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Paper: Variation in urea kinetics associated with ruminant species, dietary characteristics, and ruminal fermentation: A meta-analysis

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Supplemental material

Table S1. Characteristics of studies included in the developmental database.

First author	Year	Ruminant Species	Experimental design	Objective ¹
Archibeque	2001	Beef cattle	Double Latin square 4×4	Effects of two forage species and N levels
Archibeque	2002	Beef cattle	Double Latin square 4×4	Effect of level of N intake and ruminally protected methionine supplementation
Bailey	2012a	Beef cattle	Latin square 4×4	Effects of supplemental glucose and degradable intake protein
Bailey	2012b	Beef cattle	Latin square 4×6	Effects of supplemental energy sources and 2 levels of degradable intake protein
Batista	2016	Beef cattle	Latin square 5×5	Effects of supplemental RDP and RUP
Brake	2010	Beef cattle	Double latin square 3×3	Effects of supplementing N as DDGS or urea in corn-based diets
Brake	2011	Beef Cattle	Latin square 6×6	Effects of zilpaterol-HCl on corn-based diets with N supplementation provided by DDGS or urea
Chibisa	2013	Lactating dairy cows	Latin square 4×4	Effects of feeding wheat or corn-wheat dried distillers grains with solubles in low- or high-crude protein diets
Davies	2013	Beef cattle	Latin square 4×4	Effects of dietary ruminally degradable starch and RDP levels
De seram	2019	Lactating dairy cows	Latin square 4×4	Effects of partial replacement of barley starch by lactose
Doranalli	2007	Sheep	Latin square 4×4	Effects of barley grain processing and RDP

Doranalli	2010	Sheep	Latin square 4×4	Effects of partial ruminal defaunation on low or high dietary crude protein concentrations
Doranalli	2011	Sheep	Latin square 4×4	Effects of sunflower and dietary ruminally fermentable carbohydrate
Gozho	2008	Lactating dairy cows	Latin square 4×4	Effects of methods of barley grain processing and source of supplemental fat
Holder	2015	Dairy cattle - steers	Double Latin square 4×4	Effects of RDP level and slow release urea
Koenig	2000	Sheep	Change-over	Effects of protozoa
Lobley	2000	Sheep	Cross-over	Effect of diet quality
Marini	2003	Dairy cattle - heifers	Latin square 4×5	Effect of dietary N level
Marini	2004	Sheep	Completely randomized	Effect of N intake
Mutsvangwa	2016	Lactating dairy cows	Latin square 4×4	Effects of dietary crude protein and RDP concentrations
Obitsu	2011	Lactating dairy cows	Cross-over	Effects of exposure to hot environment
Oullet	2010	Lactating dairy cows	Double Latin square 3×3	Effect of the method of conservation of forage
Recktenwald	2014	Lactating dairy cows	Change-over	Effects of 2 levels of dietary crude protein and 2 levels of starch, with and without Rumensin
Ruiz	2002	Lactating dairy cows	Completely randomized	Effect of a ruminal N deficiency
Sarraseca	1998	Sheep	Latin square 3×3	Effect of intake
Wickersham	2008	Beef cattle	Latin square 4×4	Effect of RDP supplementation in low-quality forage
Wickersham	2009a	Beef cattle	Completely randomized	Effect of supplemental soybean meal in low-quality grass hay
Wickersham	2009b	Beef cattle	Latin square 4×4	Effect of RUP supplementation
Zhou	2015	Sheep	Latin square 4×4	Determine the requirements for maintenance in Tibetan sheep when fed oat hay
Zhou	2017	Beef cattle	Latin square 4×4	Effect of N concentration in the diet
Zhou	2019	Sheep	Double Latin square 4×4	The effect of breed

¹N: nitrogen, RDP: rumen degradable protein, RUP: rumen undegradable protein, DDGS: dried distillers grains with solubles.

Table S2. Papers rejected in the Meta-analysis and exclusion criteria.

First author	Year	Exclusion criteria
Berends	2014	Inability to estimate ME, TDN, RDP and RUP at milk replacer used in this study. Also, the animal category used in this study (Dairy calves) were unique compared to the other studies used in this meta-analysis.
Doranalli	2011	Oscillating dietary crude protein concentrations
Sunny	2007	Urea infusion effect
Titgemeyer	2012	Exp. 1: AA, glucose and VFA infusion Exp. 2: Animals had anabolic implants
Wickersham	2008	Oscillating dietary crude protein concentrations

Table S3. Models and fit statistics estimated from Monte Carlo cross validation for UER (urea-N entry rate, g/day) models using ruminant species (RS), dietary characteristics (DC), ruminal factors (RF) and experimental variables (EV) data sets individually and in combination.

Model number and name	N ¹	Intercept	SD ²	Variable	Value	SD	VIF ³	CCC ⁴
1. RS	100	78.2	9.90	Sheep	-54.6	10.0	1.23	0.776
	100			Non-lactating heifers	-8.20	13.7	1.09	
	86			Lactating dairy cows	266.7	40.5	1.23	
2. DC	100	-285.3	121.1	CP, % DM	8.78	2.09	1.84	0.168
	100			TDN, % DM	3.22	1.51	1.39	
	100			Lignin, % DM	26.1	11.4	1.41	
3. RF	100	121.4	34.5	N-NH ₃ , mg/dL	6.61	2.54	1.00	0.049
4. DC+RF	100	-568.4	288.4	CP, % DM	9.01	3.64	5.51	0.231
	100			TDN, % DM	5.29	2.80	2.17	
	100			NH ₃ , mg/dL	3.57	2.10	2.81	
	100			Acetate, % molar	4.13	2.47	2.03	
5. DC+EV	100	-63.9	14.6	DMI, kg/d	14.6	1.33	1.03	0.906
	100			CP, % DM	4.92	1.17	1.03	
	100			Sheep	-90.2	18.7	1.36	
6. DC+RS	100	-222.8	109.4	Non-lactating heifers	-64.0	39.0	1.18	0.797
				Lactating dairy cows	199.9	37.8	1.61	
				CP, % DM	7.96	2.12	1.79	
				TDN, % DM	2.16	1.29	1.65	
				Lignin, % DM	22.3	12.45	1.55	
				Sheep	-95.7	44.1	1.17	
				Lactating dairy cows	244.8	54.8	1.17	
7. RS+RF	100	46.4	10.9	NH ₃ , mg/dL	5.89	2.66	1.02	0.642
	100			DMI, kg/d	15.6	0.963	1.26	
	93			OMD, %	-4.51	1.16	4.09	
8. RS+DC+RF+EV	100	26.8	43.4	CP, % DM	5.87	2.07	3.40	0.917
	100			ME, Mcal/kg	76.0	23.8	3.18	
	100			NH ₃ , mg/dL	2.63	1.20	2.42	
	100							
	100							

