to support animal functions (Van Soest, 1994). They supply energy and essential nutrients in the form of protein, vitamins and minerals. Energy and protein are often the most limiting factors for ruminants and have received the most attention under several production and evaluation systems (Van Soest, 1994). Pastoral dairy production systems in temperate regions are no exception, and in these particular cases 'the excess' protein supplied by the base dietary forage has become the 'limitation'. This limitation relates to the efficiency of nitrogen (N) utilization by dairy cows, which rarely exceeds 30% (Castillo et al., 2001). This means that at least 70% of the N ingested is not utilized to support animal production (e.g. milk, live weight gain), and is excreted, mainly (over 60%) as urinary nitrogen (UN) (Kebreab et al., 2001; Gregorini et al., 2010a).

It has been reported that in pasture-based dairy production systems, approximately 82% of UN is discharged onto pastures (Oudshoorn et al., 2008; Clark et al., 2010). From this UN around 20–30% is leached and 2%

Table 1
Chemical composition (g/g) and metabolisable energy (MJ/kg DM) of feeds used in the formulation of binary diets.

Name	ME	CP	Fat	ST	SC	NDF	ADF	Ash
	MJ/kg DM				g/g			
Barley grain	12.40	0.115	0.016	0.570	0.022	0.210	0.064	0.055
Barley herbage	11.50	0.110	0.038	0.080	0.078	0.589	0.300	0.115
Barley silage	9.77	0.092	0.022	0.149	0.119	0.450	0.281	0.087
Barley straw	6.50	0.042	0.015	0.000	0.000	0.854	0.488	0.080
Lotus herbage	11.49	0.296	0.046	0.005	0.097	0.391	0.282	0.108
Chicory	13.10	0.142	0.042	0.010	0.106	0.528	0.240	0.077
Faba bean	13.30	0.273	0.013	0.420	0.110	0.149	0.107	0.037
Faba herbage	10.00	0.224	0.013	0.013	0.050	0.591	0.297	0.114
Fodder beet grazeable	13.48	0.106	0.041	0.062	0.595	0.131	0.086	0.071
Fodder beet leaves	13.00	0.181	0.049	0.011	0.217	0.281	0.100	0.238
Fodder beet roots	11.90	0.069	0.052	0.010	0.681	0.137	0.071	0.074
Italian ryegrass	12.70	0.185	0.051	0.013	0.179	0.457	0.193	0.128
Kale	11.50	0.145	0.003	0.006	0.441	0.309	0.226	0.137
Lablab herbage	9.20	0.196	0.028	0.032	0.093	0.472	0.320	0.117
Lablab hay	8.20	0.192	0.026	0.037	0.012	0.544	0.319	0.124
Lucerne herbage	10.60	0.199	0.028	0.029	0.191	0.379	0.309	0.111
Lucerne hay	8.40	0.193	0.022	0.032	0.096	0.477	0.334	0.113
Lucerne silage	8.90	0.207	0.025	0.022	0.075	0.483	0.365	0.124
Lupin herbage	10.30	0.241	0.035	0.034	0.182	0.348	0.256	0.096
Lupin seeds	14.20	0.473	0.060	0.077	0.057	0.272	0.201	0.062
Maize silage	10.60	0.070	0.031	0.330	0.128	0.310	0.240	0.053
Oat grain	12.20	0.110	0.051	0.379	0.016	0.344	0.248	0.111
Oat herbage	11.53	0.183	0.045	0.017	0.164	0.474	0.248	0.109
Oat silage	10.20	0.095	0.039	0.189	0.125	0.443	0.317	0.047
Pasja	11.00	0.247	0.032	0.011	0.215	0.312	0.248	0.140
Pea straw	7.90	0.092	0.031	0.001	0.030	0.749	0.387	0.098
Pea herbage	10.30	0.196	0.031	0.159	0.080	0.330	0.231	0.148
Persian clover	10.30	0.248	0.036	0.039	0.087	0.323	0.213	0.162
Pearl millet	10.80	0.118	0.019	0.005	0.026	0.615	0.345	0.117
Radish grazeable	11.50	0.266	0.015	0.001	0.450	0.170	0.160	0.100
Rape grazeable	10.62	0.250	0.030	0.005	0.360	0.280	0.225	0.110
Red clover	10.40	0.226	0.035	0.030	0.126	0.384	0.260	0.120
Sorghum herbage	9.70	0.104	0.019	0.010	0.100	0.600	0.350	0.081
Sorghum herbage silage	8.90	0.107	0.026	0.005	0.075	0.620	0.418	0.081
Subterranean clover herbage	10.60	0.210	0.044	0.036	0.140	0.360	0.250	0.120
Sugar beet roots	12.50	0.078	0.052	0.010	0.610	0.204	0.127	0.069
Sulla herbage	9.70	0.205	0.025	0.024	0.134	0.368	0.288	0.114
Sulla silage	8.10	0.143	0.052	0.023	0.028	0.519	0.420	0.105
Swedes	11.60	0.119	0.012	0.001	0.503	0.213	0.175	0.112
Sunflower herbage	8.9	0.150	0.022	0.139	0.075	0.416	0.359	0.131
Sunflower silage	9.2	0.130	0.050	0.090	0.060	0.448	0.359	0.122
Triticale herbage	10.7	0.175	0.027	0.041	0.136	0.431	0.242	0.120
Triticale silage	9.7	0.082	0.027	0.168	0.050	0.538	0.290	0.066
Triticale grain	12.9	0.117	0.015	0.675	0.037	0.146	0.037	0.021
Turnips	11.7	0.171	0.015	0.001	0.460	0.230	0.249	0.125
Wheat silage	9.8	0.091	0.029	0.180	0.070	0.500	0.284	0.045
White clover	12.0	0.251	0.032	0.038	0.139	0.470	0.240	0.081
Kikuyu herbage	9.7	0.151	0.029	0.010	0.029	0.595	0.350	0.100
Plantain	12.0	0.133	0.042	0.011	0.090	0.550	0.260	0.080
Tall fescue	10.0	0.180	0.034	0.026	0.110	0.534	0.300	0.110
Ryegrass | white clover June	10.1	0.251	0.040	0.010	0.126	0.452	0.291	0.105
Ryegrass | white clover July	9.7	0.252	0.038	0.011	0.127	0.450	0.288	0.106
Ryegrass | white clover August	10.0	0.251	0.038	0.011	0.126	0.450	0.289	0.105
Ryegrass | white clover September	10.5	0.203	0.041	0.018	0.115	0.505	0.315	0.102
Ryegrass | white clover October	10.3	0.203	0.041	0.018	0.115	0.503	0.313	0.102
Ryegrass | white clover November	10.0	0.204	0.038	0.018	0.115	0.503	0.312	0.102
Ryegrass | white clover December	10.0	0.191	0.039	0.017	0.086	0.544	0.377	0.105
Ryegrass | white clover January	10.1	0.191	0.039	0.017	0.086	0.545	0.378	0.105
Ryegrass | white clover February	10.2	0.190	0.040	0.016	0.086	0.544	0.377	0.105
Ryegrass | white clover March	10.2	0.245	0.042	0.016	0.112	0.455	0.305	0.102
Ryegrass | white clover April	10.3	0.245	0.043	0.016	0.112	0.456	0.306	0.102
Ryegrass | white lover May	10.3	0.245	0.043	0.016	0.112	0.458	0.308	0.102