EAAP-2013-Nantes

Major components of feed efficiency in ruminants

D.Sauvant

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Thanks to:

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N.Friggens, H.Phuong (UMR INRA-AgroParisTech MoSAR)
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INTRODUCTION, CONTEXT

Reniew of interest to improve feed conversion efficiency into milk and meat:

- *Efficiency is linked with competitivness & productivity*
- *Reduce of the excretion of Nurea, ammonia, N2O*
- *Reduce of the excretion of OM and carbon (CH4, CO2, faeces…)*
- *Increase the efficiency of good feed sources*
- *Larger use of cheap feed sources (forages, trees…)*

Ruminants are less efficient than monogastrics

PLAN

1. Method of approach
2. Expressions to assess Feed Efficiency ?
3. Components of FE: digestive and metabolic
   - *3.1. Variation of digestive efficiency*
   - *3.2. Variation of metabolic efficiency*
4. Feed efficiency and multicriteria responses to diet
5. Feed Protein efficiency
6. Toward a more systemic approach of efficiency ?

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1. Method of approach

➔Pooling experimental data into bases

➔Encoding of data (experiment, treatment…) study of the meta-design…

➔Meta-analysis according to the objectives *(StPierre, 2001; Sauvant et al., 2008)*

➔ Quantitative synthesis of knowledge

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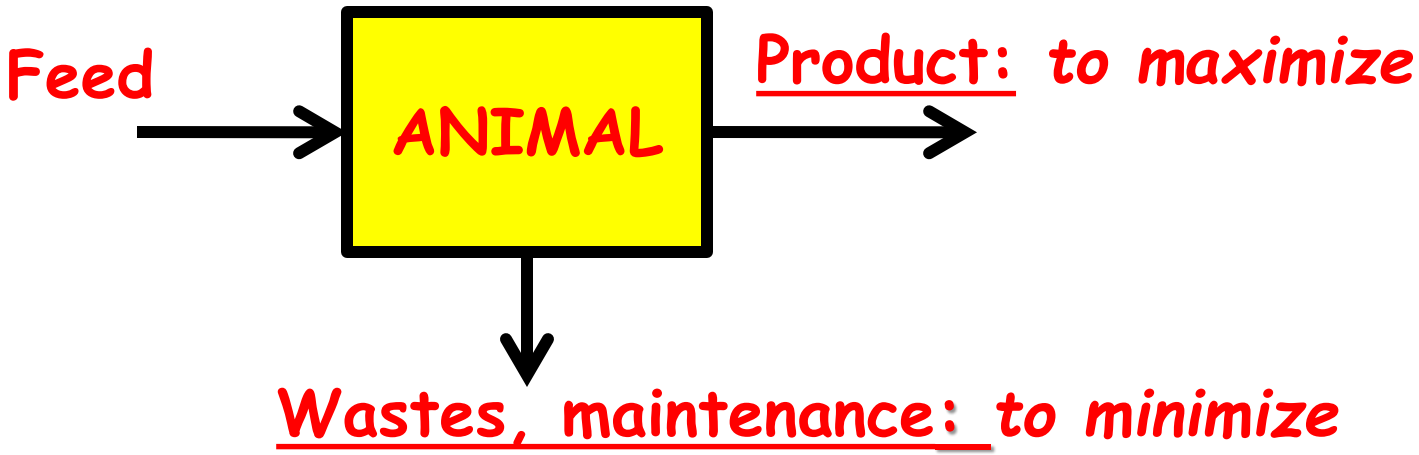
2. Basic expressions to assess Feed Efficiency ?



