Challenges of utilization of High Protein Forages by Lactating Dairy Cows

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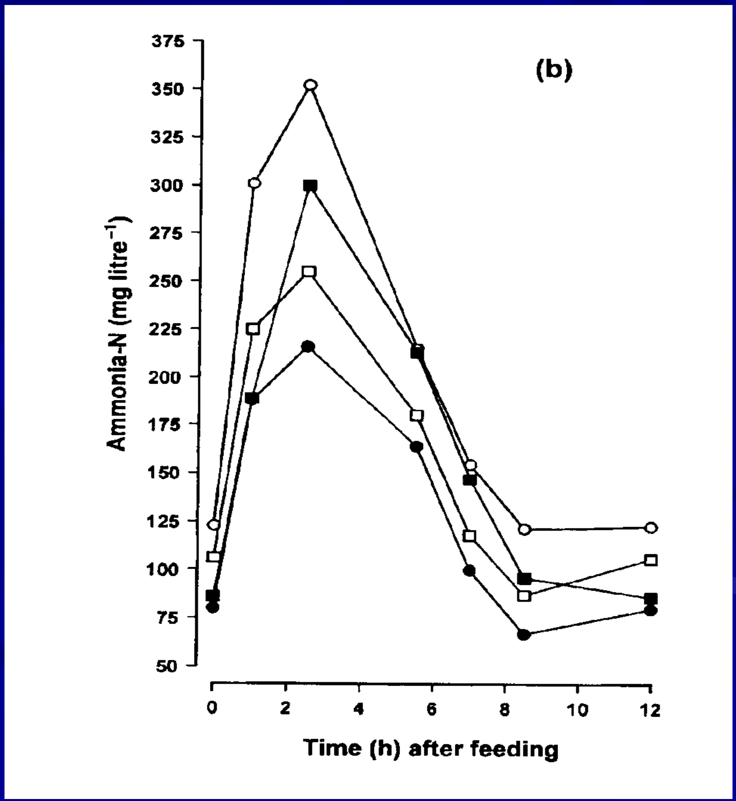
Introduction

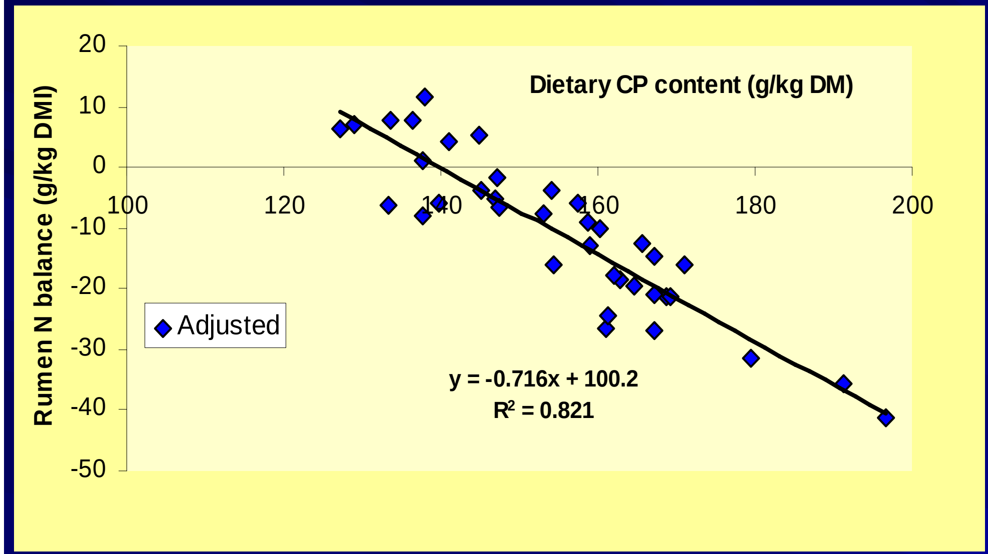
- Forages are essential for cow health
- High quality forages often have high concentrations of CP
- Forage (silage) N is rapidly and extensively degraded in the rumen → High rumen ammonia concentrations and rumen N losses
- N utilization can be low (20-25%) in cows fed high quality forages (silages)
- Increased risk of
  - Ammonia volatilization
  - Nitrate losses

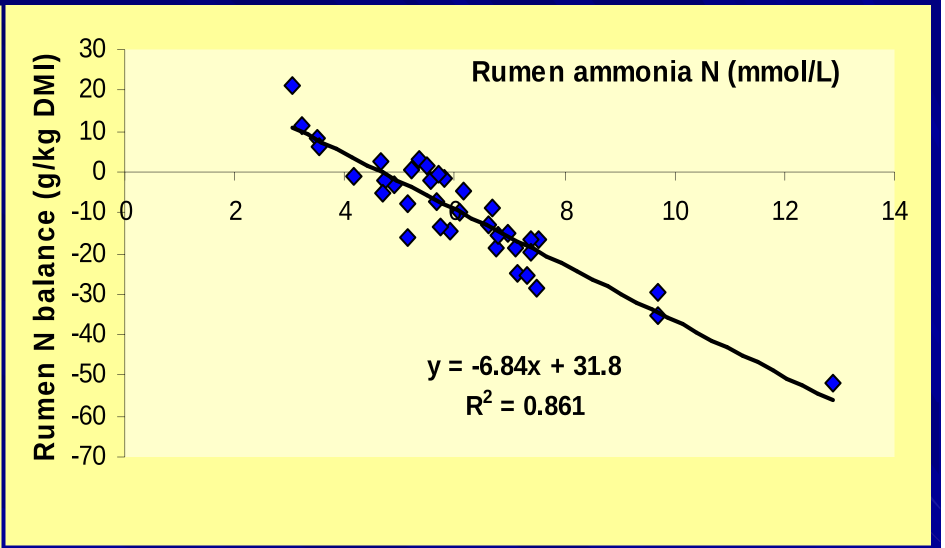
Rumen ammonia concentration in cows fed diets based on grass silage (Kim et al., 1999)

- CP content 196 g/kg DM
- In cows fed grass or legume silages rumen postprandial rumen ammonia N is very high
- High peak values



Effects of dietary CP and rumen ammonia on rumen N losses in cows fed grass silage based diets (MTT data)



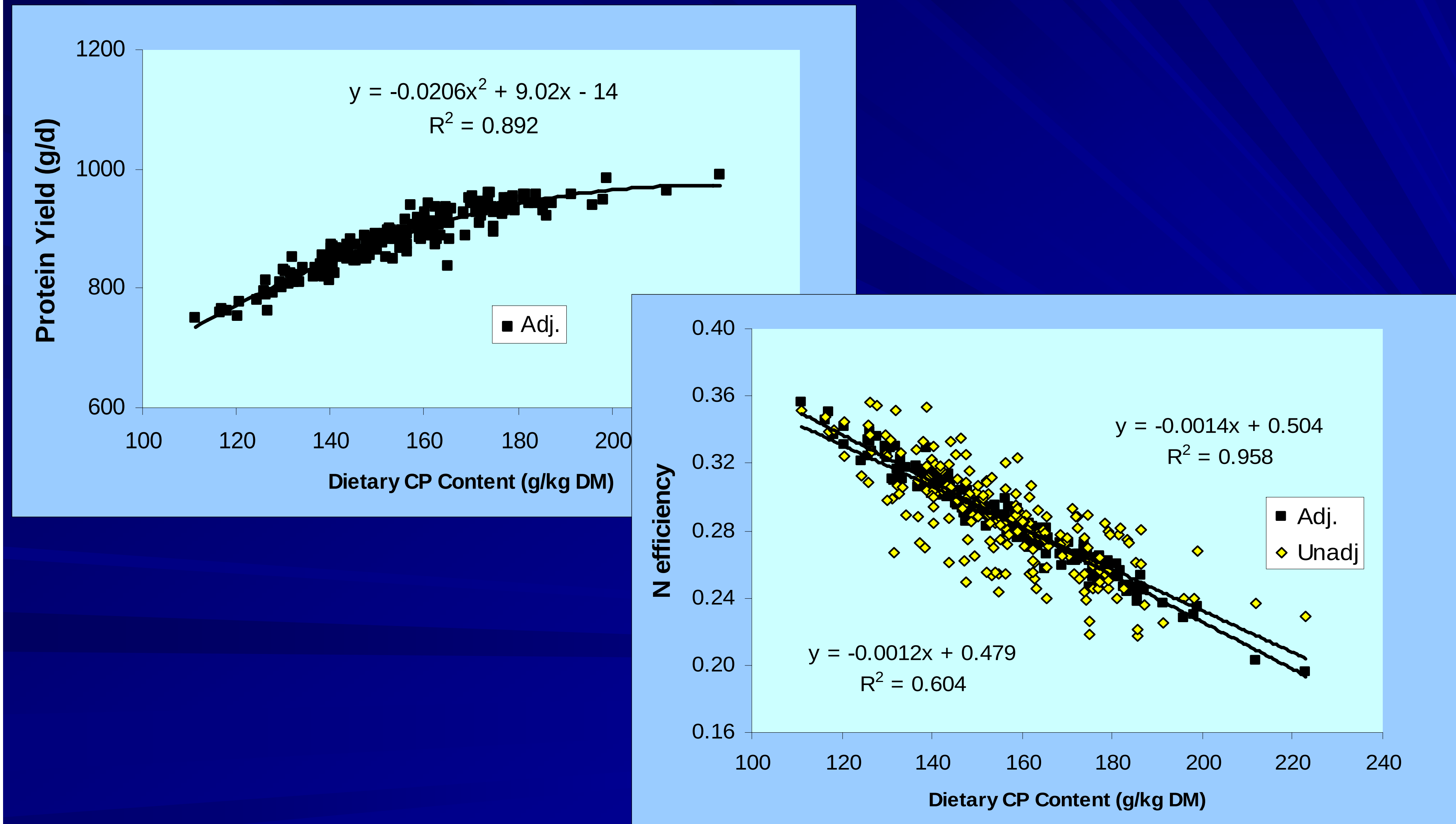


- Rumen N losses increase with increasing Dietary CP content (70% of increased CP lost from the rumen)
- Rumen N losses increase with rumen ammonia concentration

