Role of rumen digestion in low-input systems

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Overview

Factors influencing rumen function and consequences on nutrient supply in the context of organic and low input systems

- **Forage maturity**
- **Forage species; comparison of grasses and forage legumes**
- **Forage conservation**

Introduction

- High quality forages are central to meeting the nutrient requirements for milk production in organic and low input systems
- Increased interest in the use of forage legumes to fix atmospheric nitrogen and decrease reliance on inorganic fertilizers
- Forage conservation is important to on-farm feed security

Importance of forage quality in low input systems

- Much larger variation in energy content of forages than concentrate ingredients-decreases with increases in maturity
- Contribution of a single forage to total intake is higher compared with concentrate ingredients
- Forage digestibility is positively related to intake potential, whereas concentrate energy content has a marginal or no influence
- Close association between forage energy content and milk production

Forage intake potential

- Forage intake is the main determinant of nutrient supply and production in dairy cows
- Intake phenotypic is a function of the host animal and diet characteristics
- It is often difficult to separate animal and dietary factors regulating intake

  Influence of forage may be underestimated and/or biased

- Using milk yield as a term in models for the prediction of intake is "retrospective prediction"

Regulation of feed intake

Role of forage NDF content and digestibility in the regulation of intake

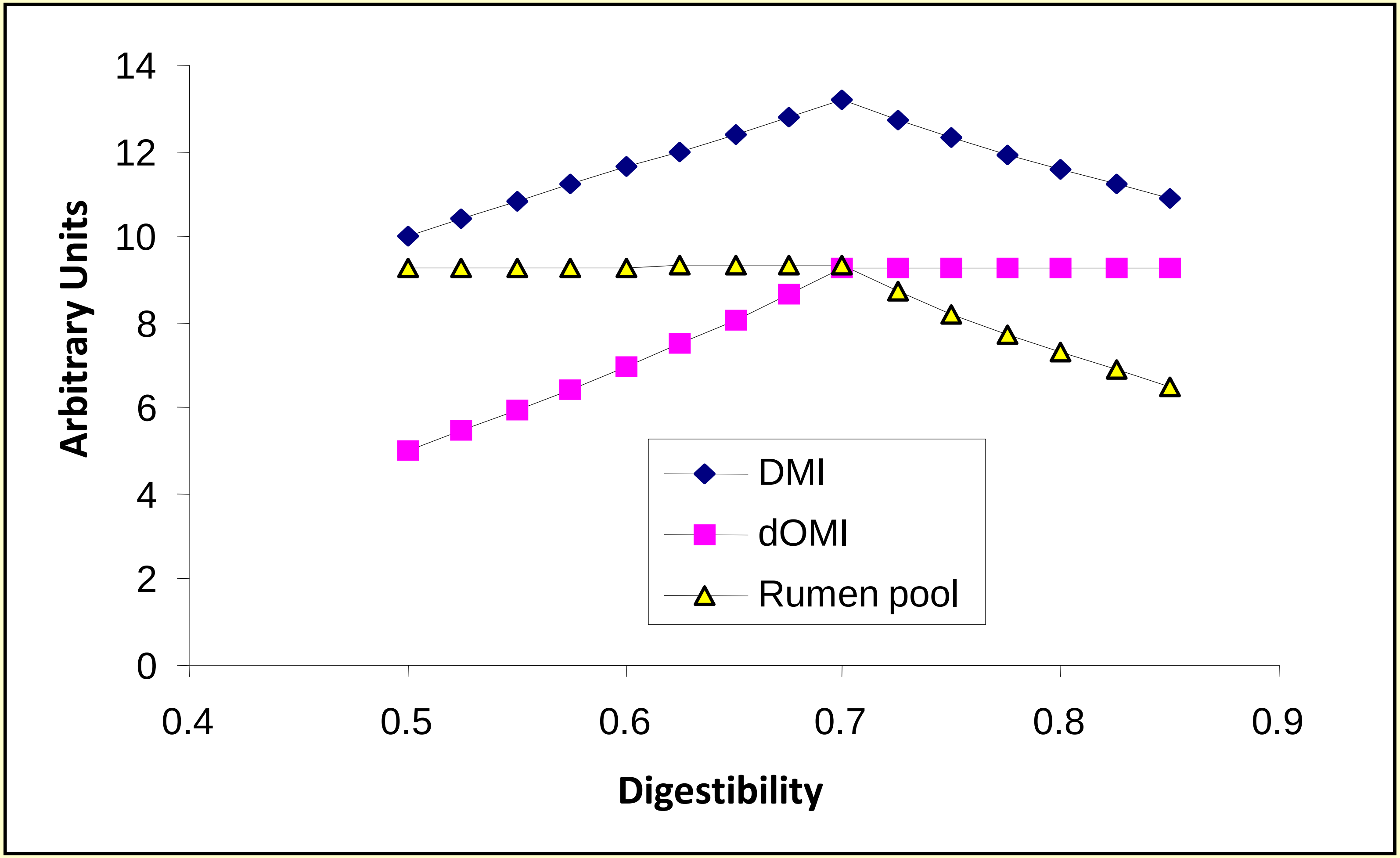
Current theories of the regulation of intake consider the involvement of two key mechanisms;