Feed Efficiency = FE = Product/Feed

Feed Conversion Ratio = FCR = Feed/Product = 1/FE

Residual feed intake = FI – pred FI = f(energy balance)

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3.Components of Feed Efficiency

*FE = Digestive Eff. * Metabolic Eff.*

Ex1: Including the role of DOM intake (DOMI):

FE = (DOMI/DMI)*(Product/DOMI)

Ex2: Including the role of ME Intake (MEI)

FE = (MEI/DMI)* (Product/MEI)
= [ME/DM] * Met.Eff of ME

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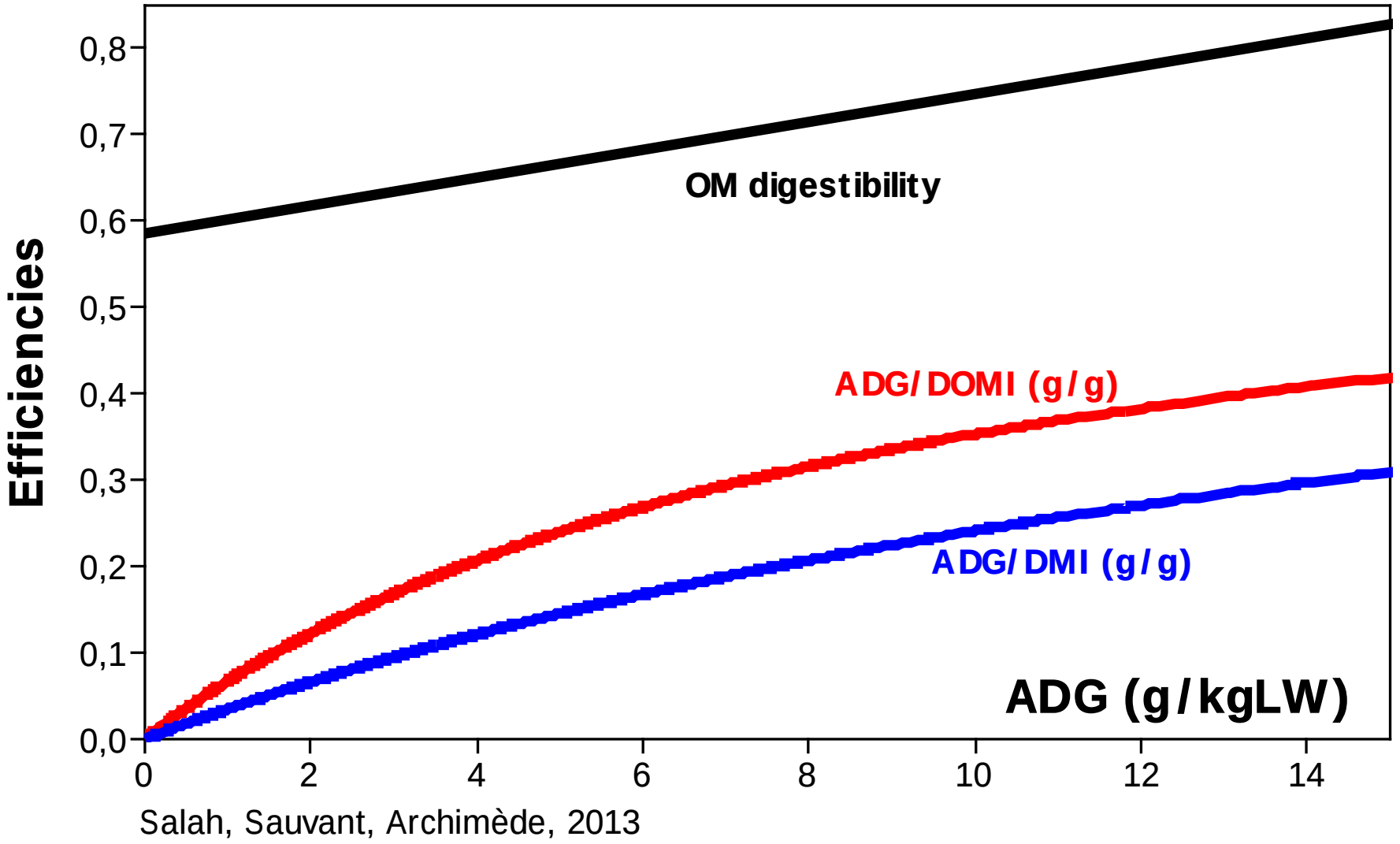
Fitted relationships between ADG/LW and components of efficiency in growing ruminants



Salah, Sauvant, Archimède, 2013

361 publications, 1270 treatments on cattle, sheep and goats
Similar trends between DEff and MEff