Effects of protein supplementation of grass silage based diets

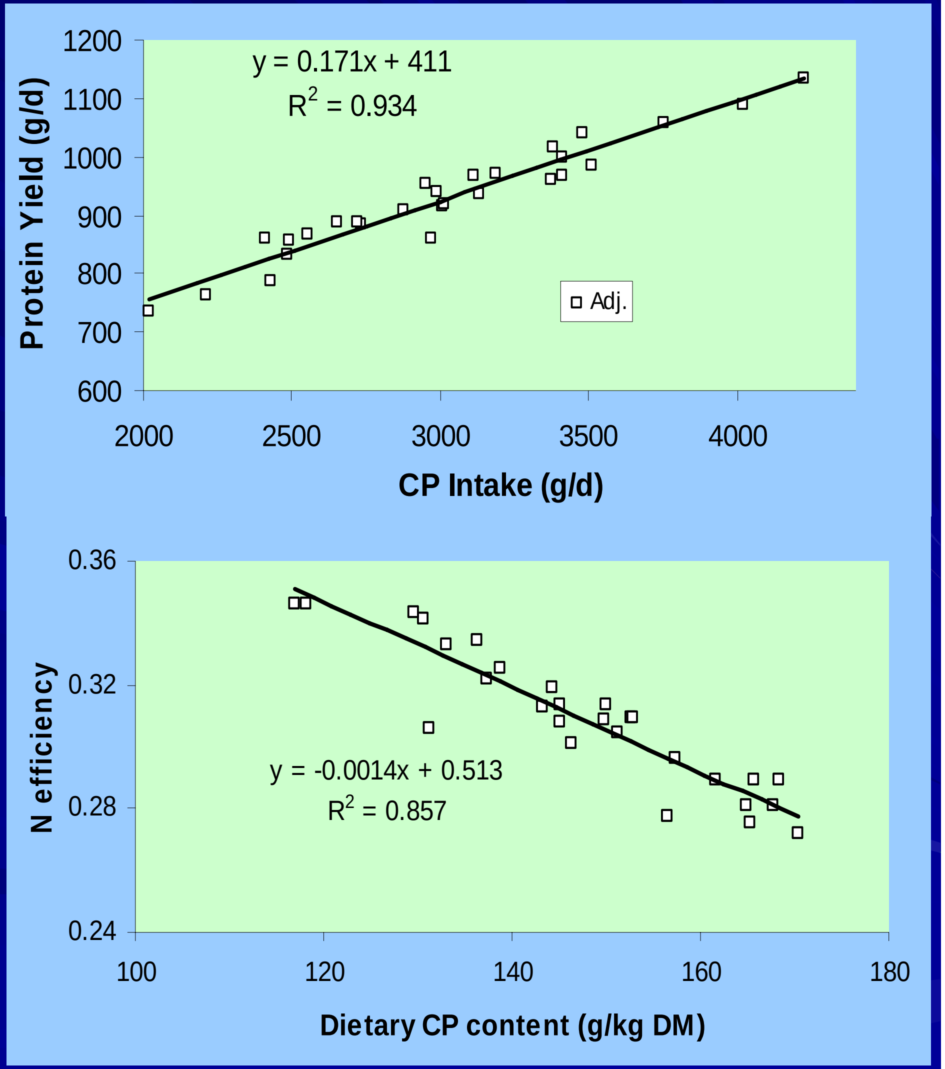
- Substantial production responses are obtained to supplementary protein, but:
  - Marginal responses have been relatively low (Fish meal 0.15, Rapeseed (Canola) 0.15, Soybean 0.12)
  - N efficiency (Milk N / N intake) always decreases
  - Nearly all incremental manure N excreted as urinary N
- Production economy and environment in conflict

Effects of increasing dietary CP concentration of grass silage based diets on protein yield and N efficiency



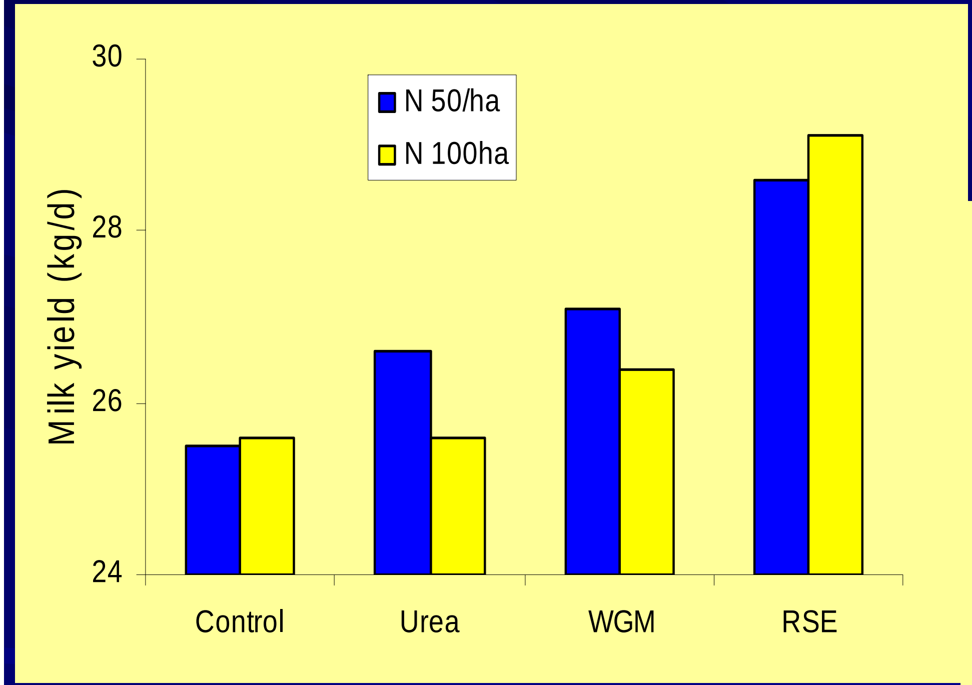
Effects of increased CP intake from earlier harvest to protein yield and N efficiency

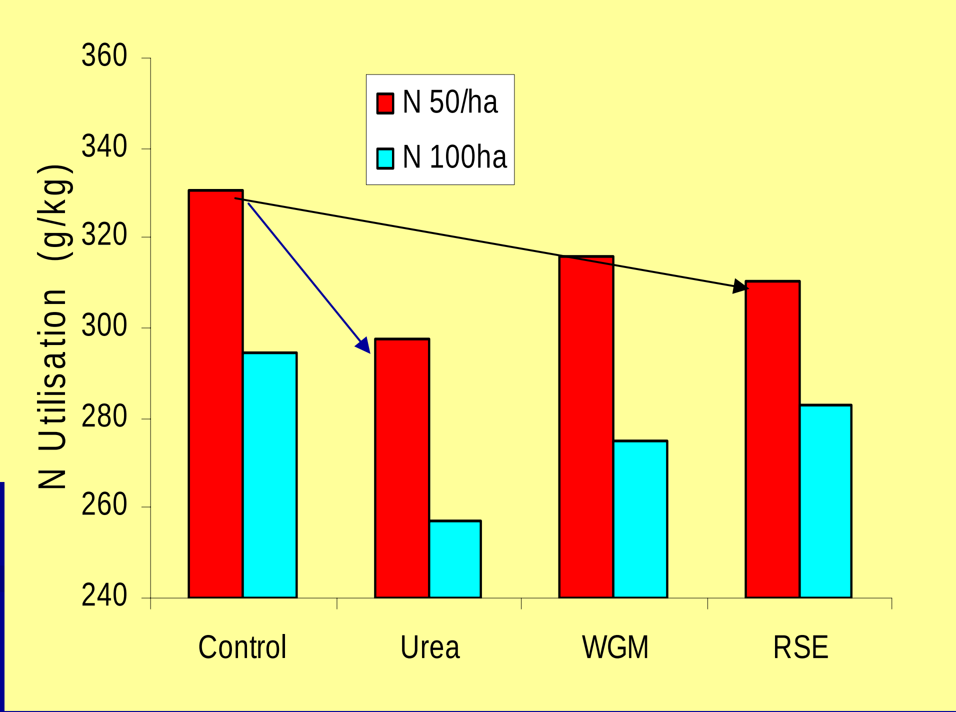
- Protein yield responses to earlier harvest of grass silage as good as with the best protein supplements
- Increased ME supply
  - Intake
  - Digestibility
- Provided grass not harvested too early



Data from Rinne et al. 1999; Kuoppala et al. 2005

Effect of protein supplementation on protein yield & N utilization



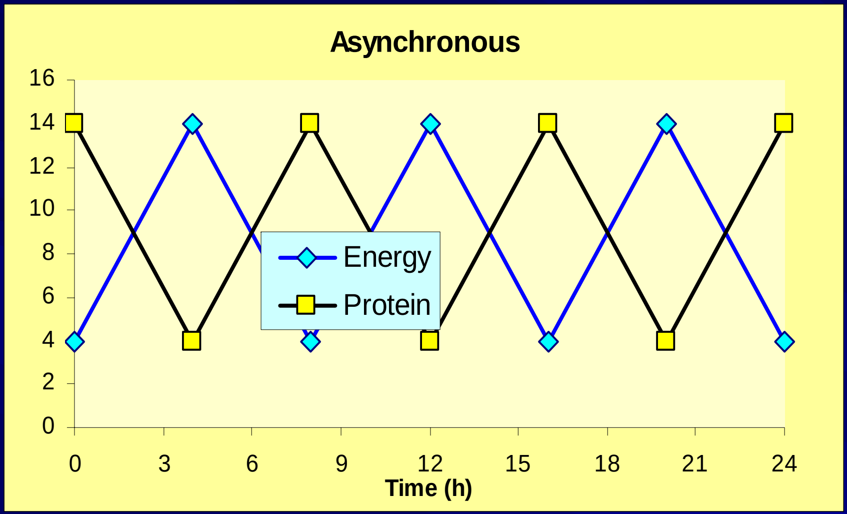


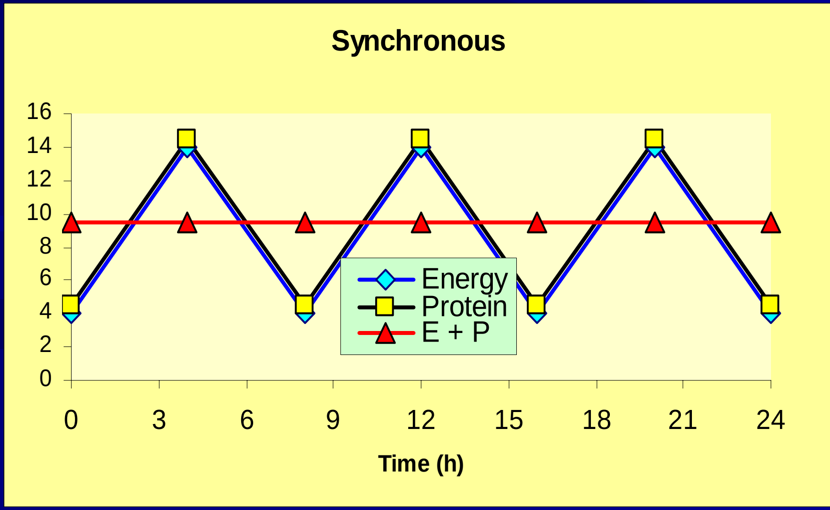
Shingfield et al. (2001)

