The control of voluntary feed intake and diet selection in cattle with particular reference to nitrogen

J Michael Forbes
Institute of Integrative and Comparative Biology
University of Leeds, UK
j.m.forbes@leeds.ac.uk

Innovative and practical management approaches to reduce nitrogen excretion by ruminants

Part One

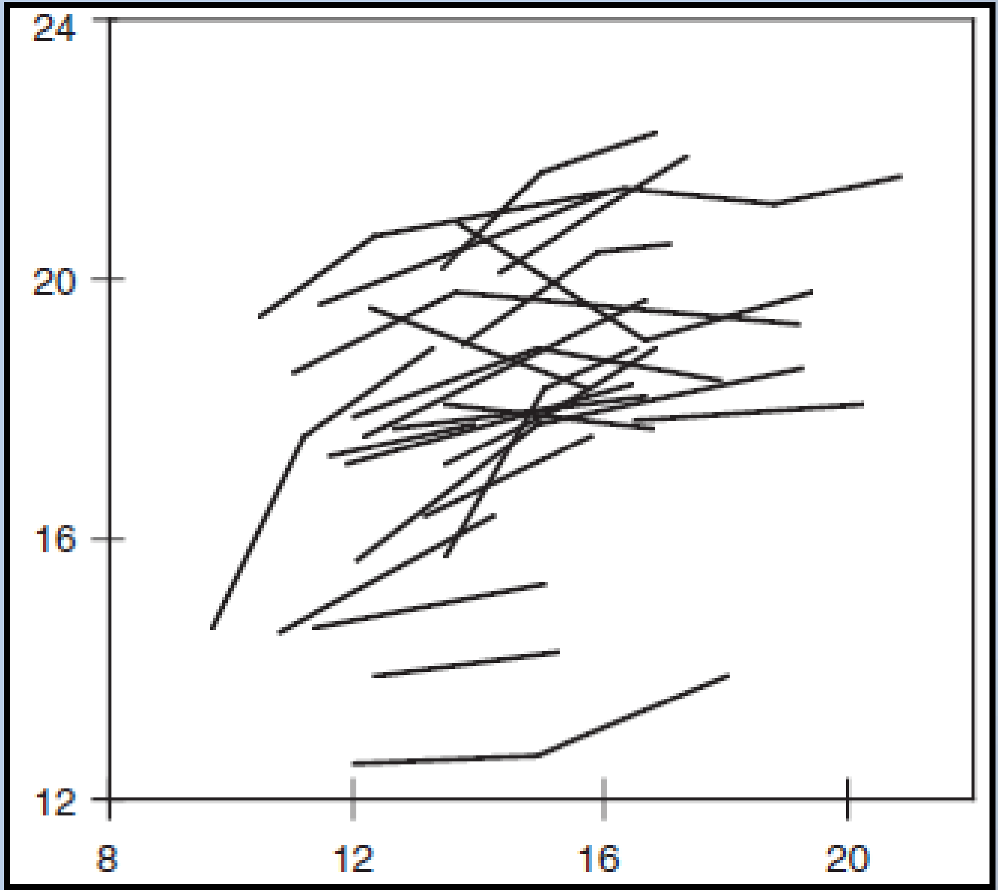
The facts

acknowledgements to Faverdin et al , INRA, Rennes

INRA Prod. Anim., 2003, 16 (1), 27-37

Overall effect of N content of diet on intake by lactating cows

DM intake (kg/day)



Dietary nitrogen x 6.25 / kg DM

Summary of the literature
(Jarige et al, 1983)

A - Rumen

- Nitrogen is necessary for functioning of the rumen microbial system
- Comes from dietary protein and NPN
  - and from recycled urea in saliva
- Lack of N in rumen depresses microbial metabolism:
  - reduced protein synthesis and supply to hind gut
  - reduced fermentation and fibre digestion so bulk effects
- Low N status of rumen depresses intake

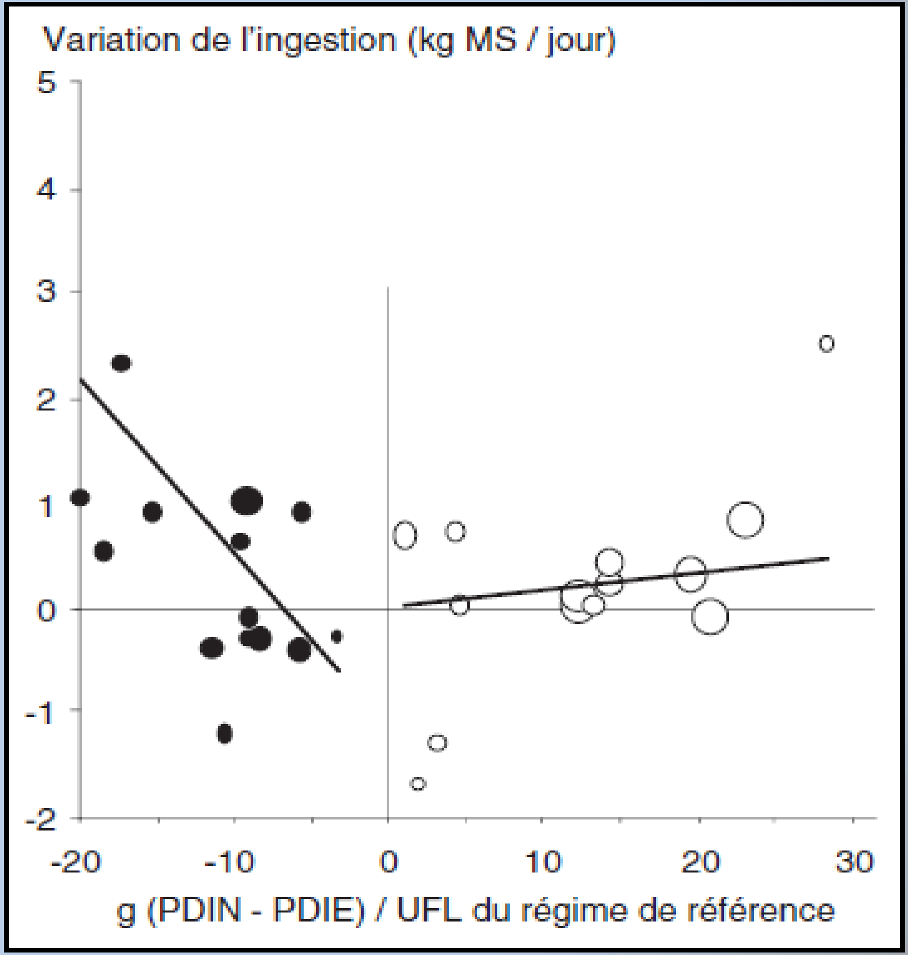
Addition of urea to maize silage-based diet (Journet et al 1983)

	Control	With urea
Intake (kg DM/day)		
urea	-	0.21
maize silage	11.7	13.8*
total DM	15.7	18.0
Production		
milk, 4% (kg/day)	26.1	30.8*
Maximal body weight loss (kg)	65.6	51.8

Supplementation with rumen degradable nitrogen

Intake responses to supplementation with rumen-degradable nitrogen without increasing the protein supply (Rico-Gomez et Faverdin 2001, from the literature).