Rumen fill and Metabolic feedback

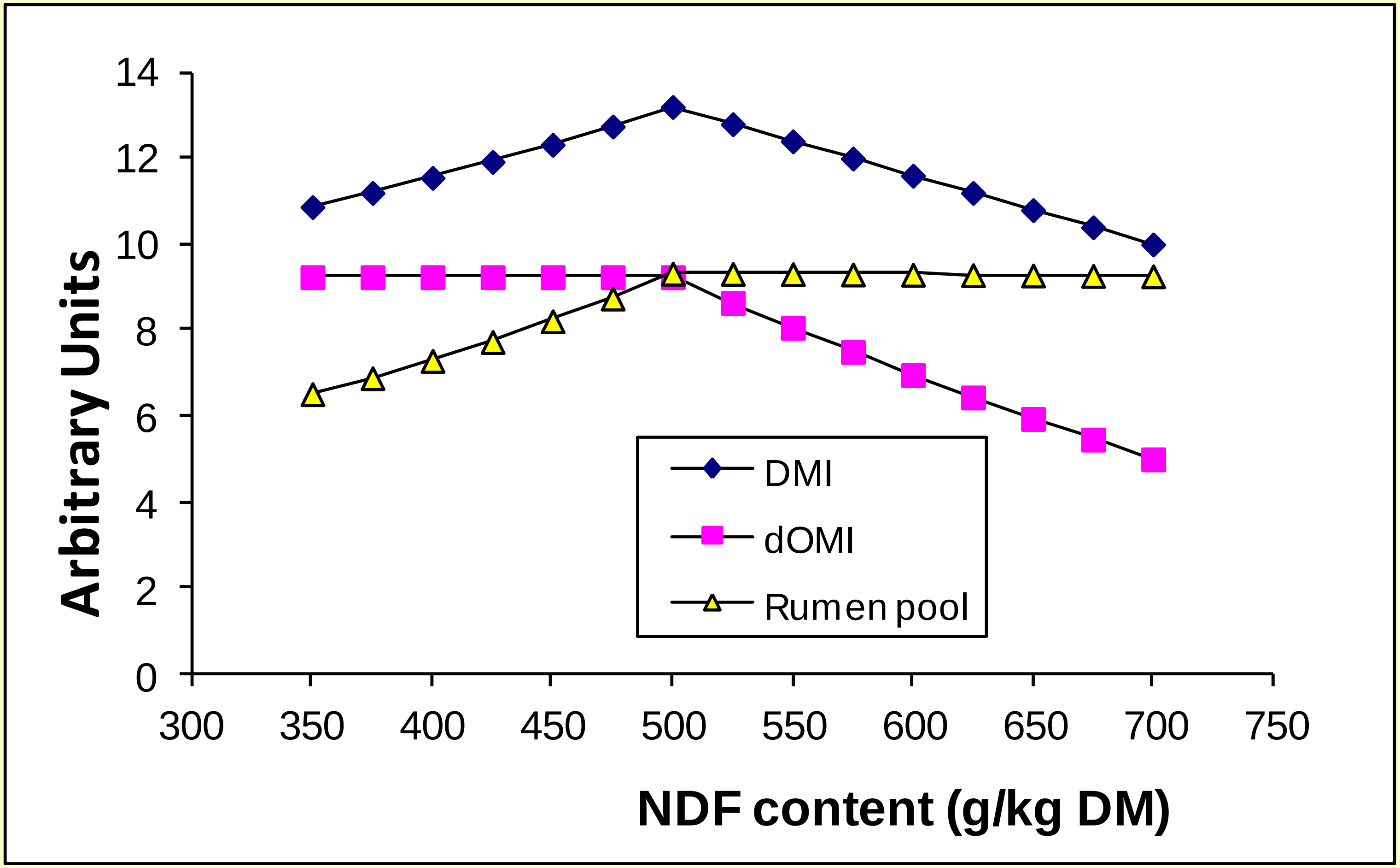
- **At low D/high NDF improvements in digestibility increase DM and energy intake at a constant rumen pool size (physical regulation)**
- **Above a set-point dry matter declines but energy intake is constant while rumen pool size decreases**

(metabolic regulation)

Relation between digestibility, dry matter intake and energy intake (digestible organic matter)