¹N = number of iterations, ²SD = standard deviation, ³VIF = variance inflation factor, ⁴CCC = concordance correlation coefficient.

Table S4. Models and fit statistics estimated from Monte Carlo cross validation for UER (urea-N entry rate, g/kg^{0.75}) models using ruminant species (RS), dietary characteristics (DC), ruminal factors (RF) and experimental variables (EV) data sets individually and in combination.

Model number and name	N ¹	Intercept	SD ²	Variable	Value	SD	VIF ³	CCC ⁴
1. RS	86	1.16	0.115	Sheep	0.149	0.282	1.24	0.367
	86			Non-lactating heifers	-0.011	0.220	1.09	
	86			Lactating dairy cows	1.36	0.297	1.23	
2. DC	100	-3.83	0.877	CP, % DM	0.103	0.047	3.50	0.567
	100			TDN, % DM	0.056	0.024	2.05	
	100			Starch, % DM	-0.012	0.012	2.18	
	100			Lignin, % DM	0.247	0.109	1.91	
	100			TDN/RDP ratio (g/g)	-0.024	0.036	3.10	
3. RF	100	1.06	0.160	NH ₃ , mg/dL	0.076	0.016	1.00	0.268
4. DC+RF	100	-3.52	1.42	CP, % DM	0.092	0.042	1.28	
	100			TDN, % DM	0.073	0.030	2.29	
	100			Starch, % DM	-0.047	0.014	2.23	
5. DC+EV	100	-5.52	1.74	NH ₃ , mg/dL	0.659	0.166	1.23	0.739
	100			DMI, g/kg ^{0.75}	0.010	0.002	1.07	
	100			CP, % DM	0.120	0.016	1.33	
	100			TDN, % DM	0.052	0.022	2.15	
	100			ADF, % DM	0.047	0.019	2.37	
6. DC+RS	85	-3.40	1.08	Sheep	-0.303	0.267	1.38	0.656
	85			Non-lactating heifers	-0.722	0.306	1.17	
	85			Lactating dairy cows	0.461	0.276	1.62	
	85			CP, % DM	0.101	0.052	3.50	
	85			TDN, % DM	0.052	0.029	2.53	
	85			Starch, % DM	-0.013	0.013	2.90	
	85			Lignin, % DM	0.212	0.095	2.03	
	85			TDN/RDP ratio (g/g)	-0.021	0.039	3.17	
7. RS+RF	100	0.602	0.155	Sheep	0.165	0.292	1.21	0.431
				Lactating dairy cows	1.21	0.374	1.21	
				NH ₃ , mg/dL	0.078	0.048	1.05	
8. RS+DC+RF+EV	100	-2.52	0.787	CP, % DM	0.067	0.030	1.35	0.816
	100			ME, Mcal/kg	1.15	0.475	3.36	
	100			Starch, % DM	-0.032	0.010	2.86	
	100			NH ₃ , mg/dL	0.049	0.012	1.31	
	100			DMI, g/kg ^{0.75}	0.009	0.002	1.33	

¹N = number of iterations, ²SD = standard deviation, ³VIF = variance inflation factor, ⁴CCC = concordance correlation coefficient.

Table S5. Models and fit statistics estimated from Monte Carlo cross validation for GER (gastrointestinal entry rate, g/day) models using ruminant species (RS), dietary characteristics (DC), ruminal factors (RF) and experimental variables (EV) data sets individually and in combination.

Model number and name	N ¹	Intercept	SD ²	Variable	Value	SD	VIF ³	CCC ⁴
1. RS	85	55.8	6.28	Sheep	-42.5	6.75	1.24	0.735
	85			Non-lactating heifers	-22.1	6.38	1.10	
	85			Lactating dairy cows	170.5	31.9	1.24	
2. DC	100	201.6	38.9	RDP, % CP	-1.38	0.462	1.27	0.137
				NDF, % DM	-2.10	0.577	2.60	
				Lignin, % DM	25.9	6.56	2.48	
				TDN/RDP ratio (g/g)	-3.51	0.725	1.35	
				NH ₃ , mg/dL	3.61	1.26	1.00	
3. RF	100	90.6	19.9	RDP, % CP	-1.65	0.804	1.10	0.020
4. DC+RF	100	187.5	46.4	NH ₃ , mg/dL	4.17	1.20	1.10	0.022
5. DC+EV	100	14.2	7.91	DMI, kg/day	9.89	1.30	1.04	0.853
	100			TDN/RDP ratio (g/g)	-1.76	0.538	1.04	
6. DC+RS	90	183.3	28.4	Sheep	-68.1	11.1	1.56	0.783
	90			Non-lactating heifers	-73.1	34.0	1.30	
	90			Lactating dairy cows	137.3	31.5	1.86	
	90			RDP, % CP	-1.34	0.410	1.30	
	90			NDF, % DM	-1.71	0.489	3.27	
	90			Lignin, % DM	22.2	7.53	2.71	
	90			TDN/RDP ratio (g/g)	-3.35	0.605	1.32	
	99			Sheep	-71.7	23.1	1.19	
7. RS+RF	99	42.3	9.08	Lactating dairy cows	167.4	37.2	1.19	0.668
	99			NH ₃ , mg/dL	3.17	0.961	1.04	
	99			ADF, % DM	-2.92	0.918	3.78	
8. RS+DC+RF+EV	100	205.2	79.0	NH ₃ , mg/dL	1.15	0.632	1.09	0.913
	100			DMI, kg/day	12.1	0.856	1.18	
	100			OMD, %	-2.33	1.07	2.53	
	100			Starch, % DM	-1.54	0.413	3.40	
	100							