Strategies to improve efficiency of N utilization

- Improve efficiency of microbial N synthesis
  - Ratio between RDN and fermentable energy
  - Synchronization of the rates of N and energy release
- Reduce extent of proteolysis in the silo and/or in the rumen
- Optimize energy and protein supplementation

Synchronization of energy and N release in the rumen





- Asynchronous release of energy and N from silage has been suggested as one reason for low efficiency of MPS
- The studies testing this hypothesis have often been confounded by dietary ingredients (nutrient supply)

Effect of synchronization of energy and N release on microbial synthesis in sheep (Henning et al. 1993)

	EP-NP	EP-NG	EG-NP	EG-NG
Exp1				
N intake (g/d)	14.2	13.9	14.3	14.6
NAN flow (g/d)	**13.8**	14.6	**18.2**	17.9
Microbial N (g/kg OMADR)	**15.0**	17.3	18.7	**20.3**
Exp2				
N intake (g/d)	20.3	21.8	20.6	20.6
NAN flow (g/d)	**24.5**	26.6	26.5	**27.5**
Microbial N (g/kg OMADR)	**22.1**	23.3	24.7	**29.7**

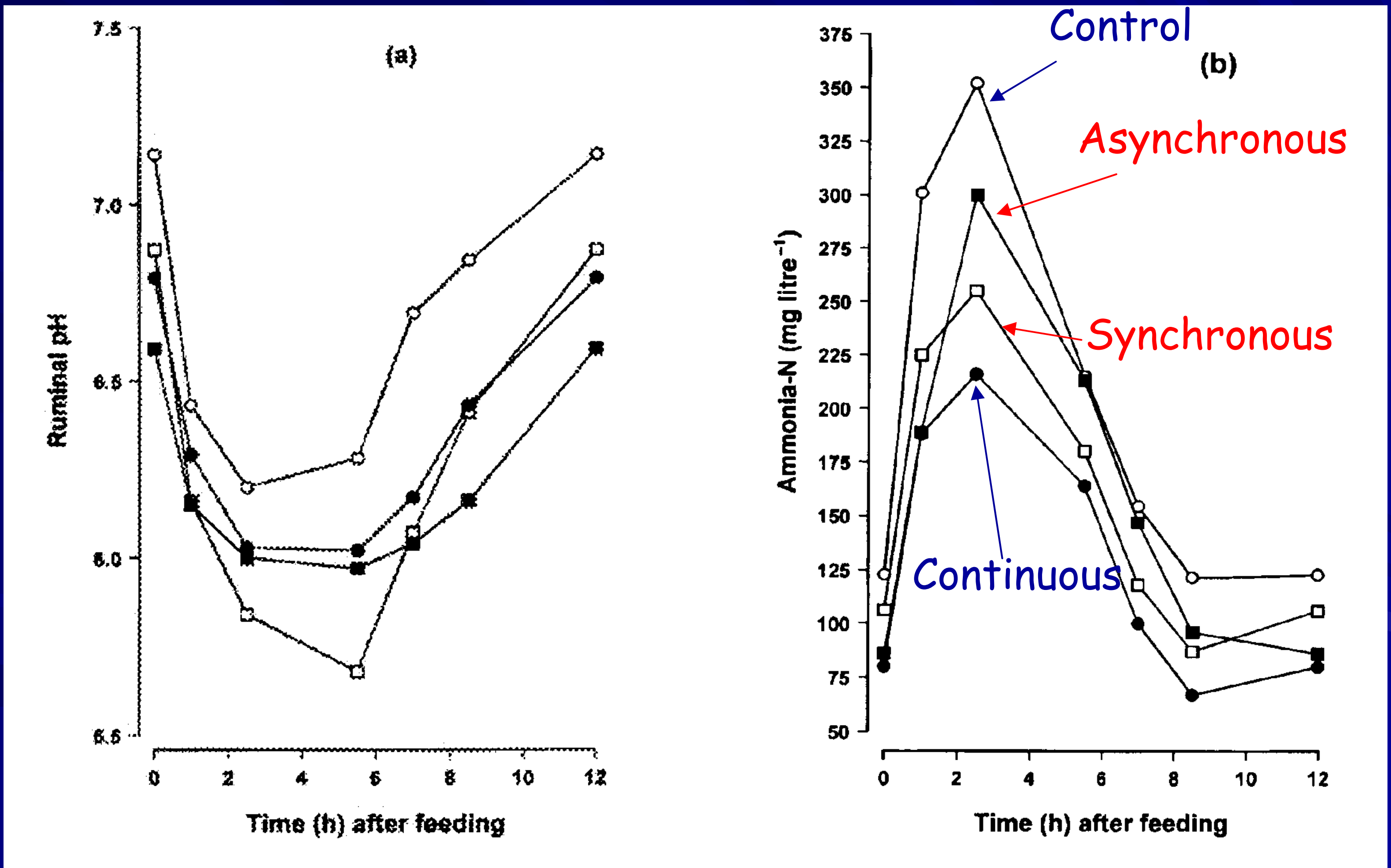
E = Energy, N = Nitrogen, P = Pulse dose 2 x day,
G = Continuous infusion

Effects of degree of synchrony of energy and N release on N metabolism (Kim et al., 1999)

	Control	Cont.	Synchr.	Asynchr.
Ammonia N (mg /L)	211	**136**	162	172
Urine N (g/d)	189	**129**	133	136
PD (mmol/d)	245	**281**	273	**241**
Microbial N (g/d)	173	204	197	**169**
Plasma urea N (mgL)	211	164	174	163

- Control diet grass silage + barley + groundnut meal (196 g CP/kg DM)
- Two kg of maltodextrin infused continuously (Cont.), 0-6 h (Synchr.) or 6-12 h after feeding (Asynchr.)

Effect of degree of synchrony of energy and N release on rumen pH and ammonia N (Kim et al., 1999)



Response to high moisture ear corn (HMEC) in cows fed alfalfa hay (AH) or silage (AS) (Vagnoni & Broderick, 1997)

HMEC, %	24		40		
Forage	AH	AS	AH	AS	Interaction
CP (g/kg DM)	170	173	162	164	
TDMI (kg/d)	22.8	21.9	24.2	23.5	
Protein (g/d)	960	900	1060	1070	0.09
N Efficiency	0.248	0.238	0.270	0.278	
Microbial CP (g/d)	1981	1925	2081	2262	0.02

- Increased HMEC increased protein yield (170 vs. 100) and microbial CP (337 vs. 100) on AS versus AH
- AS was more limited in AA supply
- Increased CHO markedly improved N efficiency

Response to fishmeal (FM) in cows fed alfalfa hay (AH) or silage (AS)

(Broderick, 1995; Vagnoni & Broderick, 1997)

Variable	AS	AH	AS+FM	AH+FM
Diet CP (g/kg DM)	168.5	153.8	185.5	170.8
DMI (kg/d)	23.0	24.7	23.8	24.7
Protein (g/d)	1093	1153	1193	1177
N efficiency	0.281	0.304	0.270	0.278

- Without FM, AH increased milk protein 70g/d
- Response to FM higher with AS than AH (100 vs. 24)
- High marginal response to supplementary protein with AS (0.185) suggests the diet was limited by AA supply

Effects of forage conservation method and proportion concentrate on rumen N metabolism in growing cattle

Forage	Silage			Hay		
Concentrate (g/kg DM)	250	500	750	250	500	750
CP (g/kg DM)	168	165	161	148	152	155
Rumen ammonia N (mmol/l)	13.9	12.8	12.0	11.3	11.7	12.0
N intake (g/d)	178	181	174	161	165	173
Duodenal flow (g/d)						
Non-ammonia N	142	152	150	132	146	150
Microbial N	77	89	85	64	76	79
Feed N	53	52	54	56	59	59
N degradability	0.71	0.72	0.68	0.65	0.65	0.65

(Jaakkola & Huhtanen, 1993)