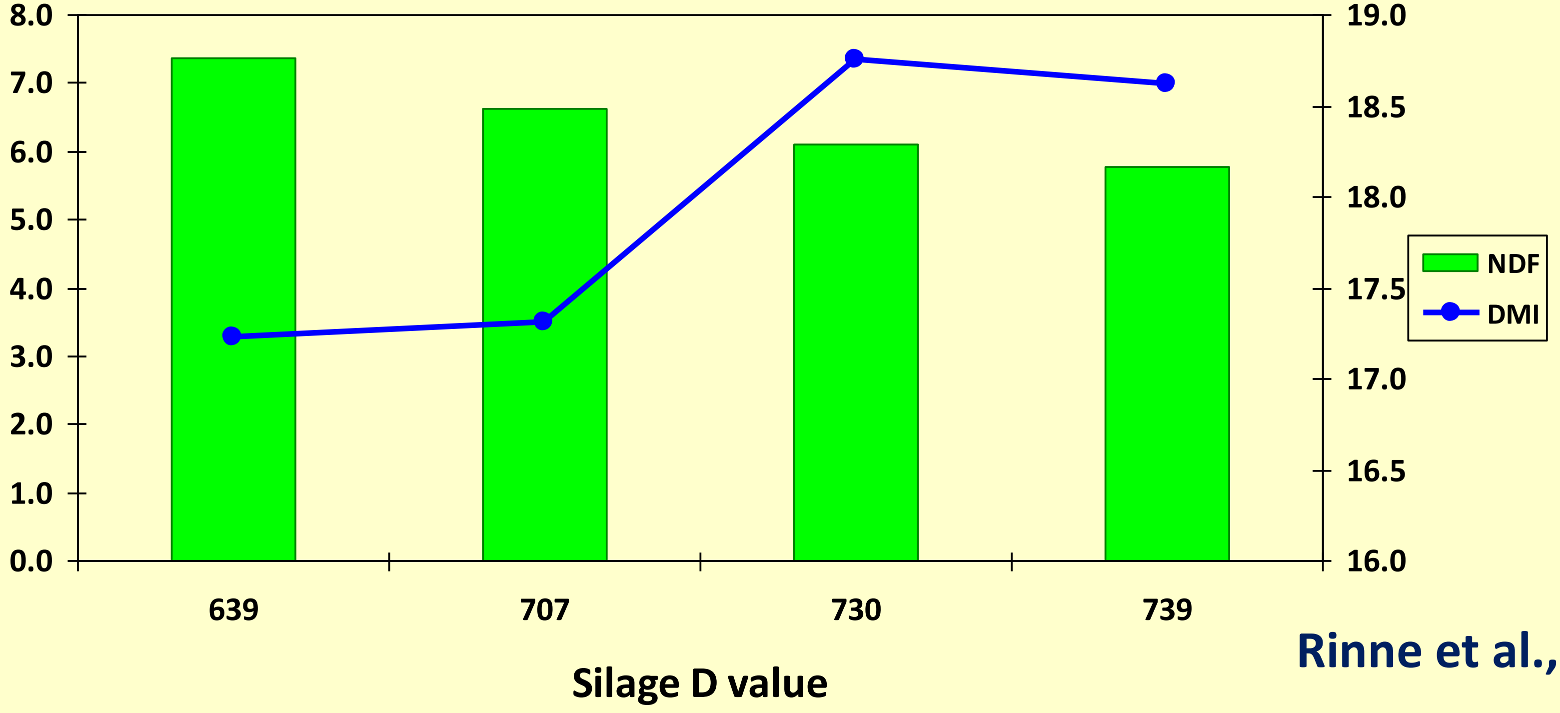
Relation between NDF content, dry matter intake and energy intake (digestible organic matter)



Forage NDF and ruminal digestion: Evidence based on rumen evacuation

Effect of grass silage D-value on intake and rumen neutral detergent fibre pool size