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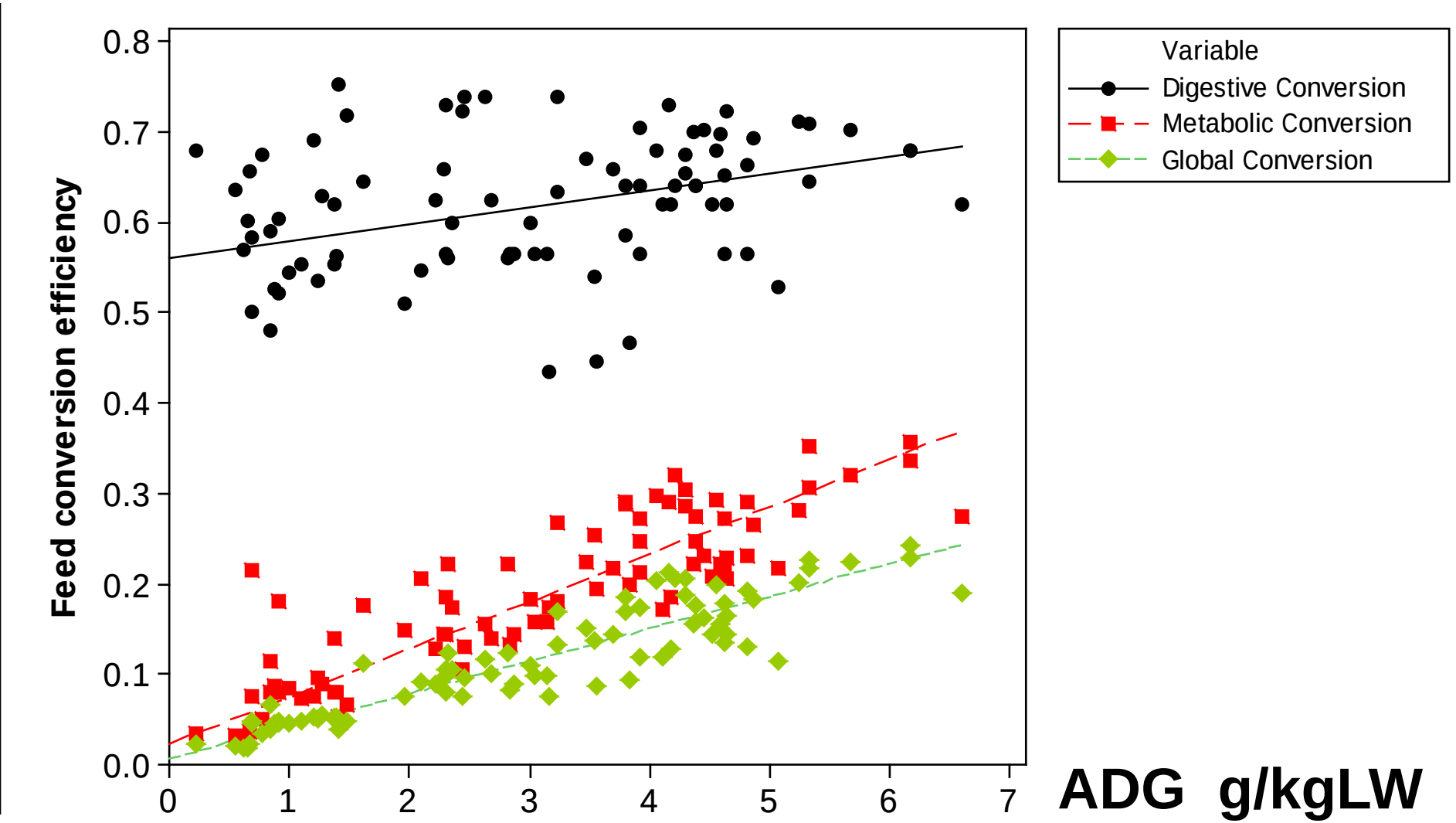
Global, digestive and metabolic efficiencies in grazing cattle