Open circles are treatments initially sufficient in degradable N; closed circles are initially deficient; size of circle is inversely proportional to the statistical variability of the response.



B - Protein and amino acid supply

- Protein deficiency in animal depresses intake
  - Good evidence for this
- Lack or imbalance of amino acids depresses animal metabolism, reduces intake
  - Evidence for this is limited in ruminants
- Excess protein – deamination uses energy and produces heat

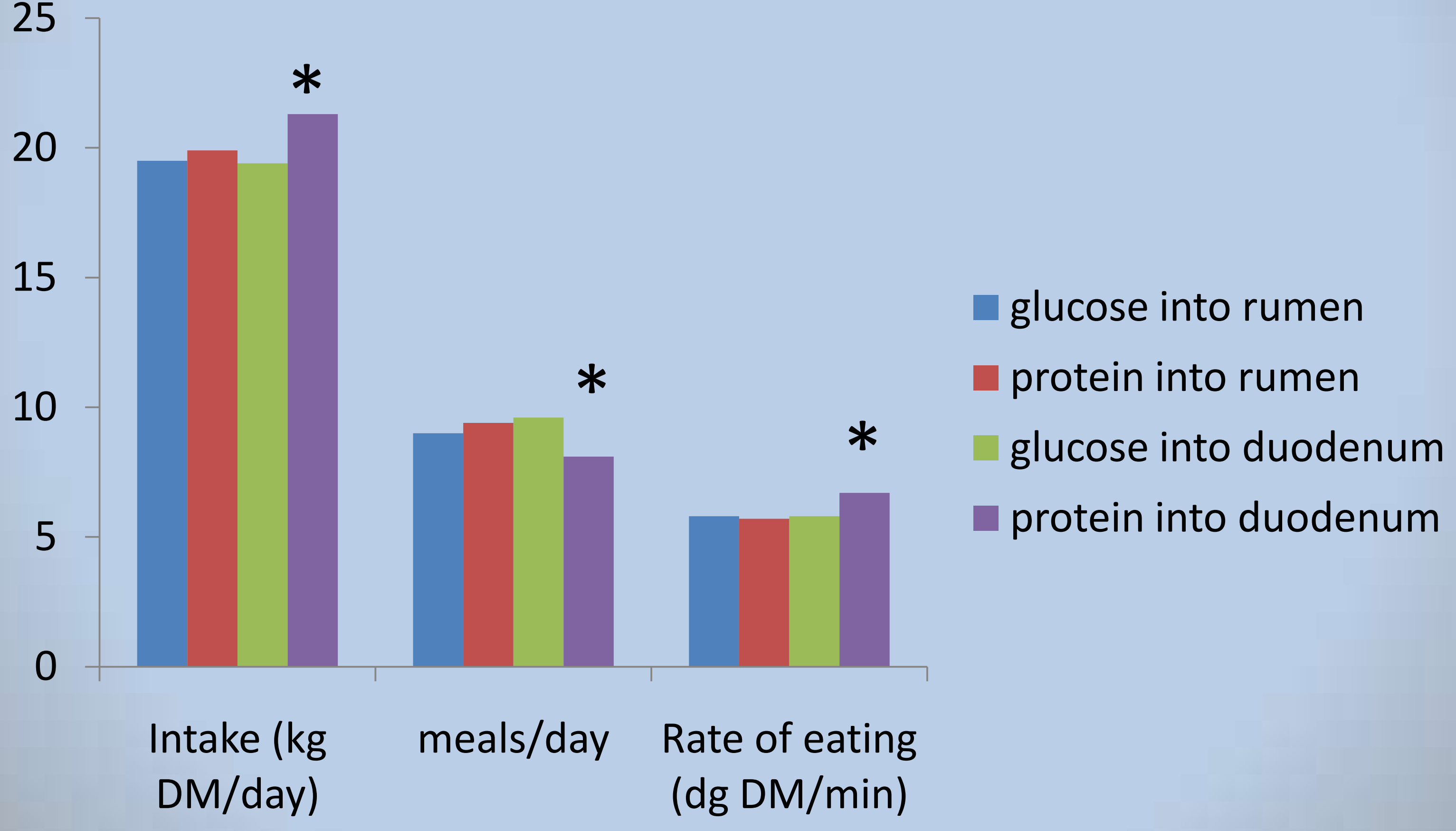
Duodenal infusions into N-depleted sheep

- **(Egan, 1965)**

	Increase in intake (%)	
	day 1	day 2
Control	*-16*	-1
Propionate	-6	+27
Casein	+115**	+74
Urea	+49	+142

Duodenal soya protein infusion

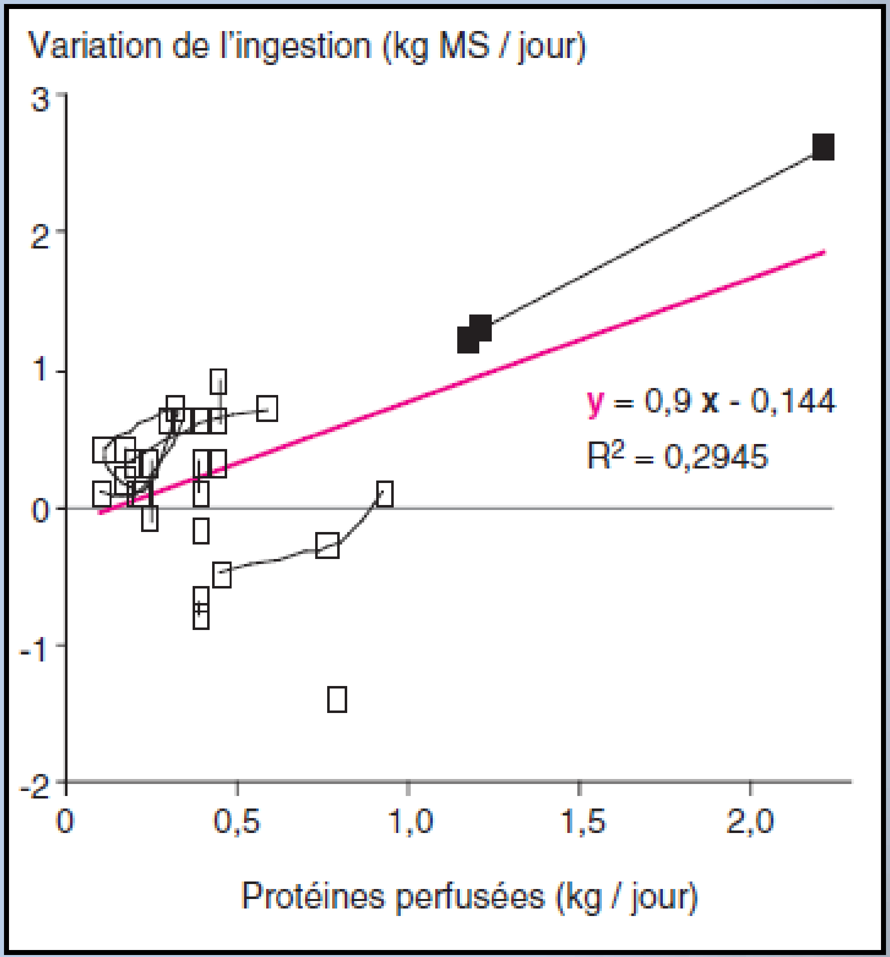
- *Lactating cows (Faverdin* et al *2002)*