Cows fed 7 kg concentrate/d + grass silage ad libitum

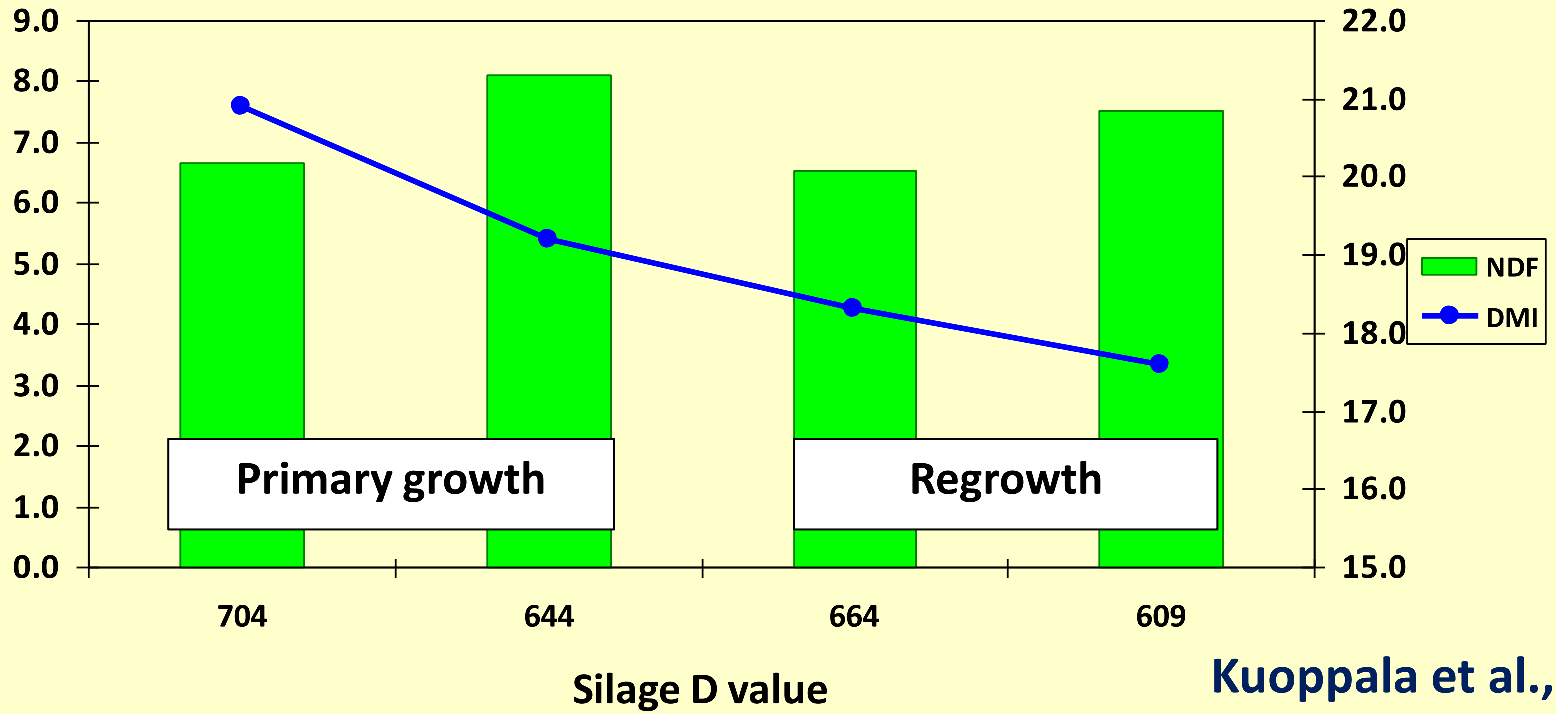


Rinne et al., 2002

Passage rate of dNDF and iNDF increased but not enough to prevent the accumulation of NDF, dNDF and iNDF in the rumen when ensiled grass of progressive maturity was fed

Effect of silage D-value for first and second cuts on intake and rumen neutral detergent fibre pool size

Cows fed 8 kg concentrate/d + grass silage ad libitum



Kuoppala et al., 2010

Chemical composition of silage, rumen fill, digestion or passage kinetics or the ratio of protein/energy of absorbed nutrients could not explain the differences in intake potential between silages prepared from primary and secondary cuts

Regulation of intake in cows fed high forage diets

- With diets based on moderate – high quality forages + concentrates rumen fill is not the only factor regulating intake
- Metabolic factors alone do not seem to be the sole mechanism – rarely does intake decrease for low NDF / high energy diets
- Regulation of intake appears to involve a complex interplay between both physical and metabolic factors

Effect of forage legumes on ruminal digestion and nutrient supply

Intake and production potential of forage legumes

	Grass	G+RC	Red Clover	G+WC	White Clover	Lucerne
Intake, kg/d						
Forage	10.2	13.9	12.1	14.9	13.6	12.4
Total	17.1	20.8	19.0	21.8	19.3	19.3
Yield, kg/d						
Milk	19.7	20.7	19.9	20.7	24.0	19.4
Fat	0.82	0.86	0.80	0.93	0.98	0.78
Protein	0.66	0.68	0.64	0.67	0.79	0.63
Lactose	0.91	0.97	0.93	0.98	1.15	0.90

Dewhurst et al., 2003

Forage legumes influence ruminal NDF pool size and particle size distribution

Cows fed 8 kg concentrate/d + silage ad libitum

	G	GRC	RC	GWC	WC	A
Number	3	4	4	4	3	3
Rumen contents	87.8	83.5	78.2	80.7	65.0	69.6
(kg fresh weight)	94.0	92.2	93.6	94.4	73.3	77.1
DM concentration in	12.17	12.28	13.09	12.32	12.85	13.08
rumen contents (%)	11.53	11.75	12.67	12.35	11.86	12.69
Rumen DM content (kg)	10.90	10.27	10.34	9.98	8.34	8.91
	11.01	10.85	12.00	11.70	8.57	9.73
Rumen NDF content (kg)	6.24	5.43	5.61	5.06	3.13	5.03
	6.51	6.17	6.59	6.26	3.51	5.64
Particles > 2 mm	38.0	33.2	35.5	38.2	39.3	30.3
(% of DM)	43.3	42.5	41.2	44.3	42.8	37.1
Particles 0.106 to 2 mm	25.4	25.8	26.9	22.6	18.2	32.1
(% of DM)	23.3	22.7	25.3	21.1	16.5	28.3
Particles < 0.106 mm	36.8	40.9	37.9	39.4	42.5	37.4
(% of DM)	33.7	34.7	33.7	34.8	40.7	34.4