Boval & al., 2013

Similar trends between DEff and MEff

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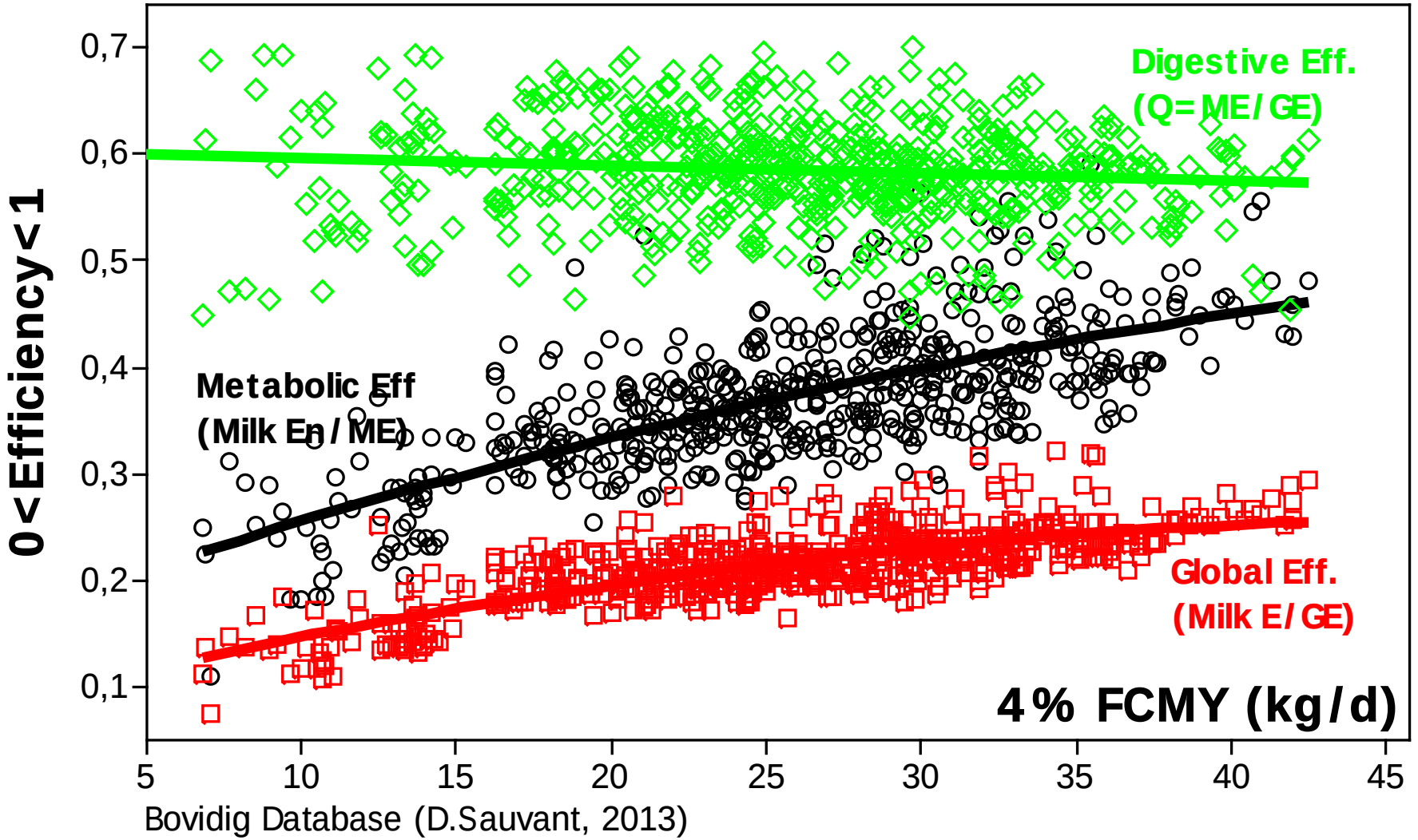
Variations of components of energy efficiency in dairy cows with FCMY



1 point = 1 treatment
Opposite trends between DEff and Meff
Similar trends for dairy goats