Post-ruminal protein infusion

Forage intake responses to post-ruminal (abomasum or duodenum) infusion of protein in lactating cows (M’Hamed 2001, from the literature).

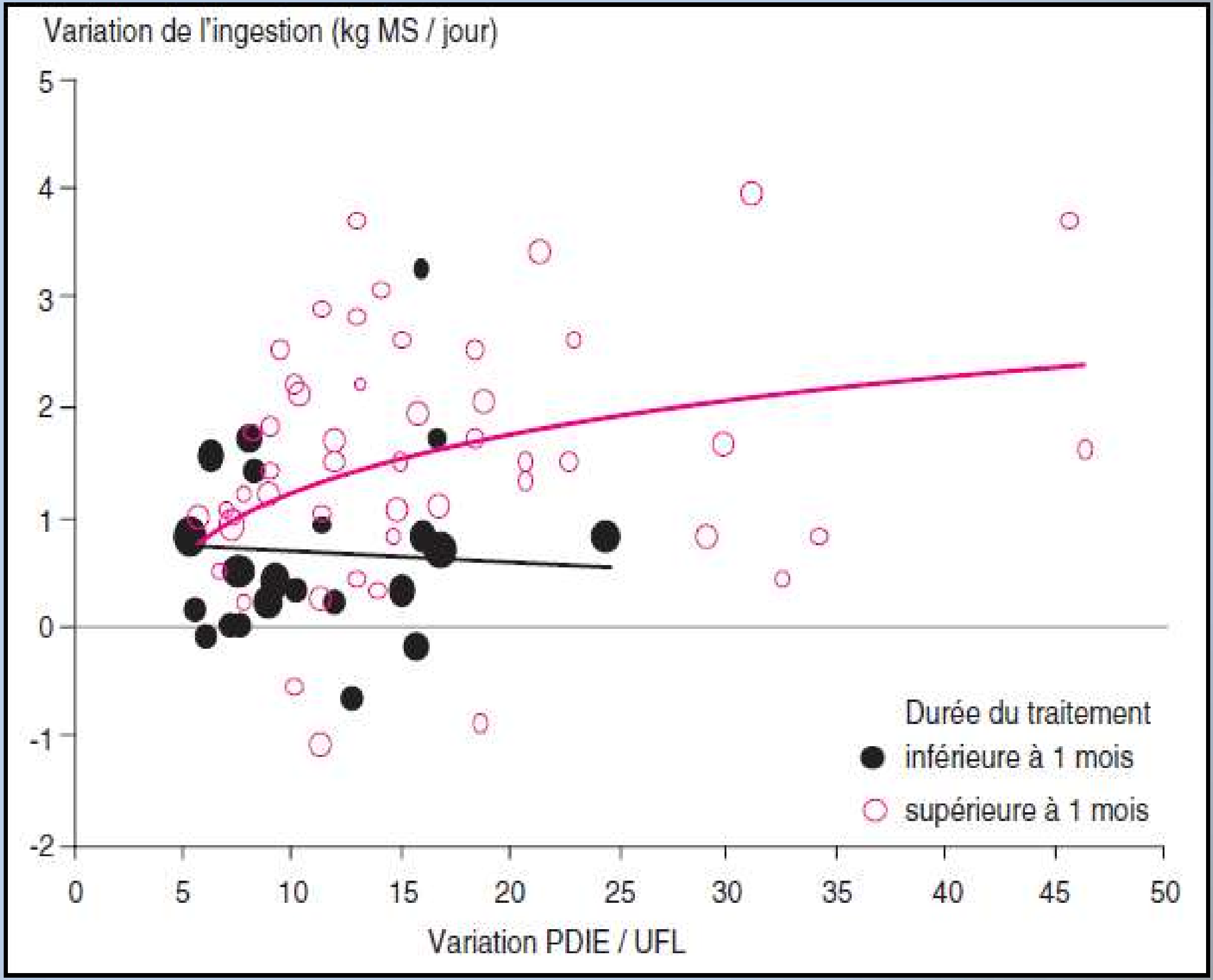
Open symbols are treatments of less than two weeks; closed symbols are treatments of more than four weeks