Upper line values at 09.00 and lower line values at 13.00 h

Dewhurst et al., 2003

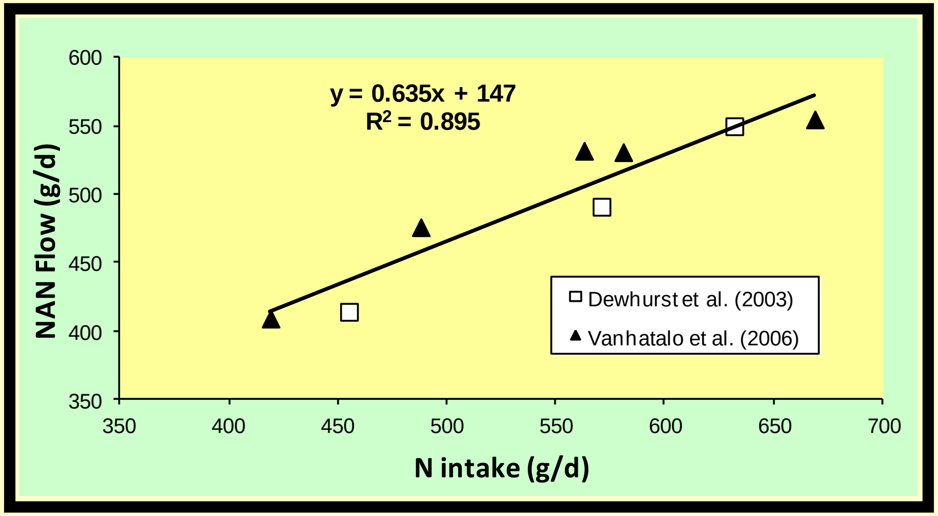
Forage legumes influence ruminal digestion kinetics

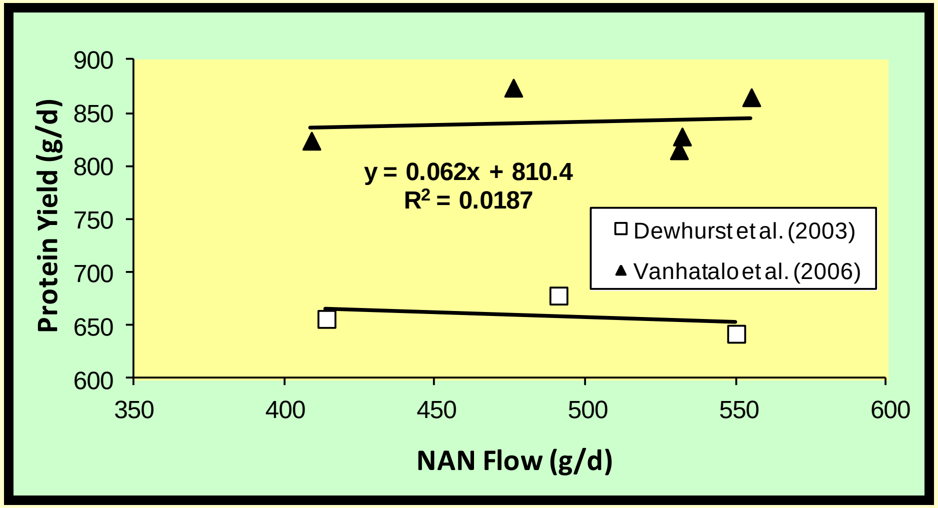
Cows fed 9 kg concentrate/d + silage ad libitum

Intake, kg/d	Grass silage Early	Grass silage Late	Mixed forage diet	Red clover silage Early	Red clover silage Late	SEM
Silage DM	13.2	12.0	14.0	11.3	12.1	0.49
Total DM	21.2	20.1	21.5	18.8	20.2	0.59
Rumen contents, kg						
NDF	7.58	8.35	8.17	6.13	7.90	0.289
iNDF	2.05	2.39	3.02	2.95	4.77	0.154
pdNDF[2]	5.53	5.97	5.16	3.17	3.13	0.221
iNDF/pdNDF	0.346	0.386	0.505	0.861	1.330	0.0653
Digestion rate						
pdNDF k_d, /h	0.0351	0.0319	0.0371	0.0401	0.0471	0.00170
Passage rate						
pdNDF k_p, /h	0.0189	0.0182	0.0181	0.0213	0.0242	0.00119
iNDF k_p, /h	0.0227	0.0236	0.0195	0.0162	0.0168	0.00111

Kuoppala et al., 2009

Effect of replacing grass silage with red clover silage on NAN flow and protein yield