¹N = number of iterations, ²SD = standard deviation, ³VIF = variance inflation factor, ⁴CCC = concordance correlation coefficient.

Table S6. Models and fit statistics estimated from Monte Carlo cross validation for GER (gastrointestinal entry rate, g/kg^{0.75}) models using ruminant species (RS), dietary characteristics (DC), ruminal factors (RF) and experimental variables (EV) data sets individually and in combination.

Model number and name	N ¹	Intercept	SD ²	Variable	Value	SD	VIF ³	CCC ⁴
1. RS	100	0.856	0.0635	Sheep	-0.091	0.202	1.24	0.474
	100			Non-lactating heifers	-0.055	0.485	1.09	
	100			Lactating dairy cows	0.806	0.291	1.23	
2. DC	100	0.542	0.641	RDP, % CP	-0.014	0.006	1.28	0.221
	100			TDN, % DM	0.034	0.008	1.99	
	100			TDN/RDP ratio (g/g)	-0.063	0.008	1.23	
	100			Starch, % DM	-0.014	0.006	2.10	
	100			NH ₃ , mg/dL	0.033	0.013	1.00	
3. RF	100	0.856	0.115	RDP, % CP	-0.03	0.006	1.06	0.033
4. DC+RF	100	2.12	0.560	TDN/RDP ratio (g/g)	-0.068	0.011	1.30	0.216
	100			TDN, % DM	0.023	0.007	1.20	
	100			Propionate, % molar	-0.014	0.012	1.04	
5. DC+EV	100	1.34	2.16	DMI, g/kg ^{0.75}	0.010	0.001	1.09	0.661
	100			CP, % DM	0.036	0.009	1.07	
	100			TDN, % DM	0.021	0.010	2.03	
	100			Starch, % DM	-0.017	0.010	2.12	
	100			OM, % DM	-0.031	0.022	1.08	
	100			Sheep	-0.229	0.152	1.42	
6. DC+RS	94	0.932	0.544	Non-lactating heifers	-0.507	0.321	1.17	0.525
	94			Lactating dairy cows	0.478	0.255	1.62	
	94			RDP, % CP	-0.015	0.013	1.16	
	94			TDN, % DM	0.014	0.026	1.78	
	94			TDN/RDP ratio (g/g)	-0.054	0.050	1.33	
	94			Lignin, % DM	0.093	0.048	1.46	
	94			Sheep	-0.297	0.450	1.23	
7. RF+RS	100	0.631	0.090	Lactating dairy cows	0.861	0.299	1.20	0.496
	100			NH ₃ , mg/dL	0.048	0.115	1.06	
	100			DMI, g/kg ^{0.75}	0.009	0.001	1.04	
8. RS+DC+RF+EV	100	0.925	0.867	RDP, % CP	-0.015	0.007	1.29	0.647
	100			TDN/RDP ratio (g/g)	-0.028	0.021	3.83	
	100			CP, % DM	0.024	0.022	3.37	

¹N = number of iterations, ²SD = standard deviation, ³VIF = variance inflation factor, ⁴CCC = concordance correlation coefficient.

Table S7. Models and fit statistics estimated from Monte Carlo cross validation for ROC (urea-N returned to ornithine cycle, g/day) models using ruminant species (RS), dietary characteristics (DC), ruminal factors (RF) and experimental variables (EV) data sets individually and in combination.

Model number and name	N ¹	Intercept	SD ²	Variable	Value	SD	VIF ³	CCC ⁴
1. RS	87	26.1	4.93	Sheep	-17.7	5.89	1.18	0.577
	87			Non-lactating heifers	-16.6	4.99	1.08	
	87			Lactating dairy cows	126.7	33.6	1.19	
2. DC	100	118.4	26.6	RDP, % CP	-0.841	0.335	1.31	0.137
	100			NDF, % DM	-1.65	0.614	2.97	
	100			Lignin, % DM	23.1	8.24	2.78	
	100			TDN/RDP ratio (g/g)	-2.19	0.617	1.43	
3. RF	100	71.8	15.7	NH ₃ , mg/dL	1.92	0.543	1.00	0.024
4. DC+RF	100	96.2	21.9	NH ₃ , mg/dL	1.97	0.594	1.00	0.007
	100			Starch, % DM	-1.35	0.846	1.00	
5. DC+EV	100	53.5	25.6	Starch, % DM	-1.43	0.323	1.52	0.685
	100			NDF, % DM	-1.69	0.387	2.71	
	100			DMI, kg/day	6.16	1.45	1.10	
	100			Lignin, % DM	13.5	5.40	2.61	
6. DC+RS	85	100.7	22.4	Sheep	-37.6	9.21	1.28	0.646
	85			Non-lactating heifers	-49.9	29.8	1.18	
	85			Lactating dairy cows	91.6	28.8	1.49	
	85			RDP, % CP	-0.873	0.331	1.32	
	85			NDF, % DM	-1.49	0.552	3.40	
	85			Lignin, % DM	22.0	8.18	2.99	
	85			TDN/RDP ratio (g/g)	-2.04	0.564	1.42	
7. RF+RS	86	18.9	6.02	Sheep	-26.3	6.82	1.12	0.490
	86			Lactating dairy cows	125.1	28.8	1.13	
	86			NH ₃ , mg/dL	1.87	0.507	1.01	
8. RS+DC+RF+EV	100	-7.26	15.5	DMI, kg/day	6.58	1.56	1.05	0.660
	100			CP, % DM	1.44	0.771	1.06	
	100			Starch, % DM	-0.839	0.327	1.05	

¹N = number of iterations, ²SD = standard deviation, ³VIF = variance inflation factor, ⁴CCC = concordance correlation coefficient.