Increasing supply of PDIE

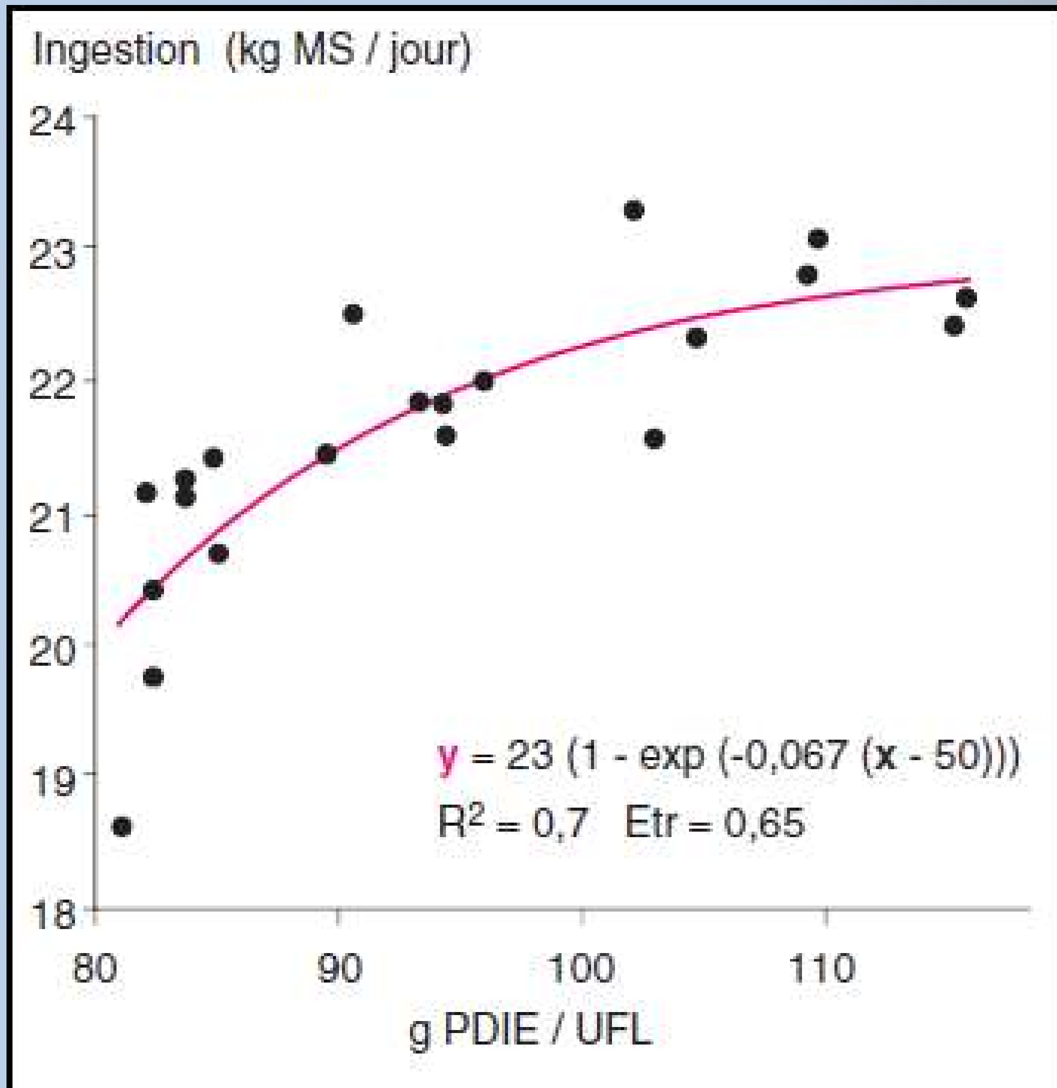
Intake responses to increasing the dietary supply of PDIE without reducing the supply of PDIN (Rico-Gomez et Faverdin 2001, from the literature).

Open symbols represent treatments lasting less than one month; closed circles are more than one month ; size of circle is inversely proportional to the statistical variability of the response.



Protein:energy balance

Intake responses to PDIE:UFL ratio (Vérité et Delaby 1998, synthesis of many INRA experiments using milk production as covariate).



Statistical analysis

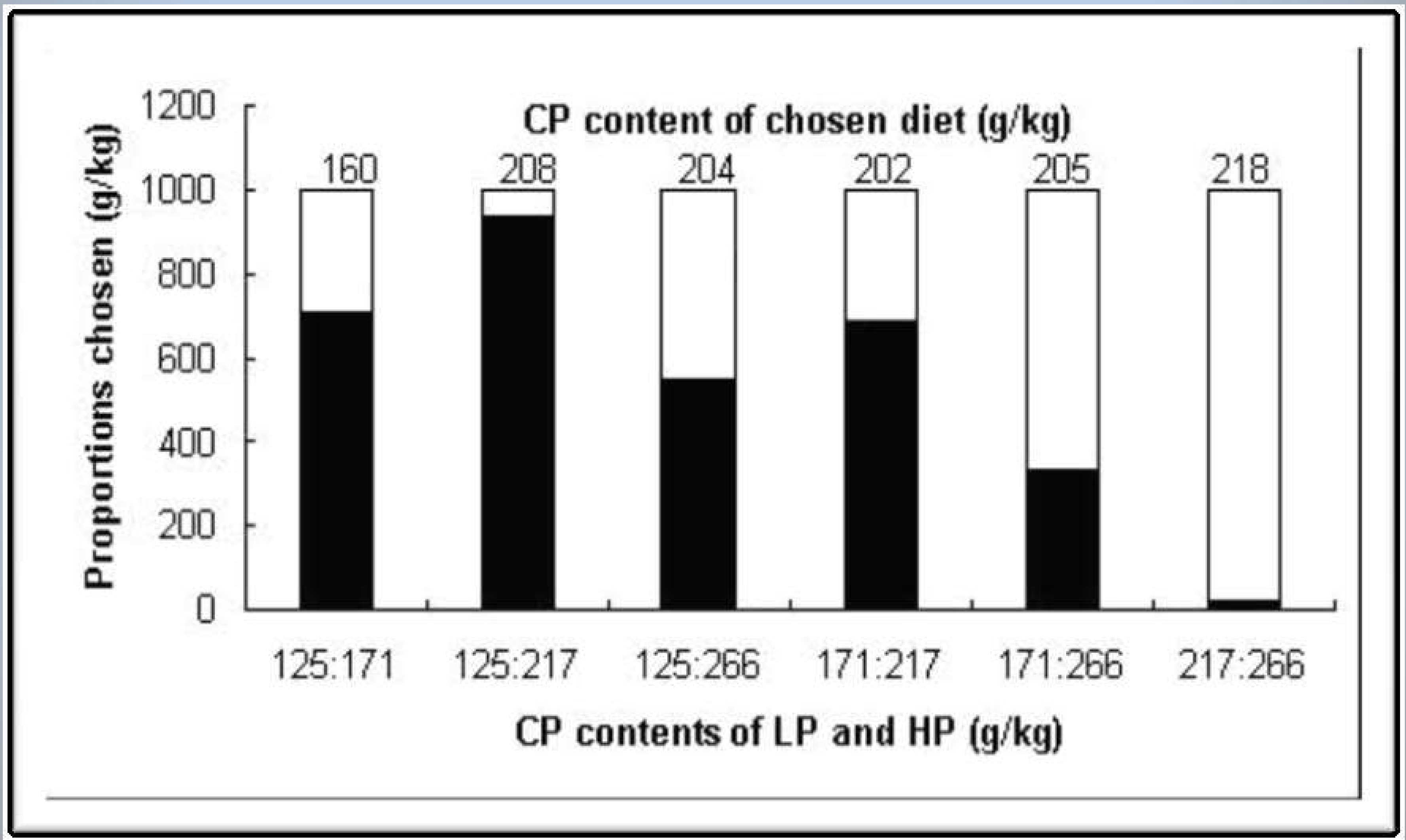
- DM intake (kg/day) = 5.77
- + 0.23 (PDIE/UFL)
- – 0,00094 $(PDIE/UFL)^2$
- + 0.033 ((PDIN-PDIE)/UFL)
- –0.00042 $((PDIN-PDIE)/UFL)^2$
- R^2 = 0.32; Syx = 0,78
- (M'Hamed, 2001)
-

C - Diet selection for protein or N

- Many animals can make nutritionally-wise selection between foods
- They learn to associate the sensory properties of each food (appearance, smell, taste, texture) with the metabolic consequences of eating the food