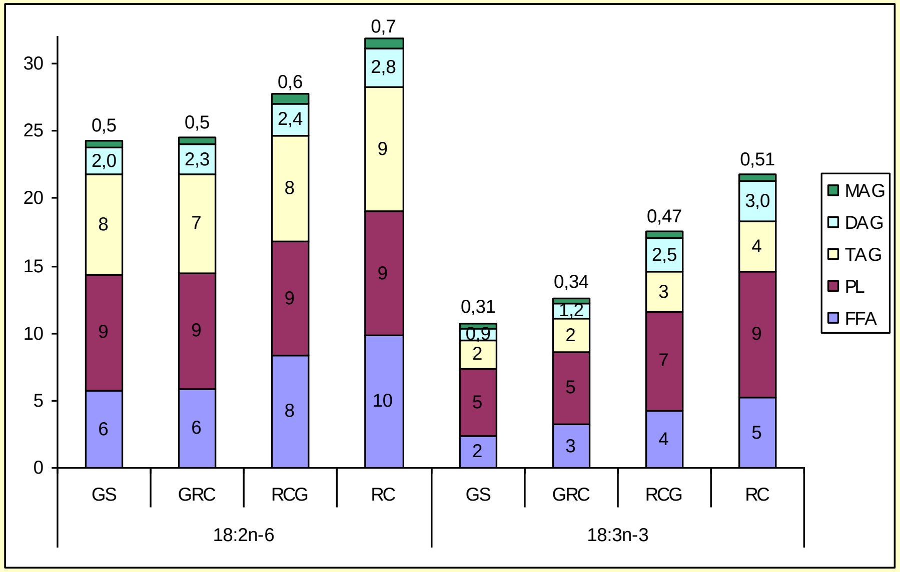




- Increased N intake from gradual or total replacement of grass with red clover increases NAN flow
- However increases in protein flow do not result in higher milk protein yield
- Red clover increases faecal nitrogen excretion

Effect of replacing grass silage with red clover silage on lipolysis and biohydrogenation

	GS	GRC	RCG	RC
Lipolysis, %	**85**	**81**	**78**	**70**
Biohydrogenation, %				
***cis*-9 18:1**	**59**	**59**	**58**	**54**
18:2n-6	**78**	**78**	**77**	**74**
18:3n-3	**93**	**91**	**89**	**85**



- Replacement of grass with red clover lowers lipolysis in the rumen
- Replacement of grass with red clover lowers ruminal 18:2n-6 and 18:3n-3 biohydrogenation
- Replacement of grass with red clover increases 18:2n-6 and 18:3n-3 flow