Table S8. Models and fit statistics estimated from Monte Carlo cross validation for ROC (urea-N returned to ornithine cycle, g/kg^{0.75}) models using ruminant species (RS), dietary characteristics (DC), ruminal factors (RF) and experimental variables (EV) data sets individually and in combination.

Model number and name	N ¹	Intercept	SD ²	Variable	Value	SD	VIF ³	CCC ⁴
1. RS	100	0.403	0.041	Sheep	0.135	0.274	1.18	0.313
	100			Non-lactating heifers	-0.124	0.330	1.08	
	100			Lactating dairy cows	0.677	0.241	1.19	
2. DC	100	0.865	0.849	RDP, % CP	-0.010	0.005	1.58	0.347
	100			TDN, % DM	0.016	0.010	2.10	
	100			Starch, % DM	-0.013	0.006	3.25	
	100			NDF, % DM	-0.016	0.007	5.33	
	100			Lignin, % DM	0.166	0.075	4.28	
	100			TDN/RDP ratio (g/g)	-0.034	0.010	2.19	
	100			NH ₃ , mg/dL	0.027	0.010	1.01	
3. RF	100	0.264	0.027	Butyrate, % molar	0.021	0.014	1.01	0.121
4. DC+RF	100	0.345	0.519	RDP, % DM	-0.013	0.004	1.26	0.294
	100			TDN/RDP ratio (g/g)	-0.039	0.013	1.81	
	100			NH ₃ , mg/dL	0.014	0.007	1.51	
	100			ME, Mcal/kg	0.781	0.203	1.72	
	100			Starch, % DM	-0.017	0.005	1.61	
5. DC+EV	100	1.44	0.834	RDP, % DM	-0.009	0.005	1.87	0.430
	100			Starch, % DM	-0.021	0.007	2.65	
	100			NDF, % DM	-0.010	0.005	2.48	
	100			TDN/RDP ratio (g/g)	-0.037	0.008	2.44	
	100			DMI, g/kg ^{0.75}	0.006	0.002	1.21	
	100			OMD, %	-0.020	0.009	2.12	
	100			ME, Mcal/kg	0.783	0.218	1.88	
	96			Sheep	-0.138	0.189	1.34	
	96			Non-lactating heifers	-0.586	0.402	1.23	
	96			Lactating dairy cows	0.239	0.204	1.67	
6. DC+RS	96	0.917	0.712	RDP, % DM	-0.005	0.012	1.57	0.520
	96			TDN, % DM	0.010	0.013	2.25	
	96			Starch, % DM	-0.014	0.006	3.30	
	96			NDF, % DM	0.010	0.076	6.44	
	96			Lignin, % DM	0.143	0.108	4.90	
	96			TDN/RDP ratio (g/g)	-0.029	0.014	2.17	
	100			Sheep	0.026	0.319	1.17	
	100			Lactating dairy cows	0.533	0.347	1.17	
	100			NH ₃ , mg/dL	0.023	0.008	1.04	
	100							
7. RF+RS	100	0.070	0.094	Sheep	0.026	0.319	1.17	0.339
	100			Lactating dairy cows	0.533	0.347	1.17	
	100			NH ₃ , mg/dL	0.023	0.008	1.04	

8. RS+DC+RF+EV	100			Butyrate, % molar	0.067	0.123	1.08	
	100	-0.123	0.334	TDN, % DM	0.024	0.004	1.83	0.400
	100			Starch, % DM	-0.015	0.003	1.95	
	100			TDN/RDP ratio (g/g)	-0.037	0.006	1.38	
	100			DMI, g/kg ^{0.75}	0.004	0.001	1.06	
	100			RDP, % CP	-0.010	0.003	1.41	

¹N = number of iterations, ²SD = standard deviation, ³VIF = variance inflation factor, ⁴CCC = concordance correlation coefficient.

Table S9. Models and fit statistics estimated from Monte Carlo cross validation for UUA (urea-N utilized for anabolic purposes, g/day) models using ruminant species (RS), dietary characteristics (DC), ruminal factors (RF) and experimental variables (EV) data sets individually and in combination.

Model number and name	N ¹	Intercept	SD ²	Variable	Value	SD	VIF ³	CCC ⁴
1. RS	92	28.5	4.37	Sheep	-22.0	4.46	1.20	0.429
	92			Non-lactating heifers	-7.94	4.41	1.10	
	92			Lactating dairy cows	40.5	16.1	1.22	
2. DC	100	20.7	5.66	CP, % DM	1.03	0.517	1.00	0.030
3. RF	100	-2.34	11.3	VFA total, Mm	0.385	0.146	1.00	0.151
4. DC+RF	100	-466.7	179.0	OM, % DM	3.70	1.74	1.20	0.332
	100			ME, Mcal/kg	17.4	14.0	2.87	
	100			Starch, % DM	-0.855	0.642	3.80	
	100			NDF, % DM	-0.600	0.240	2.08	
	100			pH	20.1	8.59	1.90	
	100			VFA total, Mm	0.431	0.201	1.29	
5. DC+EV	100	3.67	6.00	DMI, kg/day	2.97	0.969	1.00	0.392
6. DC+RS	89	19.9	4.83	Sheep	-22.7	3.79	1.20	0.423
	89			Non-lactating heifers	-10.6	3.87	1.11	
	89			Lactating dairy cows	35.4	15.8	1.26	
	89			CP, % DM	0.784	0.368	1.04	
7. RF+RS	87	18.4	6.53	Sheep	-23.9	11.2	1.10	0.350
	87			Lactating dairy cows	36.3	17.0	1.13	
	87			NH ₃ , mg/dL	1.58	1.66	1.03	
8. RS+DC+RF+EV	100	1.37	6.07	DMI, kg/day	3.31	0.930	1.00	0.418