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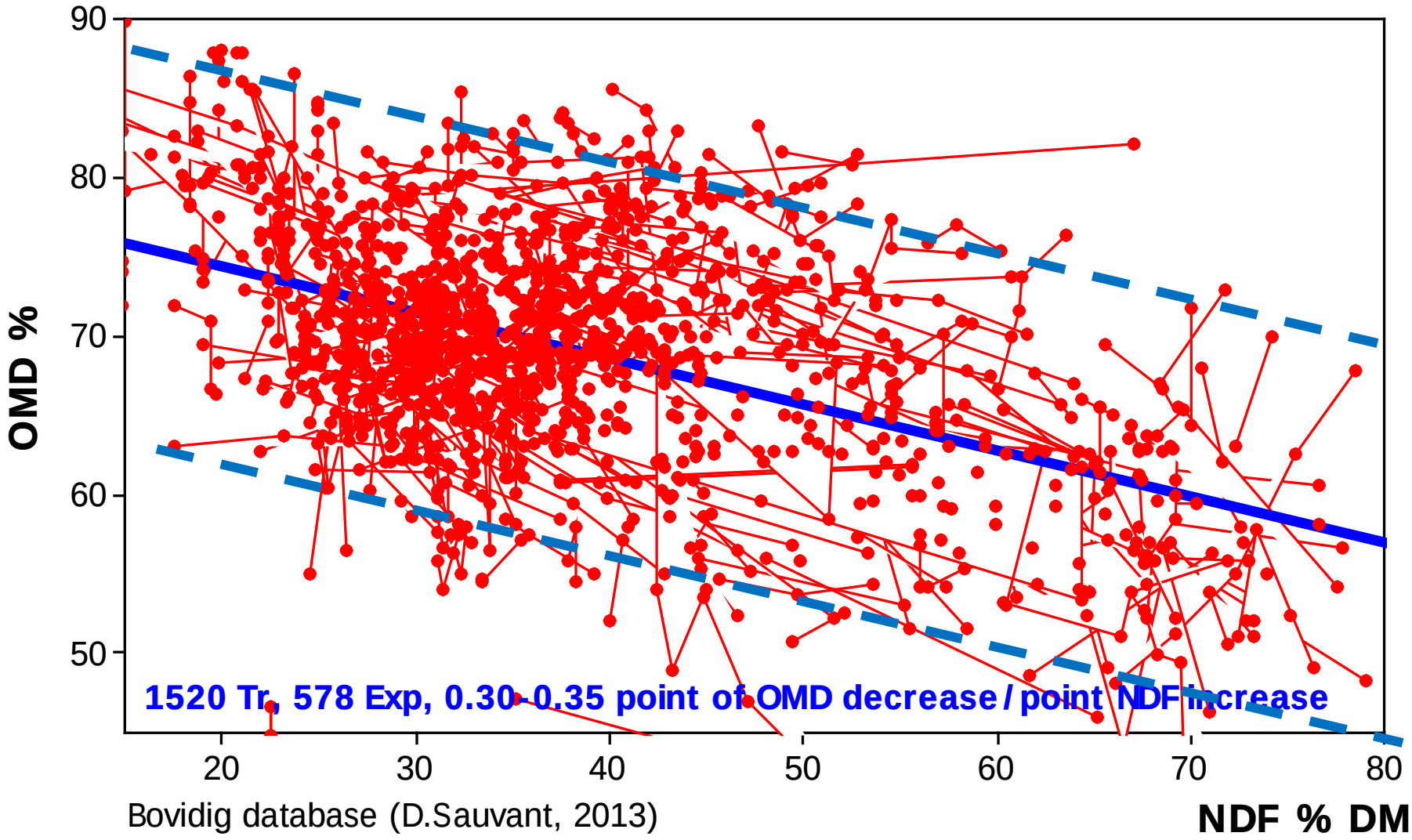
3.1. Variation of digestive efficiency

3.1.1.Large variations according to feed and diets:
Dig.Eff. = OMD ~ a – b « Cell wall »

➔ *Quality of forage = to maximize*

3.1.2.Negative influence of digestive interactions
= to minimize

Influence of dietary NDF on the OM digestibility in cattle



A low [NDF] is associated with a high risk of acidosis

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3.1.2. The negative influence of digestive interactions/prediction

1. Feeding level (FL) :
+ 1 unit of DMI%LW ➔ - 2 to 3 points of OMD%

2. % Concentrate : +10%CO ➔ - 0.3 to - 0.6 pts OMD%

3. Lack of nitrogen in the rumen (CP<140g/kgDM)
- 10g CP/DM ➔ - 0.2 to - 0.4 point of OMD%
- 10g Rumen protein balance ➔ - 0.5 point of OMD%

Quantitative consequences ?