Halmemies et al., unpublished

Effect of conservation method on rumen function and nutrient supply

Changes in composition during ensiling influencing forage protein value

Sugars → Lactic acid

Sugars → VFA

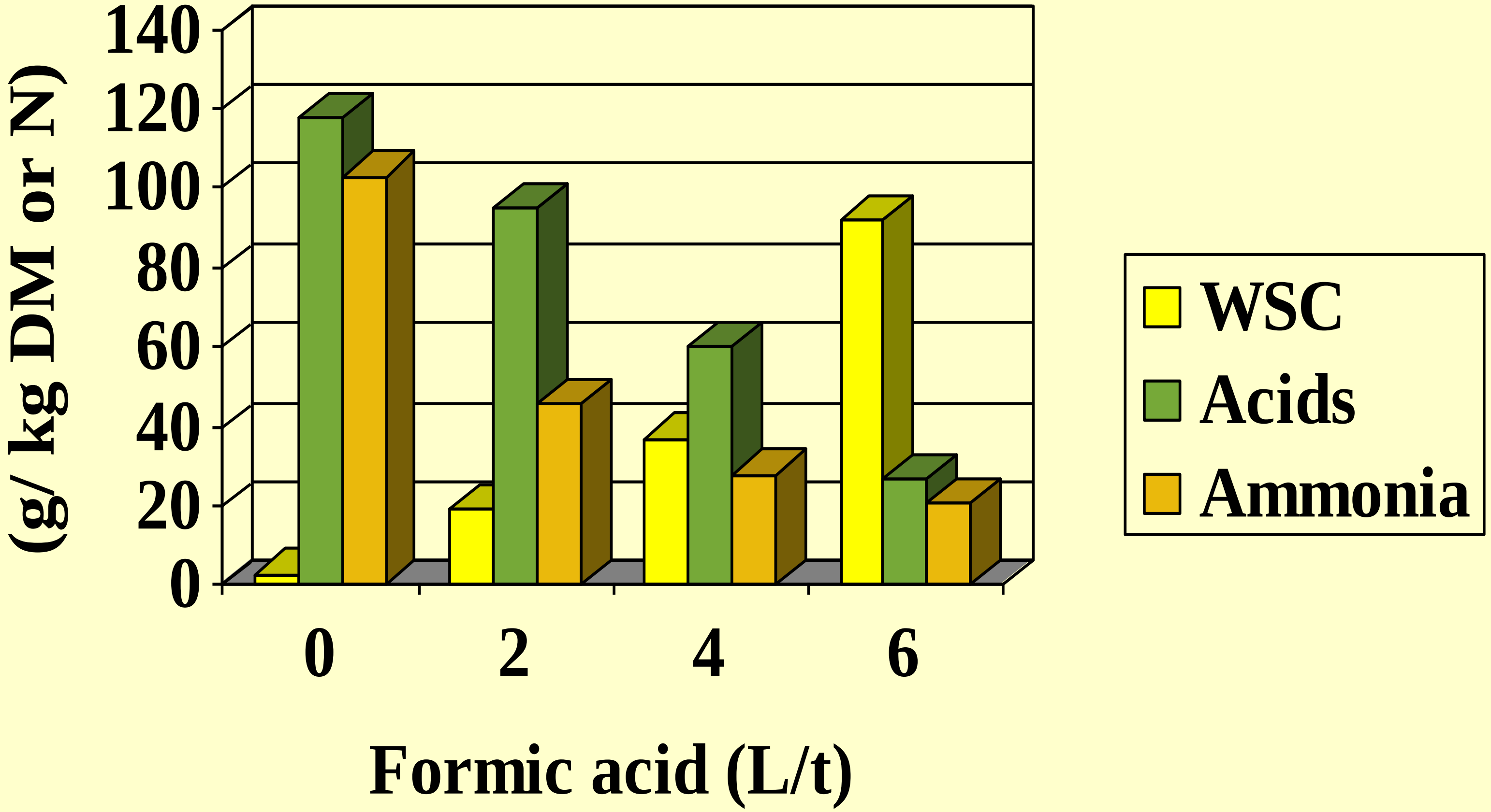
Lactic acid → VFA

Reduced intake potential
Less energy for rumen microbes
Small decrease in digestibility

Protein → NPN

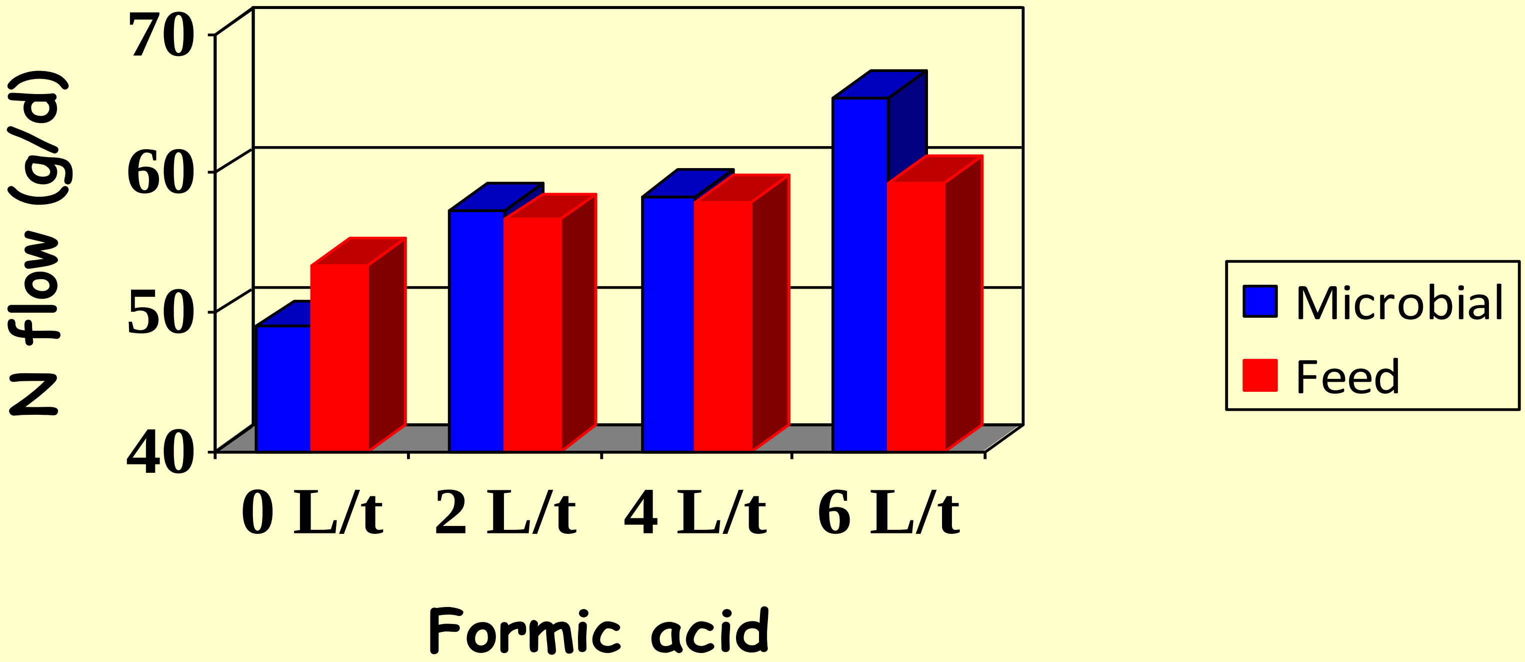
NPN	Microbes	Amino N escape
Peptides	++	++
Amino acids	+	+
Ammonia	(+)	0

Effects of formic acid on silage fermentation



Jaakkola et al., 1993

Effects of formic acid on N flow into the duodenum



Jaakkola et al., 1993

Comparison of ensiling additives on rumen digestion and nitrogen flows at the omasum