¹N = number of iterations, ²SD = standard deviation, ³VIF = variance inflation factor, ⁴CCC = concordance correlation coefficient.

Table S10. Models and fit statistics estimated from Monte Carlo cross validation for UUA (urea-N utilized for anabolic purposes, g/kg^{0.75}) models using ruminant species (RS), dietary characteristics (DC), ruminal factors (RF) and experimental variables (EV) data sets individually and in combination.

Model number and name	N ¹	Intercept	SD ²	Variable	Value	SD	VIF ³	CCC ⁴
1. RS	100	0.412	0.042	Sheep	-0.049	0.104	1.21	0.063
	100			Non-lactating heifers	-0.023	0.115	1.10	
	100			Lactating dairy cows	0.072	0.126	1.22	
2. DC	100	0.204	0.147	TDN, % DM	0.006	0.003	1.02	0.137
	100			TDN/RDP ratio (g/g)	-0.017	0.005	1.02	
3. RF	100	0.327	0.058	NH ₃ , mg/dL	0.012	0.010	1.00	-0.007
4. DC+RF	100	0.765	0.301	NH ₃ , mg/dL	0.014	0.011	1.00	0.007
	100			Lignin, % DM	-0.112	0.073	1.00	
5. DC+EV	100	1.61	0.606	RDP, % CP	-0.008	0.003	1.24	0.295
	100			ADF, % DM	-0.030	0.010	2.78	
	100			DMI, g/kg ^{0.75}	0.003	0.001	1.90	
	100			DMD, %	-0.009	0.007	2.03	
6. DC+RS	100	0.189	0.121	TDN, % DM	0.007	0.002	1.02	0.144
	100			TDN/RDP ratio (g/g)	-0.019	0.004	1.02	
7. RF+RS	100	0.343	0.062	NH ₃ , mg/dL	0.011	0.010	1.00	0.001
8. RS+DC+RF+EV	100	-0.119	0.095	Sheep	-0.0003	0.053	1.22	0.199
	100			Non-lactating heifers	-0.257	0.090	1.14	
	100			Lactating dairy cows	-0.359	0.168	2.47	
	100			DMI, g/kg ^{0.75}	0.006	0.003	2.31	
	100			CP, % DM	0.015	0.018	1.05	

¹N = number of iterations, ²SD = standard deviation, ³VIF = variance inflation factor, ⁴CCC = concordance correlation coefficient.

Table S11. Models and fit statistics estimated from Monte Carlo cross validation for GER: UER (ratio of urea production in the liver that is recycled back to the GIT, %) models using ruminant species (RS), dietary characteristics (DC), ruminal factors (RF) and experimental variables (EV) data sets individually and in combination.

Model number and name	N ¹	Intercept	SD ²	Variable	Value	SD	VIF ³	CCC ⁴
1. RS	82	73.9	3.74	Sheep	-13.5	7.69	1.23	0.101
	82			Non-lactating heifers	-30.0	4.06	1.09	
	82			Lactating dairy cows	-7.12	4.30	1.22	
2. DC	100	136.8	40.6	CP, % DM	-1.30	0.941	4.20	0.366
	100			TDN, % DM	-0.855	0.603	2.30	
	100			ADF, % DM	-0.374	0.405	2.65	
	100			TDN/RDP ratio (g/g)	1.14	0.746	3.71	
3. RF	100	-11.8	14.8	pH	15.1	2.52	1.00	0.511
	100			NH ₃ , mg/dL	-1.56	0.177	1.00	
4. DC+RF	100	-9.02	17.8	pH	14.6	3.01	1.00	0.481
	100			NH ₃ , mg/dL	-1.53	0.166	1.00	
5. DC+EV	100	154.2	39.4	DMI, g/kg ^{0.75}	0.116	0.028	1.13	0.483
	100			TDN/RDP ratio (g/g)	1.52	0.697	3.82	
	100			TDN, % DM	-1.26	0.607	2.73	
	100			NDF, % DM	-0.386	0.263	3.28	
6. DC+RS	100	168.7	30.7	CP, % DM	-1.23	0.733	4.30	0.521
	100			Sheep	-7.76	6.73	1.34	
	100			Non-lactating heifers	-18.3	3.85	1.15	
	100			Lactating dairy cows	7.96	4.32	1.50	
	100			CP, % DM	-1.38	0.842	4.33	
	100			TDN, % DM	-1.19	0.481	2.91	
	100			NDF, %	-0.439	0.201	3.30	
	100			TDN/RDP ratio (g/g)	1.32	0.760	3.85	
7. RF+RS	100	-9.19	16.0	Sheep	-18.1	11.7	1.26	0.009
	100			Lactating dairy cows	5.67	3.10	1.26	
	100			pH	14.8	2.57	1.04	
	100			NH ₃ , mg/dL	-1.56	0.176	1.03	
8. RS+DC+RF+EV	100	87.4	6.38	NH ₃ , mg/dL	-1.75	0.238		0.798
	100			Starch, % DM	-0.586	0.178		
	100			DMI, g/kg ^{0.75}	0.157	0.037		
	100			Butyrate, % molar	-0.809	0.411		

¹N = number of iterations, ²SD = standard deviation, ³VIF = variance inflation factor, ⁴CCC = concordance correlation coefficient.