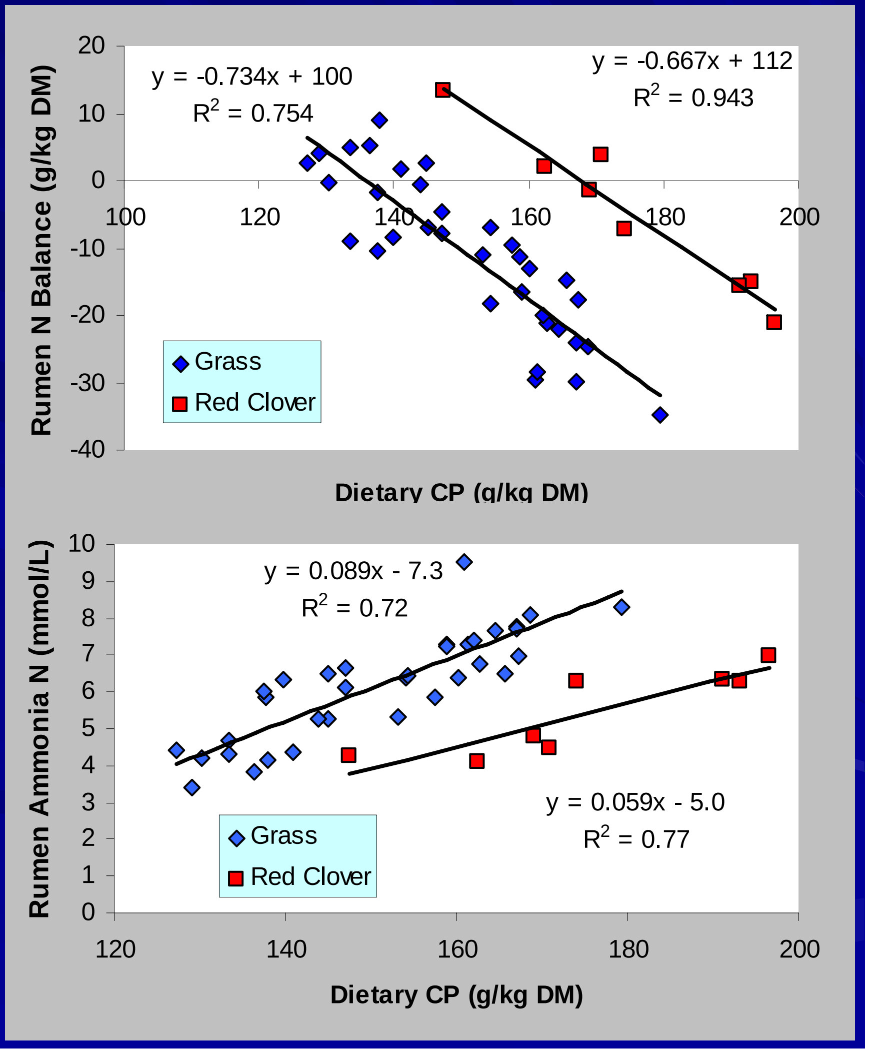
Reducing proteolysis

- NPN in red clover is markedly lower compared with grass or alfalfa silages
- Reduced proteolysis is associated with polyphenol oxidase (PPO) activity in red clover
- Comparisons of red clover vs. alfalfa and red clover vs. grass silages can be used as a model to describe potential benefits of reducing proteolysis

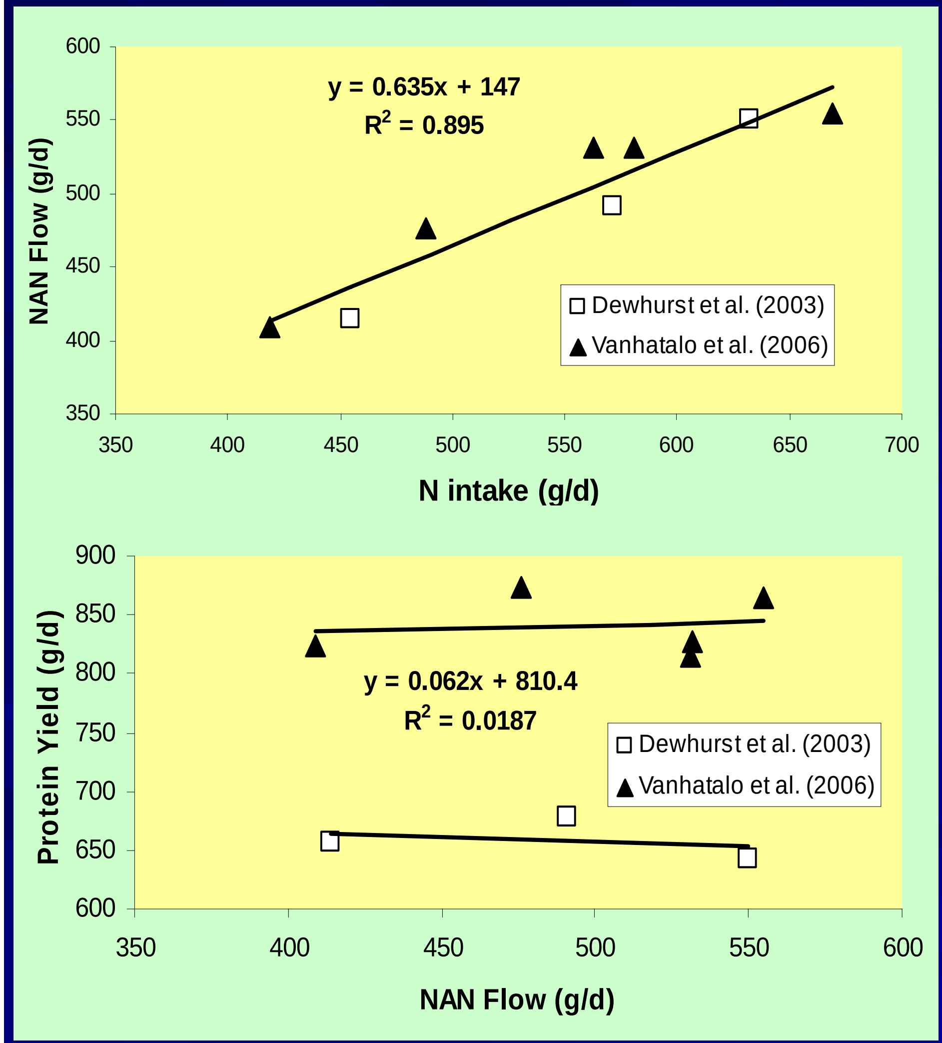
Efficiency of N utilization of red clover (RC) and grass silages in the rumen

(Data from MTT omasal sampling studies)

- N utilization in the rumen much better with RC than with grass silages (zero N balance at 136 vs. 168 g CP/kg DM)
- Lower rumen ammonia at same CP concentration
  - Reduced protein degradation
  - Improved microbial synthesis



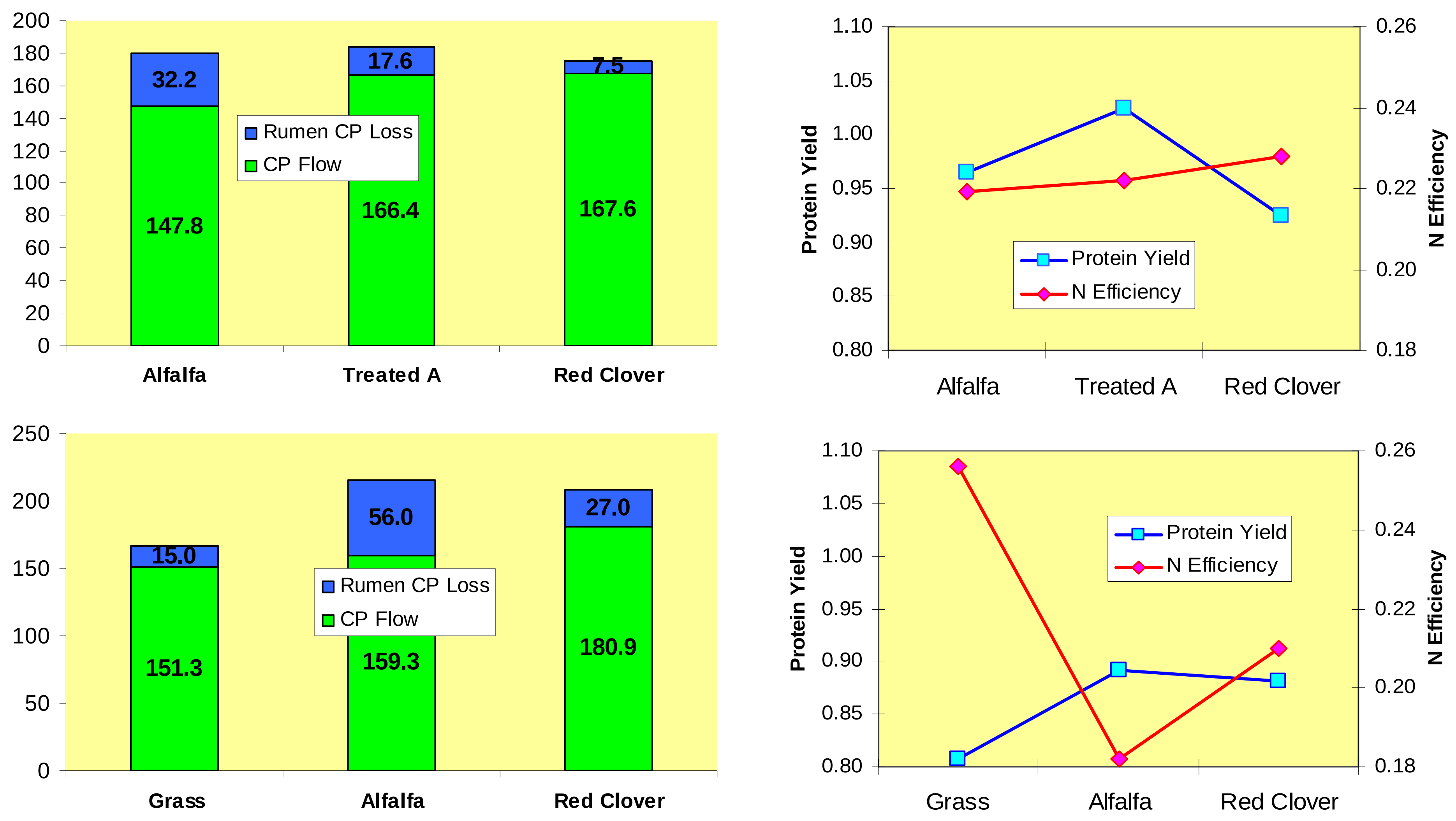
Effect of replacing grass silage with red clover silage on NAN flow and protein yield



- Increased N intake from gradual or total replacement of grass with RC increased NAN Flow
- BUT increased protein flow did not increase milk protein yield
- WHY?