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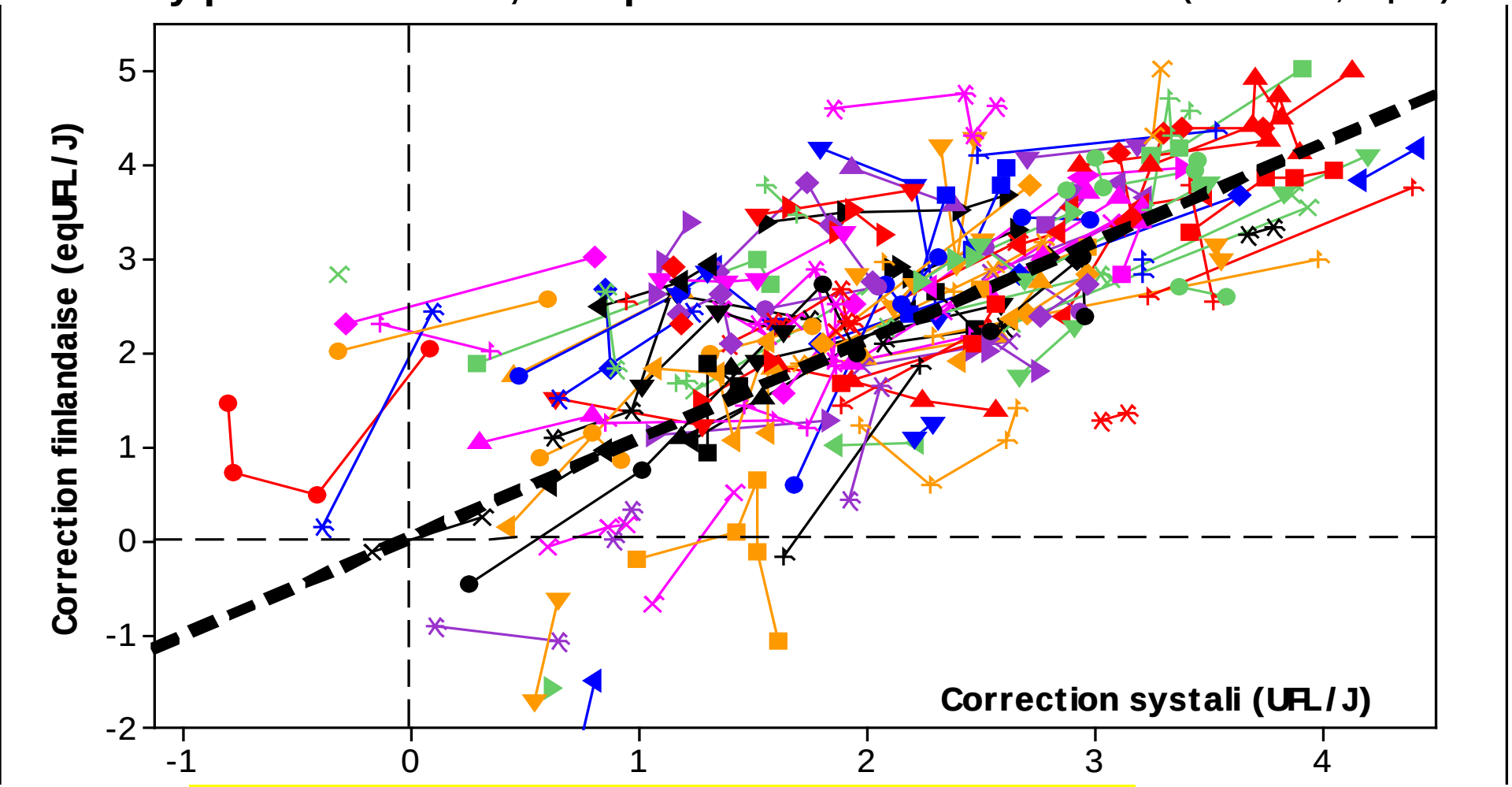
Comparison of proposals from Finland and France to take into account digestive interactions caused by feeding level, concentrate supply and dietary protein content, interpretation in milk feed unit/d (D.Sauvant, unpub)



No significant differences between both proposals
Calculated on the « Bovidig » database
1 UFL = 1 MFU = 1.7 Mcal = 7.1 MJ

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3.2. Variation of metabolic efficiency ?