Table S12. Models and fit statistics estimated from Monte Carlo cross validation for ROC: GER (ratio of urea-N returned to ornithine cycle to the recycled back to the GIT, %) models using ruminant species (RS), dietary characteristics (DC), ruminal factors (RF) and experimental variables (EV) data sets individually and in combination.

Model number and name	N ¹	Intercept	SD ²	Variable	Value	SD	VIF ³	CCC ⁴
1. RS	87	45.7	3.60	Sheep	5.05	5.39		0.132
	87			Non-lactating heifers	-19.1	5.02		
	87			Lactating dairy cows	13.0	7.54		
2. DC	100	-28.6	19.0	CP, % DM	0.951	0.370		0.304
	100			TDN, % DM	0.792	0.209		
	100			Lignin, % DM	6.90	2.41		
	100			TDN/RDP ratio (g/g)	-1.12	0.649		
3. RF	100	124.5	39.4	NH ₃ , mg/dL	0.867	0.306		0.167
	100			pH	-12.6	6.23		
4. DC+RF	100	111.1	45.3	TDN, % DM	0.911	0.406		0.225
	100			Starch, % DM	-0.463	0.465		
	100			TDN/RDP ratio (g/g)	-2.40	0.620		
	100			pH	-12.7	6.28		
	100			RDP, % CP	-0.540	0.290		
5. DC+EV	100	-14.8	37.5	Lignin, % DM	7.45	3.82	1.22	0.203
	100			CP, % DM	3.01	0.651		
	100			DMD, %	0.858	4.81		
	100			OMD, %	-0.584	4.97		
	100			Lignin, % DM	4.99	3.01		
6. DC+RS	100	12.8	20.2	Sheep	-7.82	5.22	1.39	0.402
	100			Non-lactating heifers	-39.1	13.8		
	100			Lactating dairy cows	-9.84	8.25		
	100			TDN, % DM	0.979	0.365		
	100			Starch, % DM	-0.646	0.228		
	100			ADF, % DM	-1.23	1.02		
	100			Lignin, % DM	11.4	3.90		
	100			TDN/RDP ratio (g/g)	-1.56	0.405		
	100			NH ₃ , mg/dL	0.858	0.322		
7. RF+RS	100	127.6	38.8	pH	-13.1	6.11	1.01	0.175
	100			NH ₃ , mg/dL	0.255	0.510		
8. RS+DC+RF+EV	100	-66.3	20.2	CP, % DM	2.10	0.697	1.60	0.382
	100			TDN, % DM	0.781	0.252		
	100			Lignin, % DM	10.8	3.00		
	100							

¹N = number of iterations, ²SD = standard deviation, ³VIF = variance inflation factor, ⁴CCC = concordance correlation coefficient.

Table S13. Models and fit statistics estimated from Monte Carlo cross validation for ROC: GER (ratio of urea-N returned to ornithine cycle to the recycled back to the GIT, %) models using ruminant species (RS), dietary characteristics (DC), ruminal factors (RF) and experimental variables (EV) data sets individually and in combination.

Model number and name	N ¹	Intercept	SD ²	Variable	Value	SD	VIF ³	CCC ⁴
1. RS	91	47.2	3.74	Sheep	-2.62	4.49		0.204
	91			Non-lactating heifers	15.5	6.17		
	91			Lactating dairy cows	-17.9	7.20		
2. DC	100	24.2	20.4	RDP, % CP	0.434	0.218		0.179
	100			TDN, % DM	-0.358	0.186		
	100			TDN/RDP ratio (g/g)	1.62	0.428		
3. RF	100	-31.6	36.6	NH ₃ , mg/dL	-0.756	0.308	1.00	0.123
	100			pH	12.6	5.91	1.00	
4. DC+RF	100	-22.9	52.5	RDP, % CP	0.502	0.288	1.53	0.382
	100			TDN, % DM	-1.07	0.606	2.07	
	100			Starch, % DM	0.832	0.345	2.11	
	100			TDN/RDP ratio (g/g)	2.27	0.468	1.88	
	100			pH	19.2	5.10	1.51	
	100			Acetate, % molar	-1.24	0.767	8.13	
	100			A:P ratio	5.39	4.61	7.45	
5. DC+EV	100	93.6	37.0	CP, % DM	-2.64	0.581	1.21	0.070
	100			ADF, % DM	1.88	1.13	2.95	
	100			Lignin, % DM	-12.6	4.50	3.10	
	100			DMD, %	-1.18	2.56	5.30	
	100			OMD, %	0.945	2.81	5.25	
	91			Sheep	-3.02	4.82	1.26	
	91			Non-lactating heifers	17.6	9.49	1.12	
6. DC+RS	91	0.726	12.5	Lactating dairy cows	-13.8	7.97	1.29	0.223
	91			RDP, CP %	0.546	0.217	1.17	
	91			TDN/RDP ratio (g/g)	1.44	0.448	1.16	
	100			NH ₃ , mg/dL	-0.745	0.354	1.00	
	100			pH	12.8	5.94	1.00	
7. RF+RS	100	-34.5	37.1	OM, % DM	0.778	1.32	1.40	0.377
	100			CP, % DM	-1.67	0.872	5.50	
8. RS+DC+RF+EV	100	-19.7	126.7	TDN, % DM	-0.755	0.535	1.54	
	100			pH	17.2	8.18	1.53	
	100			Acetate, % molar	-0.949	0.326	2.13	
	100			TDN/RDP ratio (g/g)	0.784	0.717	3.95	
	100							

¹N = number of iterations, ²SD = standard deviation, ³VIF = variance inflation factor, ⁴CCC = concordance correlation coefficient.