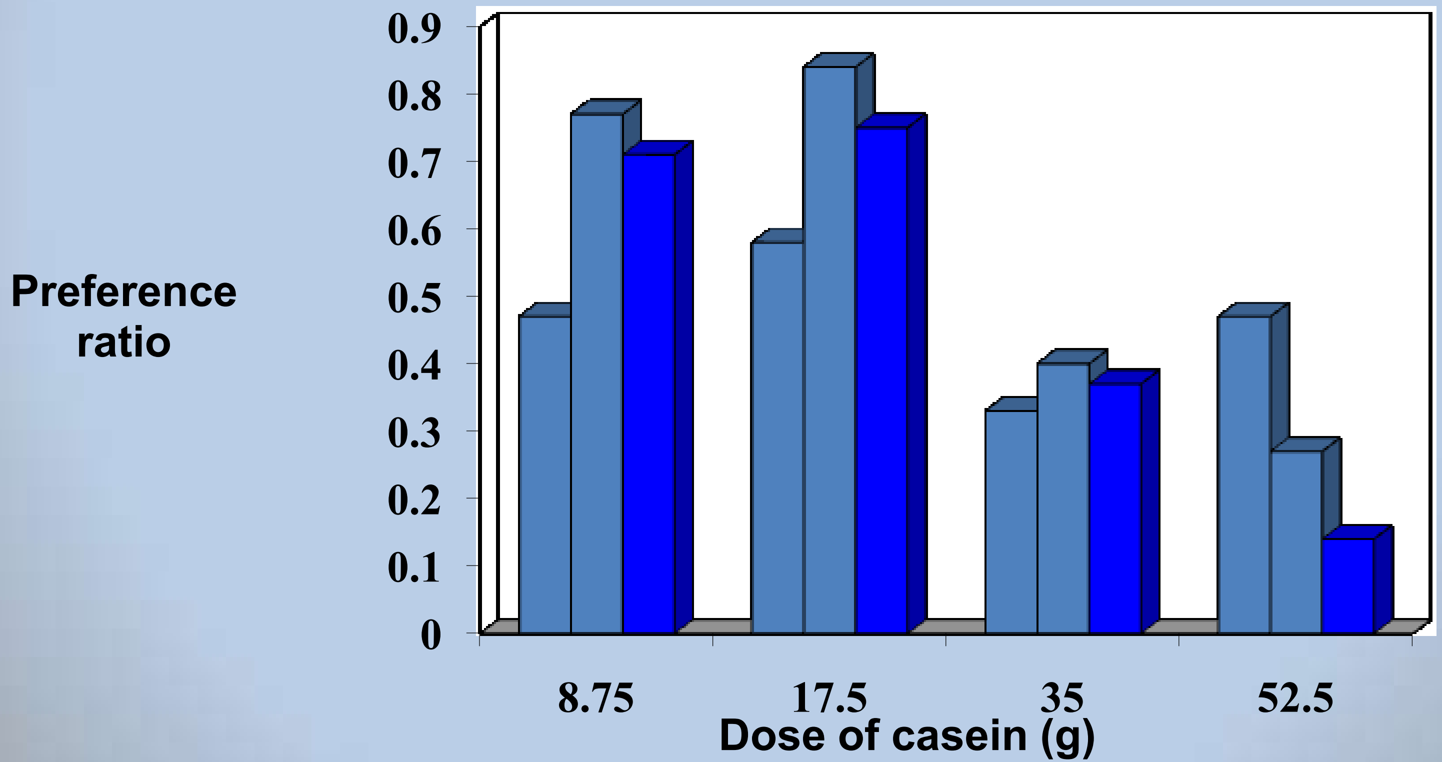
An appetite for protein?