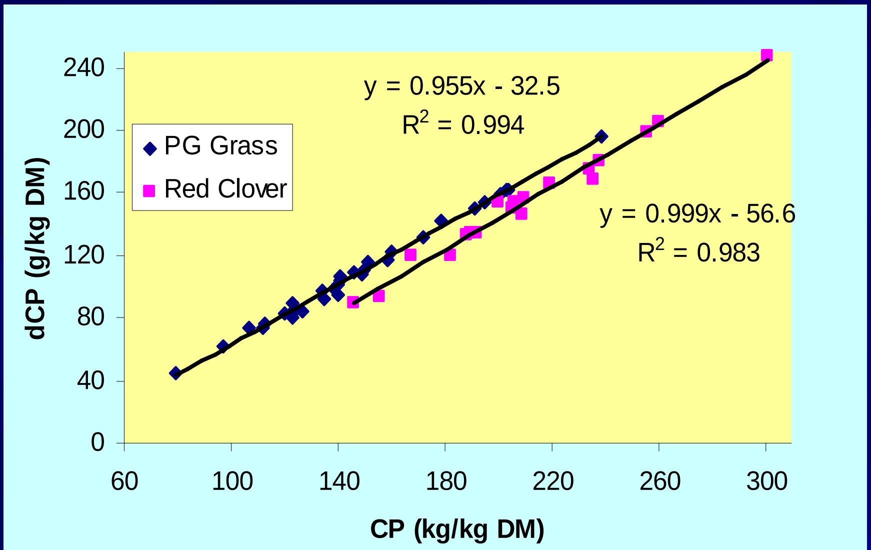
Effect of red clover versus alfalfa silages on rumen N efficiency and milk protein yield

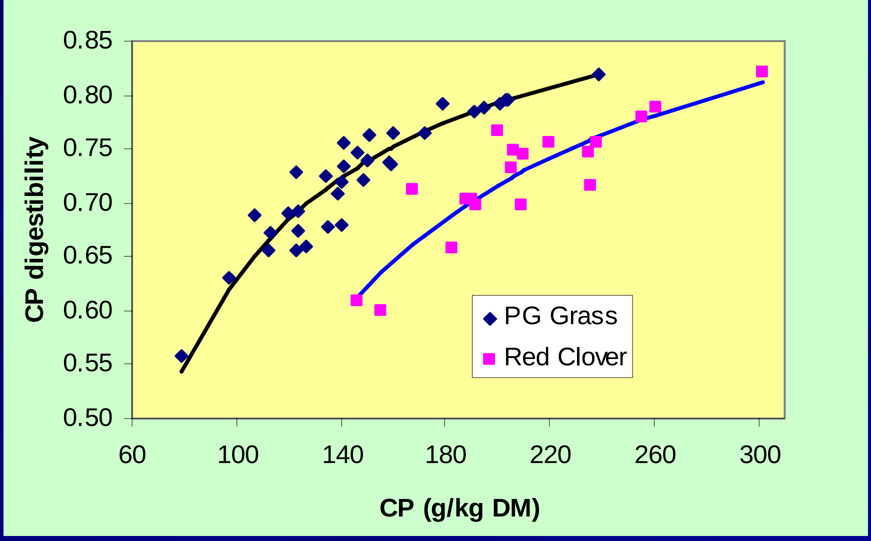
(data from Brito et el. 2006; Dewhurst et al., 2003)



Fecal CP higher for red clover (RC)

(data from MTT)





- Negative intercept in Lucas test higher for RC vs. primary growth grass
- Fecal CP per kg DMI 16 g higher for RC
- Apparent CP digestibility lower for RC
- Does PPO inhibit protein digestion in the small intestine???

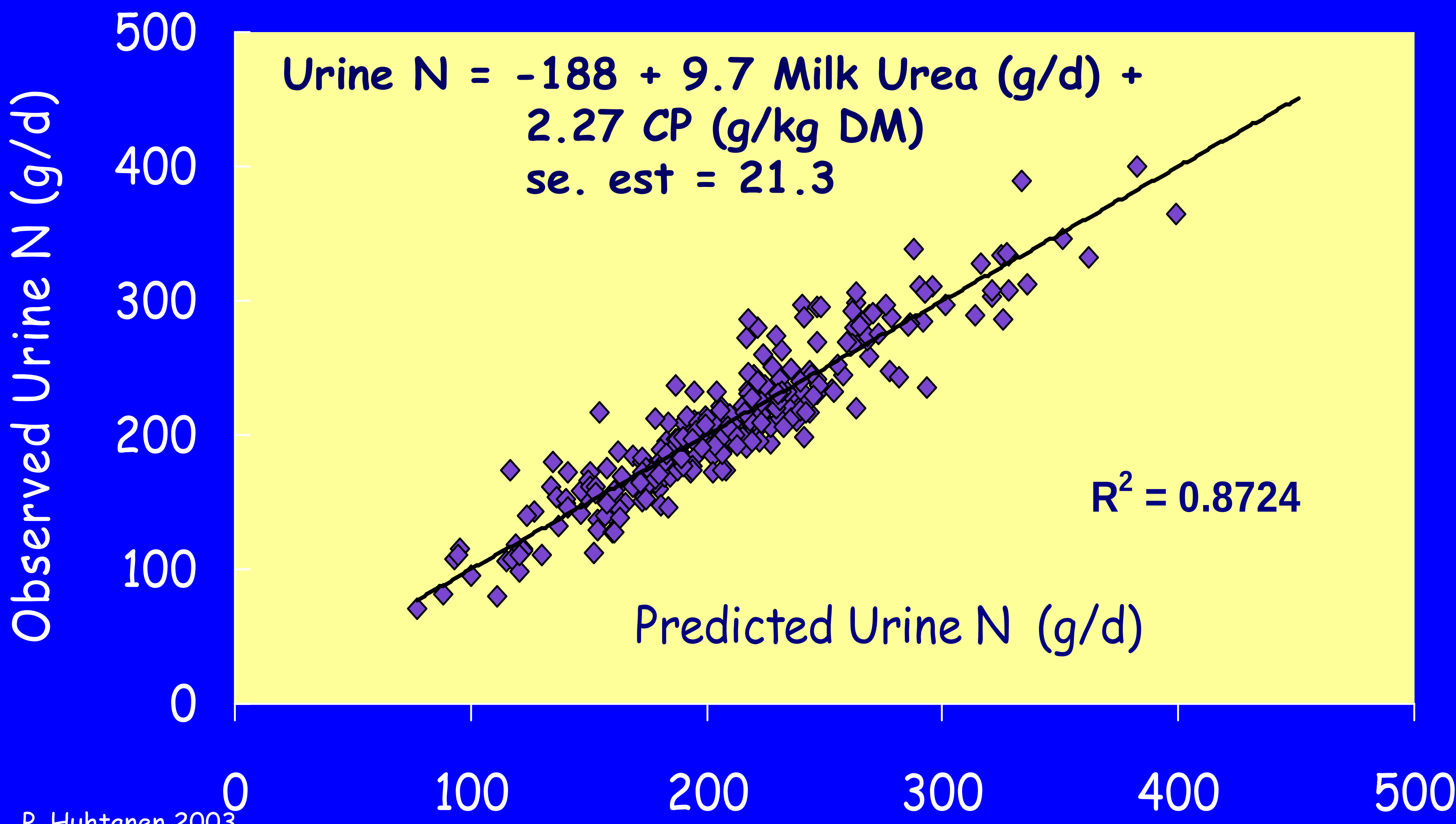
AA composition of forage RUP

- Forage protein is especially low in Met and His Compared to milk protein
- Met (+Lys) likely to be the first limiting AA on typical US dairy cow diets
- His is likely to be the first limiting AA on grass silage based diets
- Due to non-ideal AA composition of forage RUP, its utilization is likely to be lower than that protein supplements

Monitoring N efficiency on the farm

- Milk and plasma urea are closely correlated
- Milk urea concentration is closely associated with RDP excess and ammonia absorption from the rumen
- Tissue AA catabolism is another source of plasma and milk urea
- High milk urea concentrations are associated with excesses of RDP and MP

Prediction of urine N (Feed N – Fecal N – Milk N) from dietary CP concentration and milk urea output



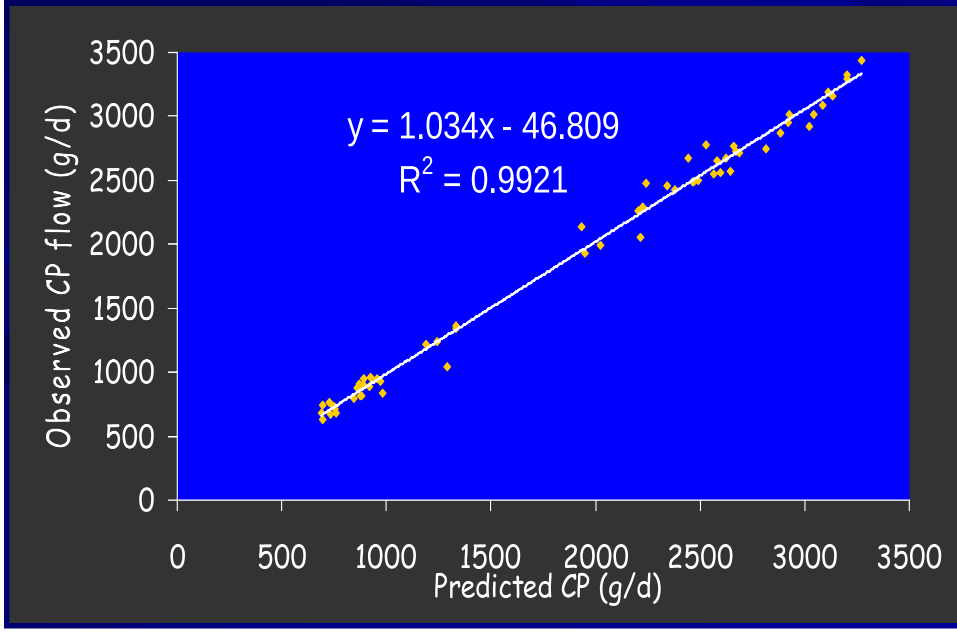
P. Huhtanen 2003

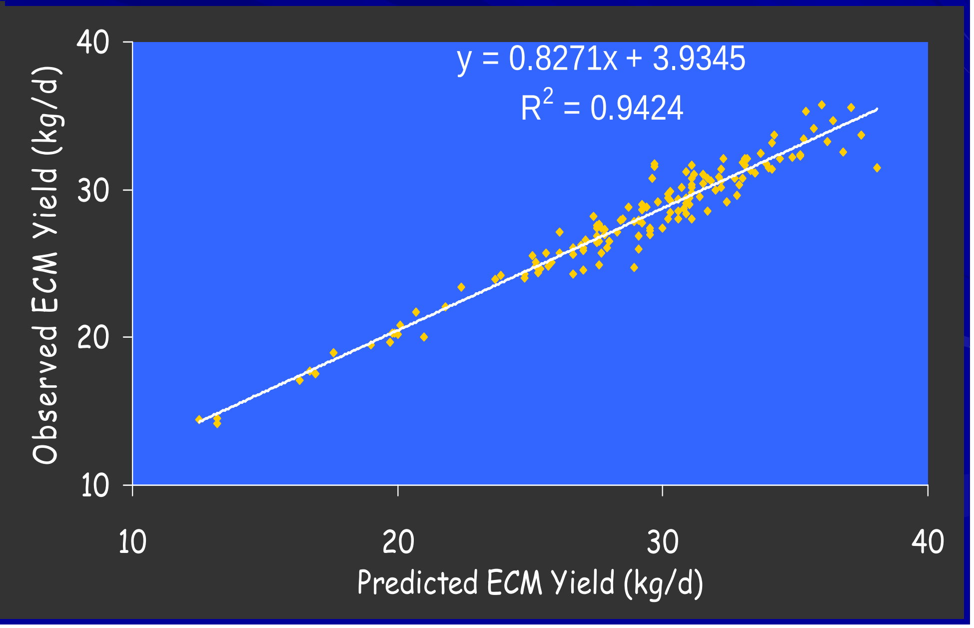
Modification of forage plants to improve N efficiency