Table S14. Models and fit statistics estimated from Monte Carlo cross validation for ROC: GER (ratio of urea-N returned to ornithine cycle to the recycled back to the GIT, %) models using dietary characteristics (DC) and ruminal factors (RF).

Model number and name	N ¹	Intercept	SD ²	Variable	Value	SD	VIF ³	CCC ⁴
1. DC	100	14.9	5.82	TDN/RDP ratio (g/g)	1.60	0.546	1.00	0.151
2. RF	100	44.0	4.79	NH ₃ , mg/dL	-1.35	0.282	1.00	0.187

¹N = number of iterations, ²SD = standard deviation, ³VIF = variance inflation factor, ⁴CCC = concordance correlation coefficient.

Table S15. Summary statistics of explanatory variables.

Variable	N ¹	Mean	SD	Minimum	Maximum
Diet characteristics ²					
OM, %DM					
Beef cattle	48	93.5	1.98	90.1	96.5
Sheep	35	90.9	2.32	83.4	93.2
Non-lactating heifers	9	93.5	0.941	92.5	94.5
Lactating dairy cows	32	92.3	1.50	88.8	94.2
CP, %DM					
Beef cattle	48	11.5	5.07	4.70	24.3
Sheep	35	12.0	4.70	6.91	25.7
Non-lactating heifers	9	14.4	3.70	9.06	21.3
Lactating dairy cows	32	15.8	1.99	9.40	18.0
RDP, % CP basis					
Beef cattle	48	55.3	7.77	38.3	68.2
Sheep	35	61.0	6.14	46.0	70.1
Non-lactating heifers	9	58.6	7.62	50.4	67.0
Lactating dairy cows	32	61.9	4.79	54.6	71.0
NDF, % DM					
Beef cattle	48	54.3	21.3	12.1	80.1
Sheep	35	44.4	13.4	21.9	68.4
Non-lactating heifers	9	36.2	5.65	29.7	42.1
Lactating dairy cows	32	35.6	1.80	32.5	41.6
ADF, % DM					
Beef cattle	48	30.0	13.2	6.23	46.5
Sheep	35	25.8	8.34	14.7	40.2
Non-lactating heifers	9	22.9	2.85	19.2	25.9
Lactating dairy cows	32	21.3	2.50	17.0	25.6
Lignin, % DM					
Beef cattle	48	3.59	1.10	1.64	5.50
Sheep	35	3.84	0.977	1.86	5.80
Non-lactating heifers	9	3.76	1.63	2.24	5.50
Lactating dairy cows	32	3.79	0.524	3.07	4.81
Starch, % DM					
Beef cattle	48	17.6	22.8	0.574	65.5
Sheep	35	19.5	10.9	1.96	35.3
Non-lactating heifers	9	20.2	9.61	10.7	30.9
Lactating dairy cows	32	25.0	4.44	19.1	35.8
TDN, % DM					
Beef cattle	48	58.8	13.9	40.0	82.4
Sheep	35	64.4	5.61	53.6	73.5
Non-lactating heifers	9	67.4	1.13	66.0	68.9
Lactating dairy cows	32	69.2	2.07	66.3	74.0
TDN/RDP ratio, g/g					
Beef cattle	48	11.1	4.67	2.46	21.8
Sheep	35	10.2	4.39	4.30	21.0
Non-lactating heifers	9	8.63	2.42	4.83	11.9
Lactating dairy cows	32	7.24	1.51	5.23	12.0
ME, Mcal/kg					
Beef cattle	48	2.05	0.622	0.776	2.98
Sheep	35	2.28	0.275	1.61	2.62
Non-lactating heifers	9	2.41	0.064	2.34	2.49
Lactating dairy cows	32	2.46	0.044	2.38	2.55

Ruminal factors³

pH

Beef cattle	24	6.37	0.42	5.59	6.85
Sheep	11	6.04	0.23	5.70	6.35
Non-lactating heifers	0	NM	NM	NM	NM
Lactating dairy cows	30	6.10	0.20	5.73	6.50
N-NH ₃ , mg/dL					
Beef cattle	28	6.78	7.50	0.231	25.1
Sheep	11	12.6	8.76	4.62	32.2
Non-lactating heifers*	0	NM	NM	NM	NM
Lactating dairy cows	30	11.5	4.94	1.20	22.8
VFA total, Mm					
Beef cattle	28	80.5	15.6	52.2	105.5
Sheep	11	94.7	6.40	79.4	101.9
Non-lactating heifers	0	NM	NM	NM	NM
Lactating dairy cows	22	109.7	21.2	72.6	143.3
Acetate, % molar					
Beef cattle	28	67.8	10.3	41.2	77.1
Sheep	11	60.1	2.78	56.8	66.5
Non-lactating heifers	0	NM	NM	NM	NM
Lactating dairy cows	22	63.6	3.85	56.4	69.4
Propionate, % molar					
Beef cattle	28	19.6	9.85	12.0	48.4
Sheep	11	21.1	3.28	17.0	26.8
Non-lactating heifers	0	NM	NM	NM	NM
Lactating dairy cows	22	21.6	3.77	15.3	28.6
Butyrate, % molar					
Beef cattle	28	8.39	2.31	5.34	14.9
Sheep	11	15.1	3.64	9.62	23.2
Non-lactating heifers	0	NM	NM	NM	NM
Lactating dairy cows	22	11.8	0.99	9.90	13.3
A:P ratio					
Beef cattle	28	4.16	1.52	0.85	6.41
Sheep	11	2.92	0.53	2.13	3.67
Non-lactating heifers	0	NM	NM	NM	NM
Lactating dairy cows	22	3.06	0.69	1.97	4.55
<i>Experimental variables⁴</i>					
DMI, kg/day					
Beef cattle	48	5.72	2.19	3.00	10.5
Sheep	35	1.12	0.526	0.303	2.24
Non-lactating heifers	9	6.49	0.638	5.84	7.23
Lactating dairy cows	32	23.6	3.47	16.8	28.7
DMI, g/kg ^{0.75}					
Beef cattle	48	78.4	19.1	49.8	121.4
Sheep	35	65.4	28.5	18.0	131.6
Non-lactating heifers	9	108.0	21.2	88.5	131.5
Lactating dairy cows	32	178.5	18.4	136.2	211.4
DMD, %					
Beef cattle	21	71.3	6.54	59.5	80.5
Sheep	8	60.3	1.58	57.9	62.4
Non-lactating heifers	4	59.4	1.10	58.2	60.7
Lactating dairy cows	21	67.3	2.32	62.0	72.3
OMD, %					
Beef cattle	36	62.0	12.3	36.8	81.6
Sheep	15	68.4	5.97	62.2	81.2
Non-lactating heifers	4	59.3	1.21	58.0	60.8
Lactating dairy cows	19	69.6	2.16	66.7	74.3