Growing pigs; Kyriazakis et al, 1991

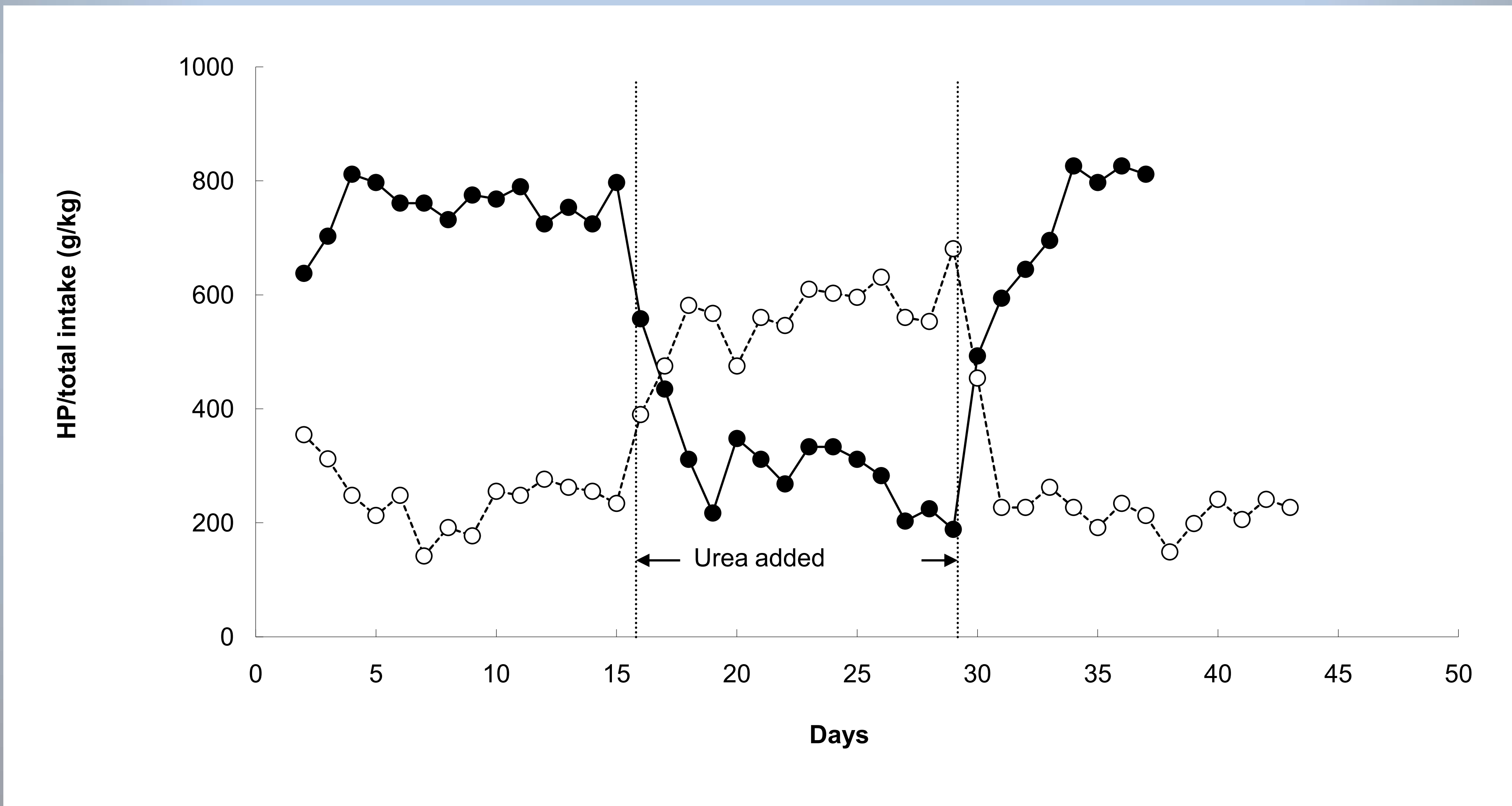


Continuum from deficiency, through sufficiency, to excess for each nutrient

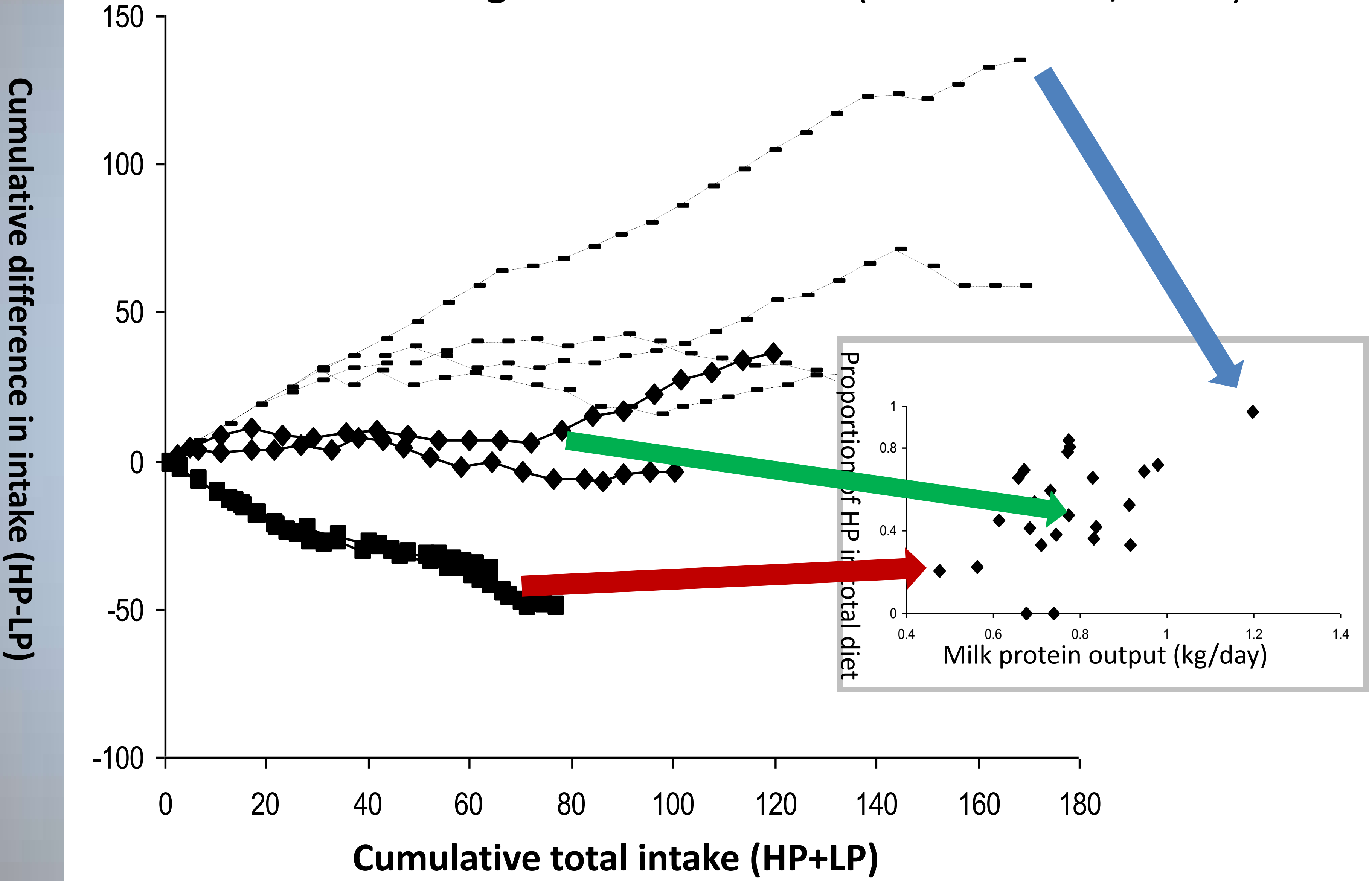
Arsenos and Kyriazakis (1999) conditioned protein-deficient sheep to flavoured foods associated with doses of casein from 9 to 53 g given by gavage.



Choice between HP (185 g CP/kg) and LP (128 g/kg) by lactating cows and the effect of adding 7.5 g/kg of urea to both (Tolkamp et al)



Diet selection pathways for 8 cows with a choice of concentrates high and low in UDP (Lawson et al, 2000)



Summary of part 1

- Deficiency of rumen degradable nitrogen depresses intake
- Deficiency (and imbalance?) of amino acid supply to animal depresses intake
- Ruminants can select for either RDP or UDP given the right conditions

Part Two

Speculation

Discomfort

- Animals behave to reduce (minimise?) discomfort
- In the context of this paper discomfort is caused by nutrient imbalances
- Discomfort caused by both excess or deficiency of a resource
- Animals (including humans) ***learn*** to avoid discomforts

Lots of discomforts!

- Discomfort of lack of energy (hunger)
- Excess of energy (satiety, overfatness)
- ***Lack or excess of protein, imbalance of amino acids***
- ***Deficiency or excess of rumen degradable N***
- Minerals and vitamins
- Stomach distension
- Social factors
- Environmental factors

Integration of discomforts

- FLT – first limiting factor – has been widely used.
- Separately calculate optimal intake for each factor
- Which ever is the lowest is predicted as the intake
- BUT this is unphysiological and incredible!

Total Discomfort

- Considerable convergence of information from viscera to central nervous system
- Discomforts from many sources are combined
- Combination by addition? - simplest way of combining information
- There is evidence for additivity of negative feedback signals

Minimum Total Discomfort

- If animals seek to minimise single discomforts then surely they seek to ***minimise total discomfort***
- (Why not ***maximise total comfort?***
- Presumably minimum discomfort can be quantified as zero ..
- while there is no limit to maximum comfort)

Learning to avoid discomfort

- Animals learn to associate sensory properties of foods with the consequences of eating those foods
- If eating a food causes discomfort then this reduces the animal’s intake and preference for that food
- If a choice of foods is available then the other food will become preferred
- If both foods cause discomfort for different reasons then a balance will be found between the positive and negative effects of eating the two foods

What next?