	Formic acid	Inoculant	Untreated	SEM	*P*
Intake, kg/d					
Silage DM	13.95	12.37	12.52	0.309	0.111
Total DM	20.11	18.58	18.66	0.312	0.115
Rumen content, kg					
NDF	6.22	6.08	5.56	0.335	0.306
pdNDF	3.79	3.74	3.41	0.198	0.360
Digestion kinetics					
pdNDF k_p	0.0164	0.0151	0.0120	0.00097	0.158
pdNDF k_d	0.0732	0.0608	0.0613	0.00462	0.303
Omasal flow, g/d					
Microbial N	321	292	295	3.8	0.053
Dietary N	114	84.4	88.6	4.26	0.066
Microbial synthesis					
EMPS (g/kg OMTDR)	23.9	23.0	22.6	0.16	0.048

Shingfield et al., unpublished

Comparison of conservation method on rumen function and nitrogen flow at the omasum

	Experiment 1				Experiment 2					
									P^5	
	Grass	Hay	SEM	*P*	Hay	UTS	RFS	SEM	Method	Extent
Intake, kg/d										
Forage DM	10.7	12.3	0.77	0.109	11.8	12.3	13.9	1.03	0.038	0.029
Total DM	16.7	18.4	0.792	0.095	19.8	20.2	21.8	1.03	0.038	0.029
Rumen digestibility, %										
OM	69.7	68.0	0.90	0.131	68.6	70.6	71.0	0.022	0.185	0.846
NDF	69.1	68.5	0.92	0.540	66.3	66.8	68.3	2.47	0.513	0.471
pdNDF	77.4	77.6	0.70	0.382	73.6	73.1	74.8	2.25	0.867	0.396
Nitrogen	-14.6	-17.5	5.42	0.620	-7.61	5.35	3.40	5.291	0.015	0.649
Omasal flow										
NDF, kg/d	2.47	2.88	0.190	0.097	3.20	2.92	3.03	0.276	0.359	0.696
pdNDF, kg/d	1.55	1.77	0.152	0.231	2.16	2.05	2.12	0.205	0.664	0.761
NAN, g/d	469	498	30.3	0.400	499	480	517	45.3	0.958	0.139
Microbial nitrogen, g/d	336	366	25.8	0.319	355	346	368	34.7	0.927	0.285
Dietary nitrogen, g/d	133	132	8.02	0.927	144	134	148	12.3	0.792	0.238

Halmemies et al., unpublished

Comparison of conservation method on ruminal lipid metabolism and fatty acid flow at the omasum

	Experiment 1				Experiment 2					
	Grass	Hay	SEM	*P*	Hay	UTS	RFS	SEM	*P*[5] Method	*P*[5] Extent
Lipolysis, %	93.4	86.3	0.83	0.001	80.2	93.3	91.7	2.49	0.005	0.635
Biohydrogenation, %										
cis-9 18:1	70.1	65.8	1.67	0.06	74.8	76.7	75.9	2.68	0.42	0.69
18:2n-6	84.1	80.7	0.43	<0.01	84.6	88.1	87.7	1.68	<0.05	0.80
18:3n-3	93.0	86.6	0.84	<0.01	87.3	95.6	95.9	0.97	<0.001	0.79
Omasal flow, g/d										
16:0	66.8	56.9	5.40	0.140	62.0	75.6	78.5	7.30	<0.001	0.300
18:0	207	175	16.1	0.116	214	290	314	26.8	<0.001	0.113
cis-9 18:1	14.9	14.2	0.86	0.450	15.6	16.0	16.5	1.81	0.574	0.694
∑ *trans*-18:1	36.2	25.0	4.05	0.052	30.9	47.8	55.7	4.13	<0.001	0.073
18:2n-6	18.2	17.2	0.771	0.272	18.3	17.8	18.7	2.40	0.993	0.506
∑ CLA	3.70	5.25	0.737	0.104	4.12	4.85	5.38	0.511	0.038	0.261
18:3n-3	10.4	7.81	1.226	0.101	6.83	7.69	7.89	1.043	0.050	0.833
∑ Fatty acids	437	365	34.3	0.106	422	551	587	51.5	<0.001	0.181

Halmemies et al., unpublished

Summary #1

- **Forage digestibility and NDF content influence intake and ruminal digestion highlighting the importance of harvesting date during forage conservation**
- **Effects of primary and secondary grass growth on rumen function differ but the explanation is not obvious**
- **Forage legumes have a higher intake potential than grasses that is not related to increases in rumen fill**

Summary #2

- Increases in NAN flow when red clover replaces grass does not stimulate higher milk protein yields
- Replacing grass with red clover lowers ruminal lipolysis and increases the flow of polyunsaturated fatty acids
- Restricting in silo fermentation increases the efficiency of microbial protein synthesis
- Conservation of grass by drying rather then ensiling lowers ruminal lipolysis and increases the flow of polyunsaturated fatty acids
- In silo fermentation has minimal influence on ruminal lipid metabolism

Thank you for your attention