- Increase microbial protein synthesis
  - Increase rate of dNDF digestion
  - Decrease concentration of iNDF
- Decrease RDP excess
  - Decrease CP concentration
  - Reduce NPN fraction (proteolysis)
  - Decrease rate of insoluble N degradation
- Decrease the rate of deamination of AA
  - Suppression of AA catabolizing microbes

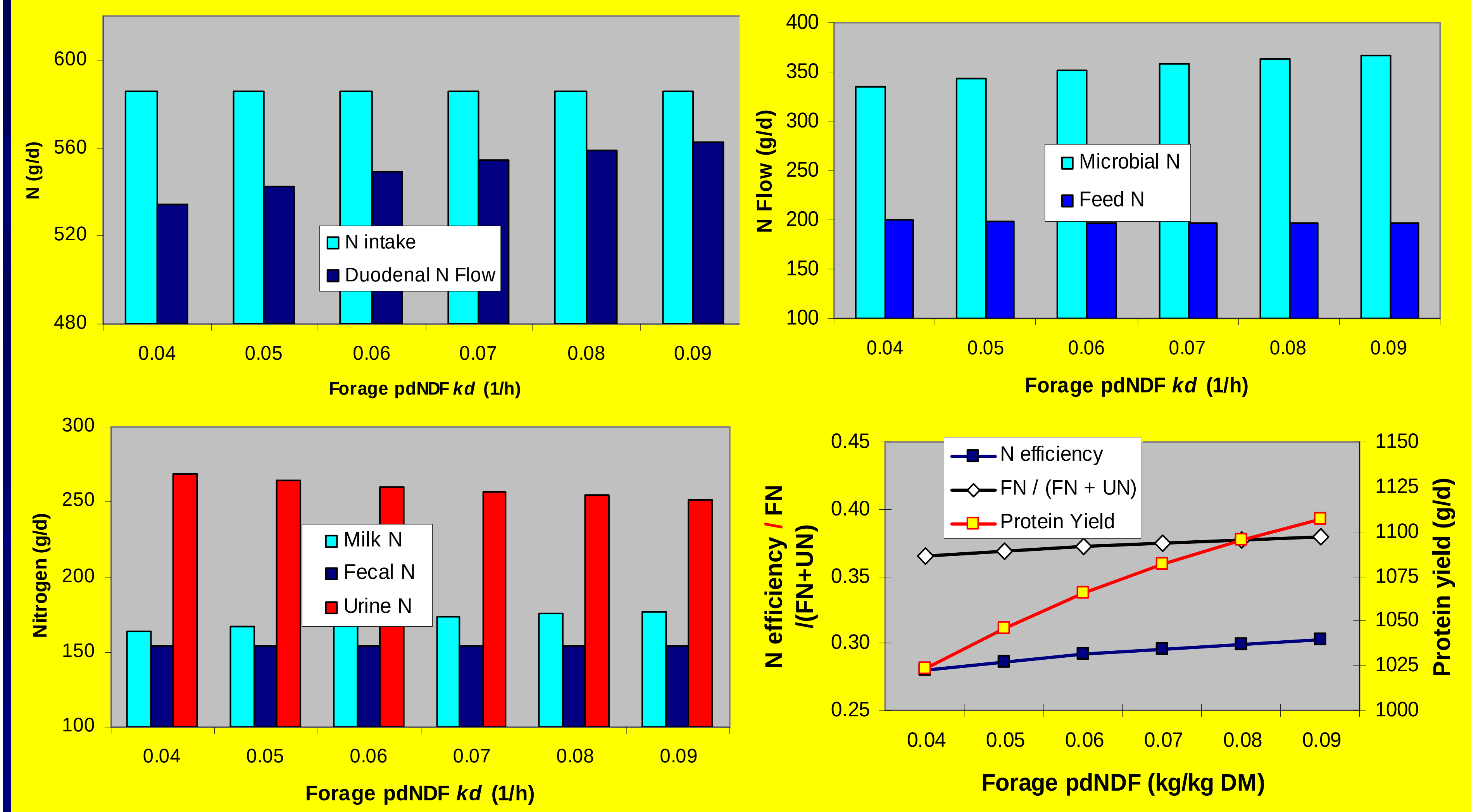
Model simulations

- Nordic Dairy Cow Model (Karoline)
- Dynamic mechanistic model (Danfær et al. 2006)
- Only one parameter changed; others constant
- Forage:Concentrate 55:45
- Concentrate CP 180 g/kg DM