- If this idea is to be useful then it must be quantified
- To combine discomforts they need to have a common currency

A common currency

- The feedback factors are of different types, represented by different units
- Express de… …tion of the optim…
- e.g. CP 're…
- CP curren…
- Deviation …
- Proportio…
- Square of this is used to calculate the discomfort due to ME supply

	Animal	Food(s)
Protein	kg/day	kg/kg
Energy (ME)	MJ/day	MJ/kg
Bulk	kg/day	kg/kg
Rate of eating	minutes/day	minutes/kg
Space allowance	square metres	

Minimising total discomfort

For each of a range of daily intakes:

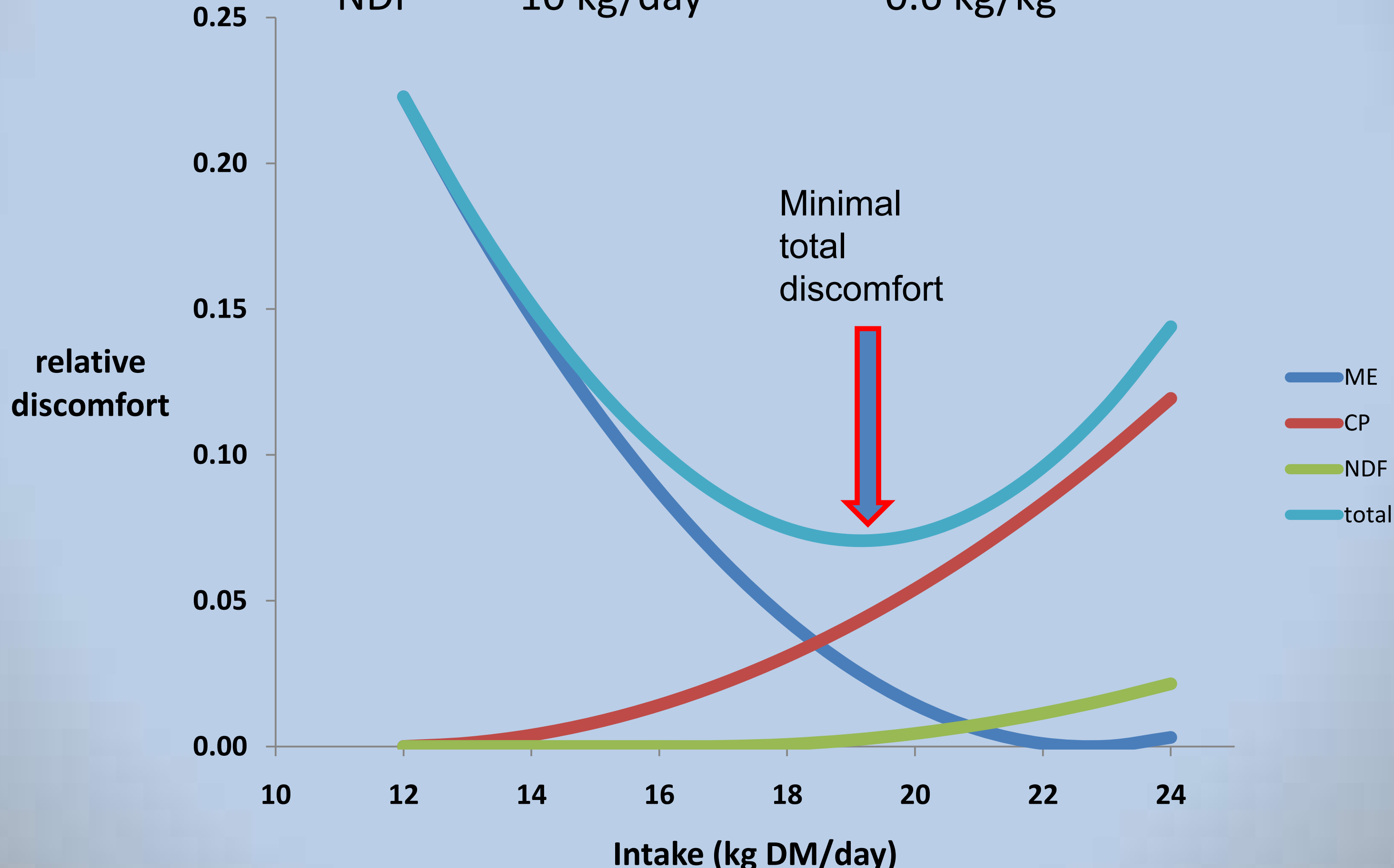
- for each of the resources under consideration:
  - calculate the proportional deviation from optimal
  - square this proportional deviation
- next resource
- add the squared proportional deviations
- Take the square root of this to give the total discomfort

next intake

Take the intake that gives the smallest total squared deviation as the predicted intake

A worked example

	animal	food
ME	250 MJ/day	11 MJ/kg
CP	1.65 kg/day	0.15 kg/kg
NDF	10 kg/day	0.6 kg/kg