¹N = number of treatments means. ²OM = Organic matter, CP = crude protein, RDP = Rumen degradable protein, NDF = Neutral detergent fiber, ADF = Acid detergent fiber, TDN = Total digestible nutrients, ME = Metabolizable energy. ³VFA = Volatile fatty acids, A:P ratio = Acetate: propionate ratio. ⁴DMI = Dry matter intake, DMD = Dry matter digestibility, OMD = Organic matter digestibility. *NM = not measured.

Table S16. Summary statistics of response variables.

Variables ¹	N ²	Mean	SD	Minimum	Maximum
<i>UER, g/day</i>					
Beef cattle	48	82.9	47.6	17.6	217.0
Sheep	35	21.9	15.6	2.4	55
Non-lactating heifers	9	72.1	33.0	31.1	135.2
Lactating dairy cows	32	361.8	123.8	91.6	531
<i>UER, g/kg^{0.75}</i>					
Beef cattle	48	1.13	0.564	0.291	2.84
Sheep	35	1.30	0.992	0.246	3.56
Non-lactating heifers	9	1.17	0.472	0.470	2.05
Lactating dairy cows	32	2.71	0.825	0.743	3.77
<i>GER, g/day</i>					
Beef cattle	48	59.2	33.9	14.9	169
Sheep	35	12.4	9.61	1.80	38.5
Non-lactating heifers	9	34.2	5.23	25.9	41.1
Lactating dairy cows	32	248.4	88.3	83	390
<i>GER, g/kg^{0.75}</i>					
Beef cattle	48	0.807	0.398	0.288	2.21
Sheep	35	0.754	0.674	0.120	2.69
Non-lactating heifers	9	0.559	0.069	0.391	0.623
Lactating dairy cows	32	1.86	0.584	0.673	2.67
<i>ROC, g/day</i>					
Beef cattle	48	28.6	21.2	2.8	84
Sheep	26	7.85	7.27	1.8	24.7
Non-lactating heifers	9	9.41	3.91	5	15.1
Lactating dairy cows	32	158.3	89.5	13.2	295
<i>ROC, g/kg^{0.75}</i>					
Beef cattle	48	0.374	0.233	0.046	1.097
Sheep	26	0.484	0.523	0.102	1.72
Non-lactating heifers	9	0.151	0.053	0.076	0.229
Lactating dairy cows	32	1.17	0.611	0.107	2.09
<i>UUA, g/day</i>					
Beef cattle	40	29.8	16.8	8.50	79.0
Sheep	26	5.96	3.18	2.11	14
Non-lactating heifers	9	20.5	3.48	14.4	24.7
Lactating dairy cows	29	81.6	52.2	24	213.8
<i>UUA, g/kg^{0.75}</i>					
Beef cattle	40	0.412	0.208	0.091	1.032
Sheep	26	0.349	0.223	0.126	0.977
Non-lactating heifers	9	0.339	0.067	0.218	0.400
Lactating dairy cows	29	0.621	0.404	0.174	1.59
<i>GER:UER, %</i>	124	68.2	18.3	6.50	98.9
Beef cattle	48	73.9	15.9	45.1	98.9
Sheep	35	64.5	23.5	6.50	95.0
Non-lactating heifers	9	49.7	18.1	29.2	83.2
Lactating dairy cows	32	68.9	9.05	49.8	90.6
<i>ROC:GER, %</i>	113	48.7	18.4	15.2	88.6
Beef cattle	46	45.0	15.4	19.4	86.0
Sheep	26	49.0	12.1	29.0	76.0
Non-lactating heifers	9	27.4	8.46	17.4	40.7
Lactating dairy cows	32	59.7	21.7	15.2	88.6
<i>UUA:GER, %</i>	102	43.7	16.7	7.20	75.0
Beef cattle	38	46.9	14.3	11.0	70.1
Sheep	26	45.2	9.39	23.0	59.0

Non-lactating heifers	9	62.2	8.35	48.8	75.0
Lactating dairy cows	29	32.5	19.3	7.20	65.9
<i>MNU:GER, %</i>	43	28.5	18.5	5.90	64.0
Beef cattle	30	32.9	19.9	8.1	64.0
Sheep	8	16.2	2.42	13.2	20.0
Non-lactating heifers	5	21.7	14.7	5.90	42.6
Lactating dairy cows	0	NM	NM	NM	NM

¹UER: Urea-N entry rate, GER: Gastrointestinal entry rate, ROC: Urea-N returned to ornithine cycle, UUA: Urea-N utilized for anabolic purposes, MNU: Microbial incorporation of recycled urea-N. ²N = number of treatments means. *NM = not measured.