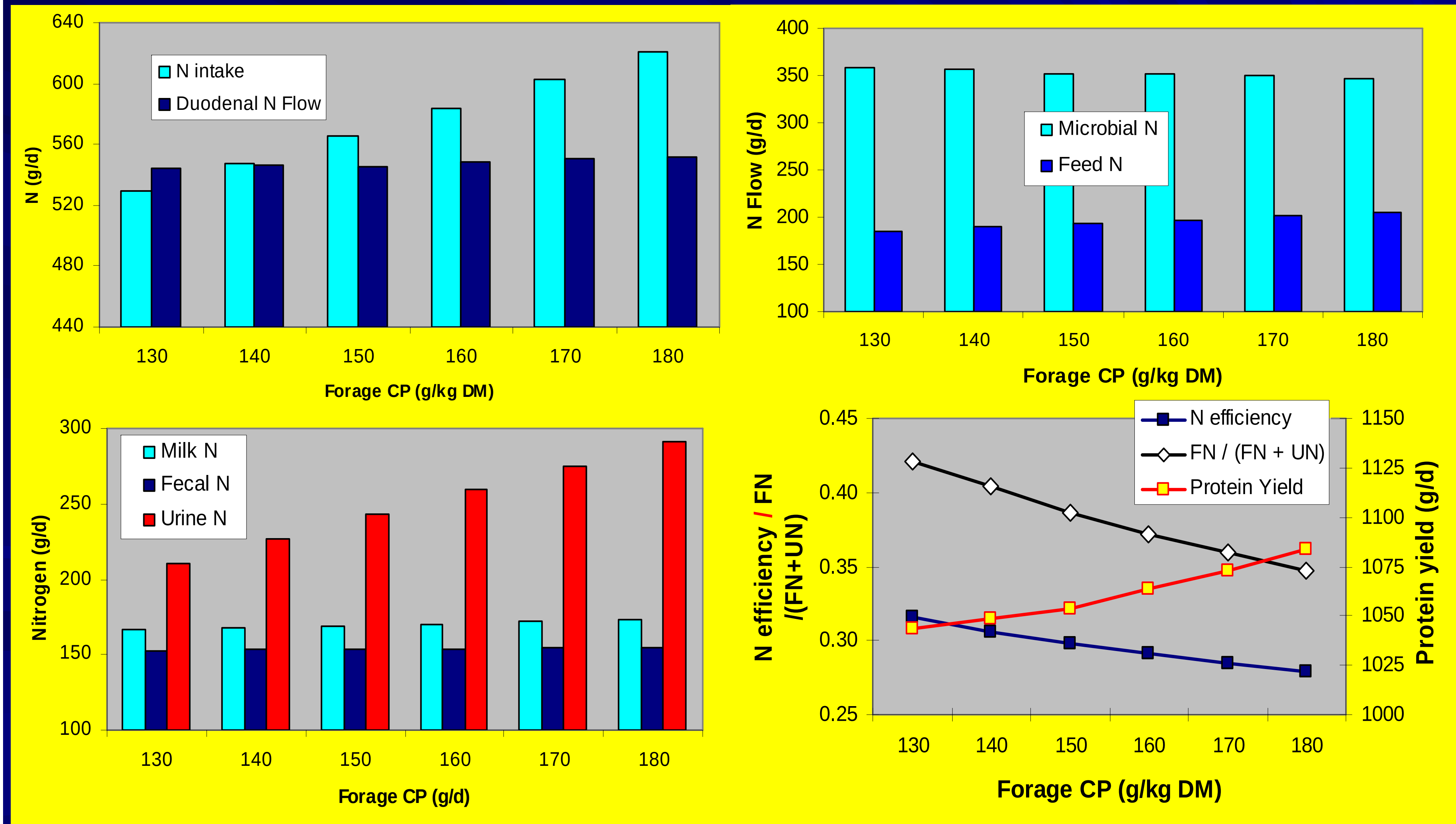




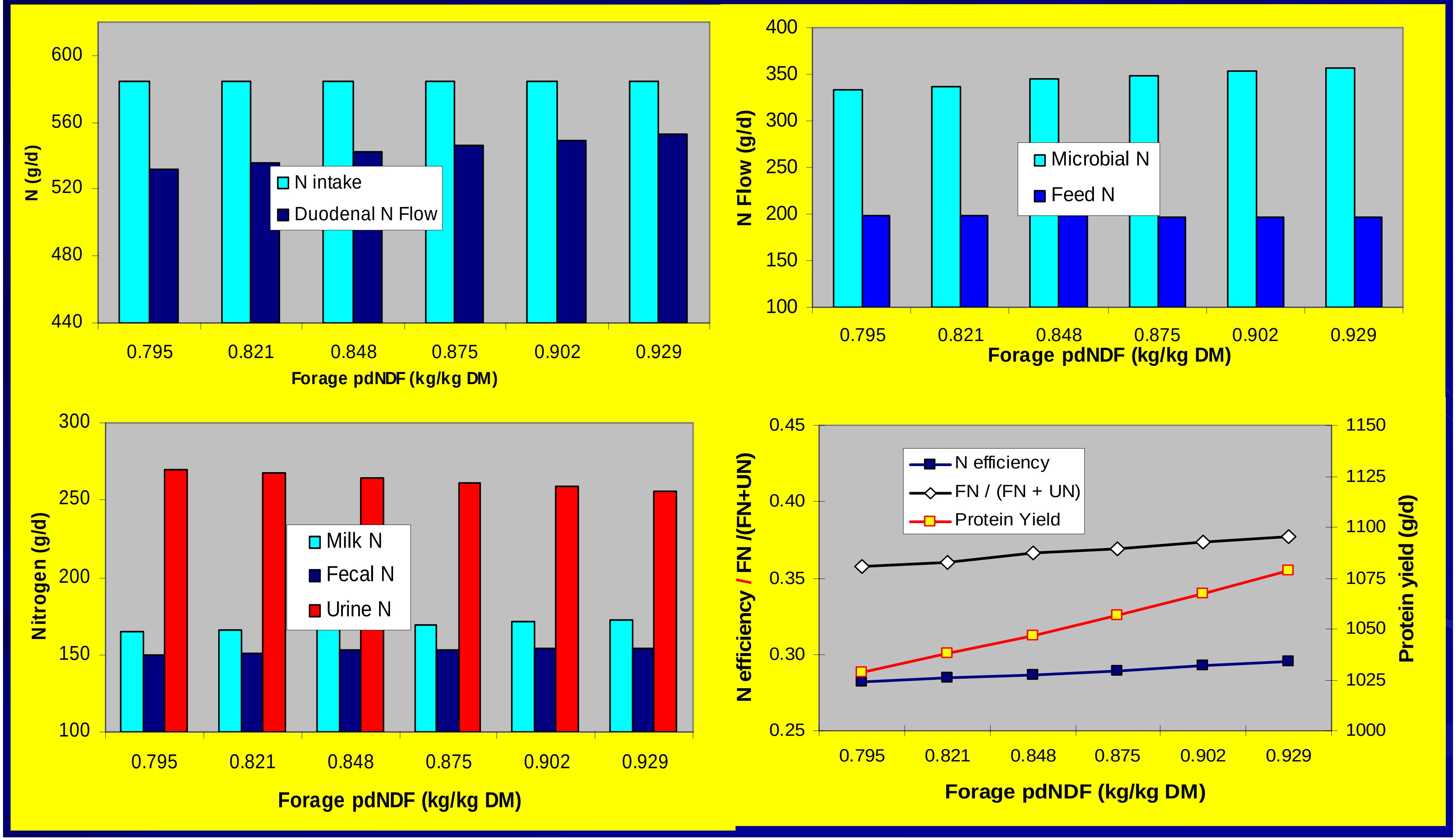
Simulated responses in N utilization to changes in rate of digestion of grass pdNDF (fixed intake)



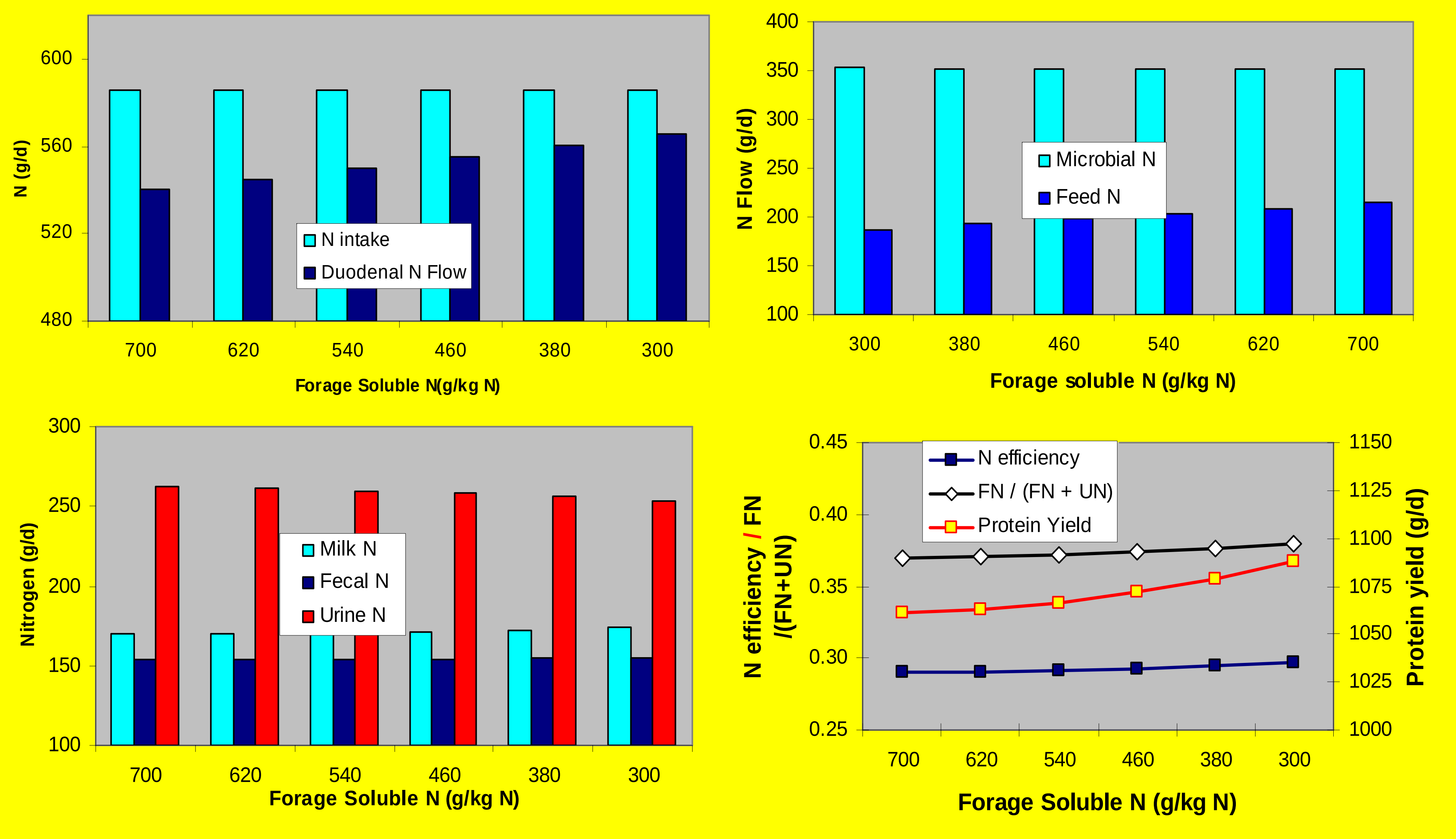
Simulated responses in N utilization to changes in CP concentration in grass



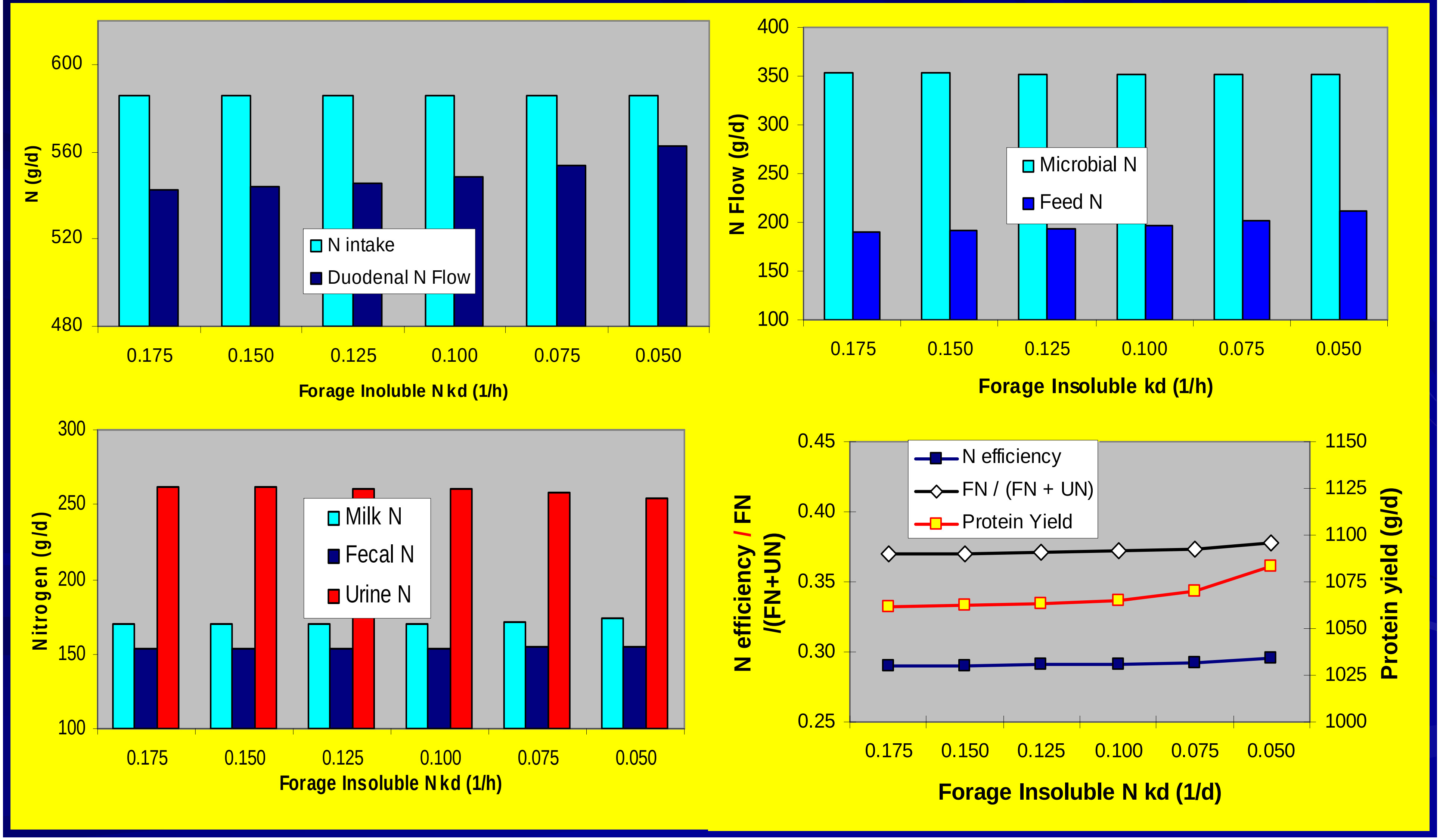
Simulated responses in N utilization to changes in pdNDF (fixed intake)