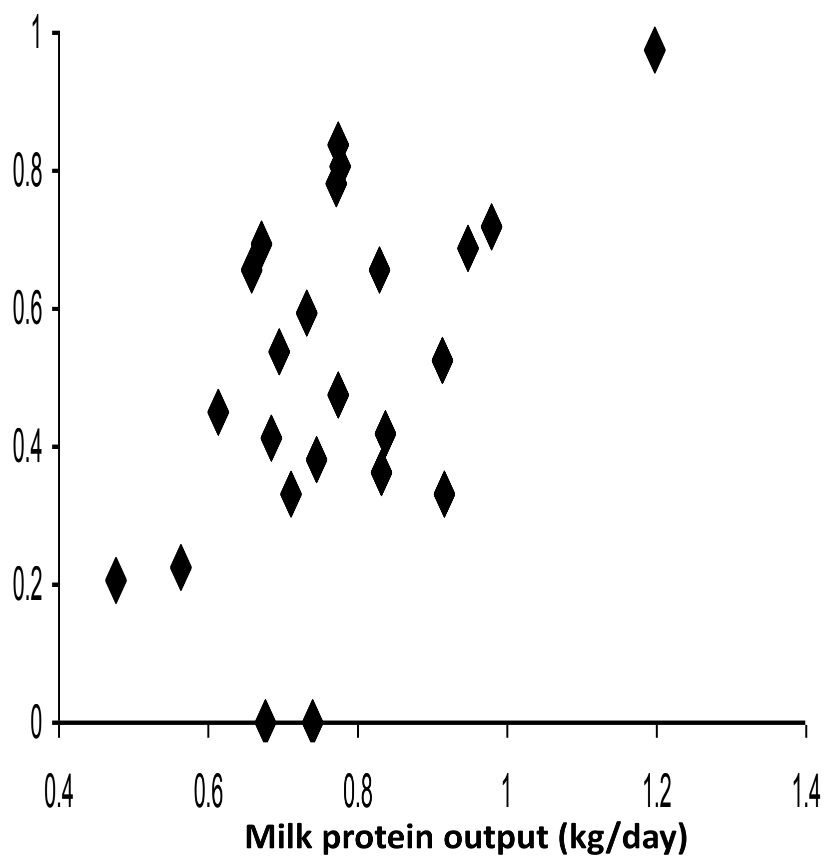


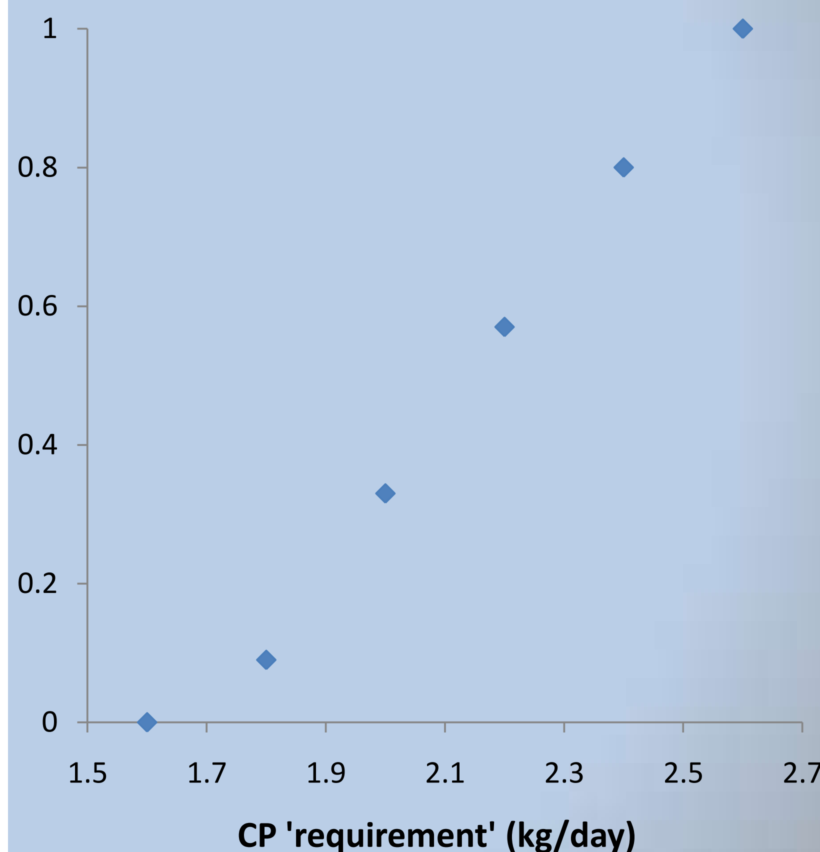
Diet selection

- The MTD model can be executed with two or more foods available
- Combinations of ranges of intakes of the foods are used and the model run for each combination
- That which yields the minimum total discomfort is the predicted intake and choice of foods.

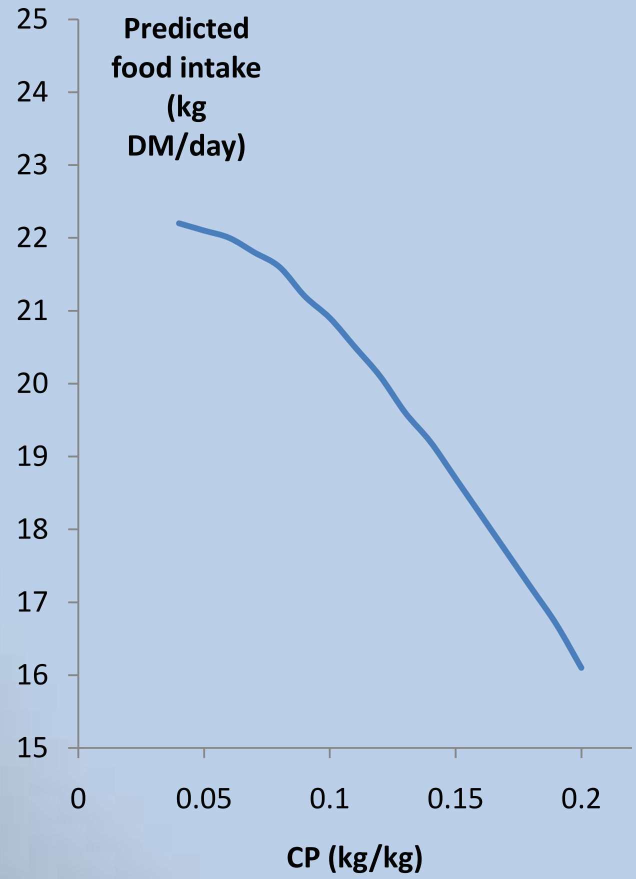
Silage ad lib and restricted choice of supplements, HP and LP

HP/total supplement intake





I need help in developing MTD for N and amino acids!



MTD predictions for CP are simply wrong!

I could play around with fudge factors but that's not acceptable!

Some ideas:
Protein:energy ratio

- So far it has been assumed that the factors are independent
- BUT, protein provides energy as well as amino acids, i.e. interaction between factors
- How do we deal with this?
- I have some ideas, but not yet well-formulated

Multiple effects of single entities

- For example a portion of dietary N can affect
  - rumen receptors
  - Rumen microbes -> protein, ^ fibre digestion
  - Microbial amino acids can affect intestinal receptors
  - Absorbed amino acids affect metabolism
- Thus one dietary resource can have multiple effects on intake-related responses
- i.e. we can ‘double-count’ in the MTD framework

MTD with degradable and undegraded protein!

- It is essential that for ruminants separate account be taken of rumen and animal requirements for N and amino acids
- What is the way forward?
- Email me at: j.m.forbes@leeds.ac.uk
- Ask me for copy of MTD spreadsheet with explanatory notes

Summary of part 2

- The MTD framework is proposed as a more physiologically-credible basis for understanding intake and choice than FLT
- It is a research model, by no means ready for use in practical prediction
- While it ‘works’ at a superficial level, it is not yet developed to deal properly with protein and nitrogen and their interactions with other food resources
- Much further thought is required in its development

Conclusions

- Voluntary food intake is influenced by the supply of nitrogen to the rumen and amino acids to the animal
- Animals can choose between foods in order to optimise their intakes of nutrients
- The MTD framework requires further thought and development to deal with protein and nitrogen, and their interactions with other resources

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It does not necessarily reflect its view and in no way anticipates the Commission's future policy in this area.