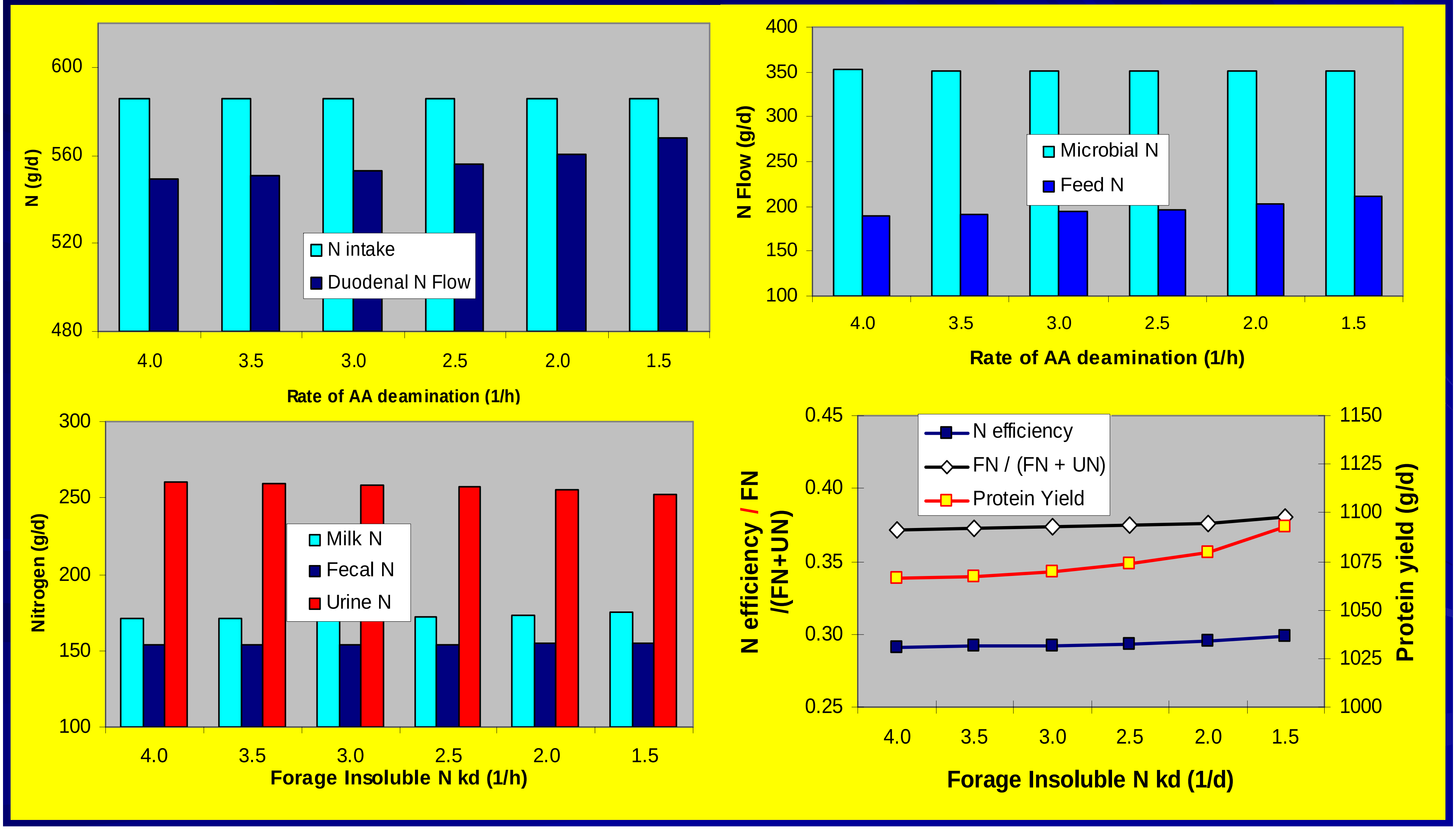
Simulated responses in N utilization to changes in soluble N in grass



Simulated responses in N utilization to changes in rate of degradation of insoluble N



Simulated responses in N utilization to changes in rate of AA deamination



Responses to increased MP partly related to increased ME supply

N	Intercept	ME (MJ/d)	MP (g/d)	RMSE	Adj R2
364	199		0.378	25.1	0.939
364	94	1.29	0.287	24.3	0.947
37	228		0.349	30.6	0.944
37	53	2.09	0.216	26.1	0.957

- When ME intake was in the model, marginal response to ME decreased both in data from production trials (n=364) and omasal flow studies (n=37)
- MP (g) = NAN * 0.80 * 0.85; ME = 16 * DOM (kg)

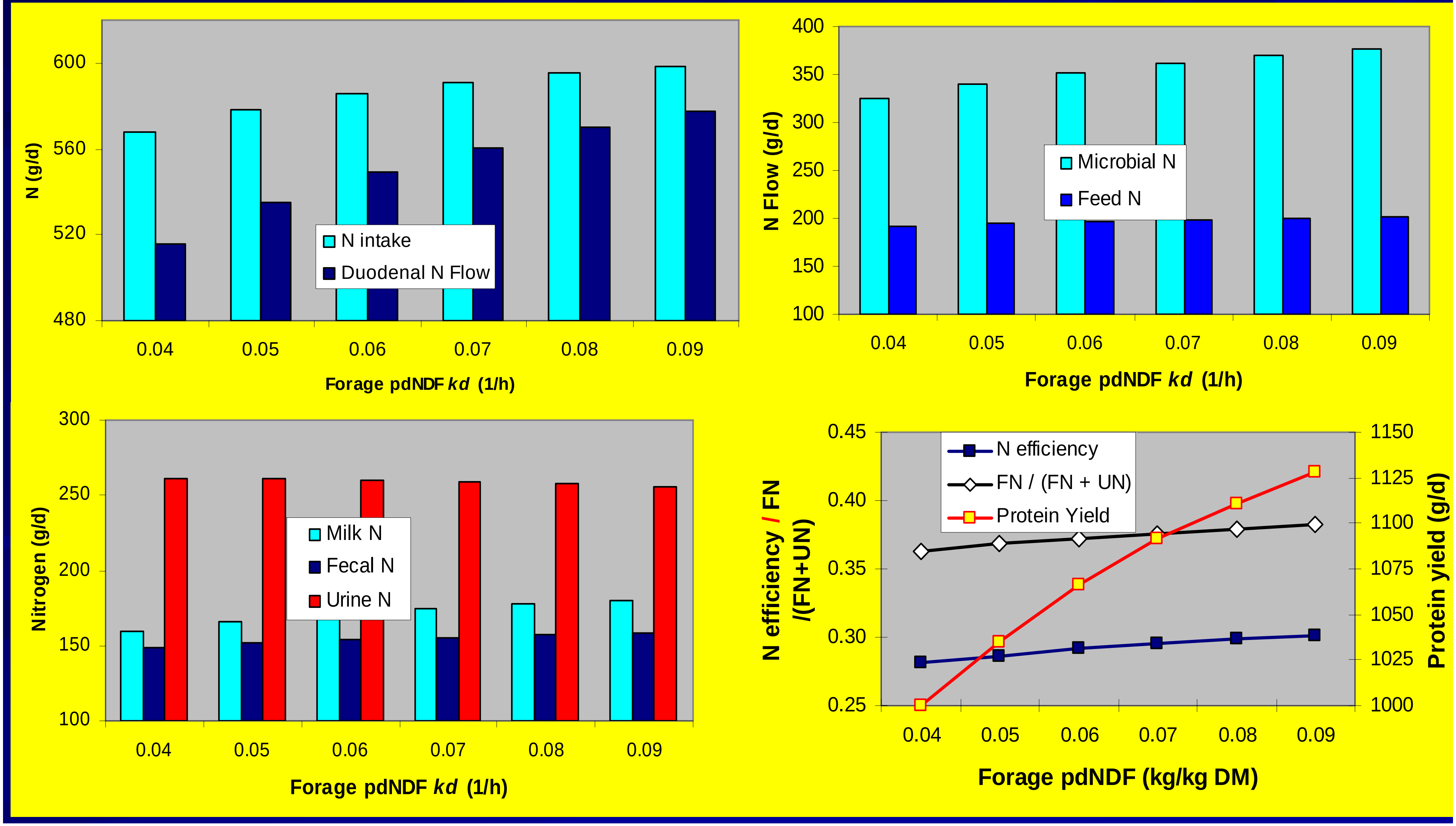
Conclusions (1)

- Meeting ME requirements of high producing dairy cows without overfeeding RDP is a challenge
- N fertilization of grass should be optimized on the basis of plant requirements
- Good ensiling management required to avoid unnecessary proteolysis and losses of WSC

Conclusions (2)

- Red clover improves N utilization in the rumen compared to both grass and alfalfa but overall protein utilization has been poor
- Modifying forages for improved N utilization:
  - Improve digestibility (less iNDF, faster kd for dNDF)
  - Reduce CP concentration
  - Reduce proteolysis in the silo (less NPN) and rate of degradation of insoluble protein

Simulated responses in N utilization to changes in rate of digestion of grass pdNDF (ad libitum intake)



Simulated responses in N utilization to changes in pdNDF (ad libitum intake)