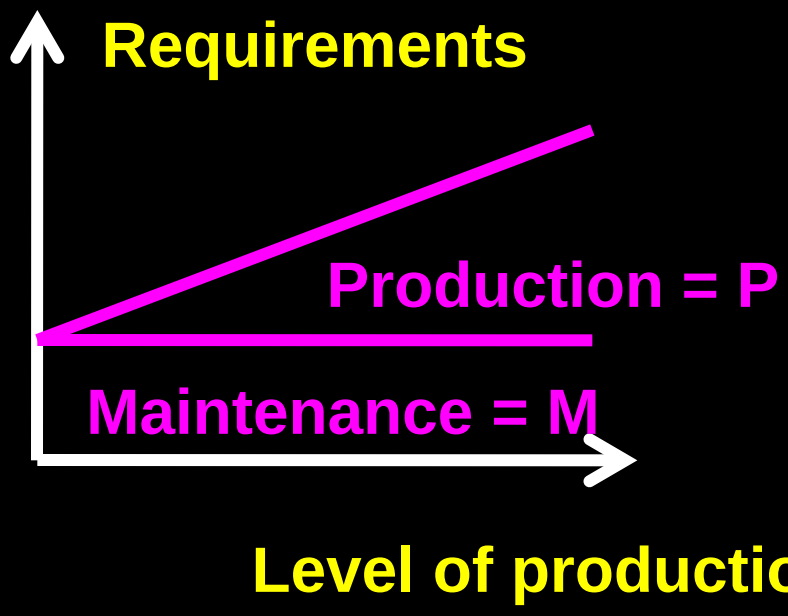
3.2.1. Role of maintenance

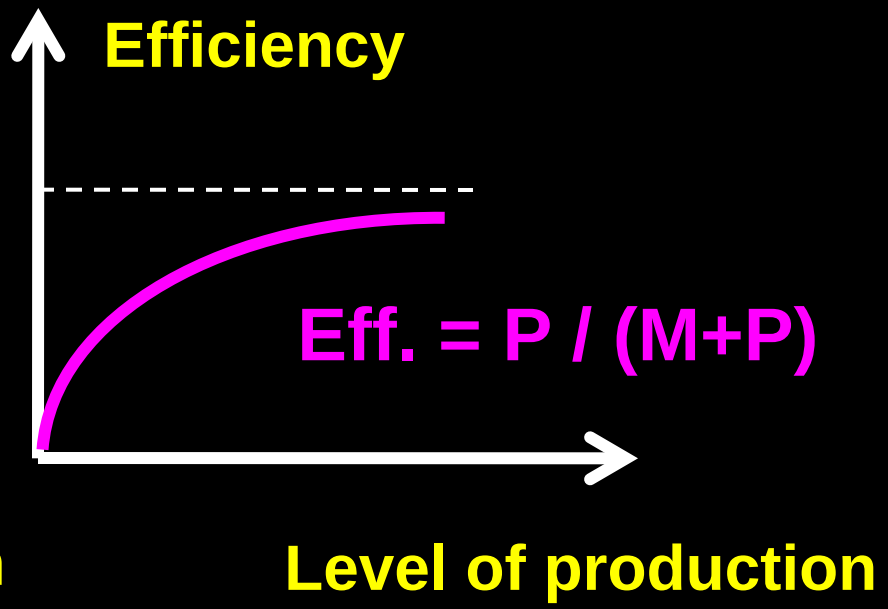
Ex for growth and lactation

3.2.2. Met.Eff. into milk: f(energy balance)

3.2.3. Variation of extra-heat and ME intake

3.2.1. The role of maintenance ?

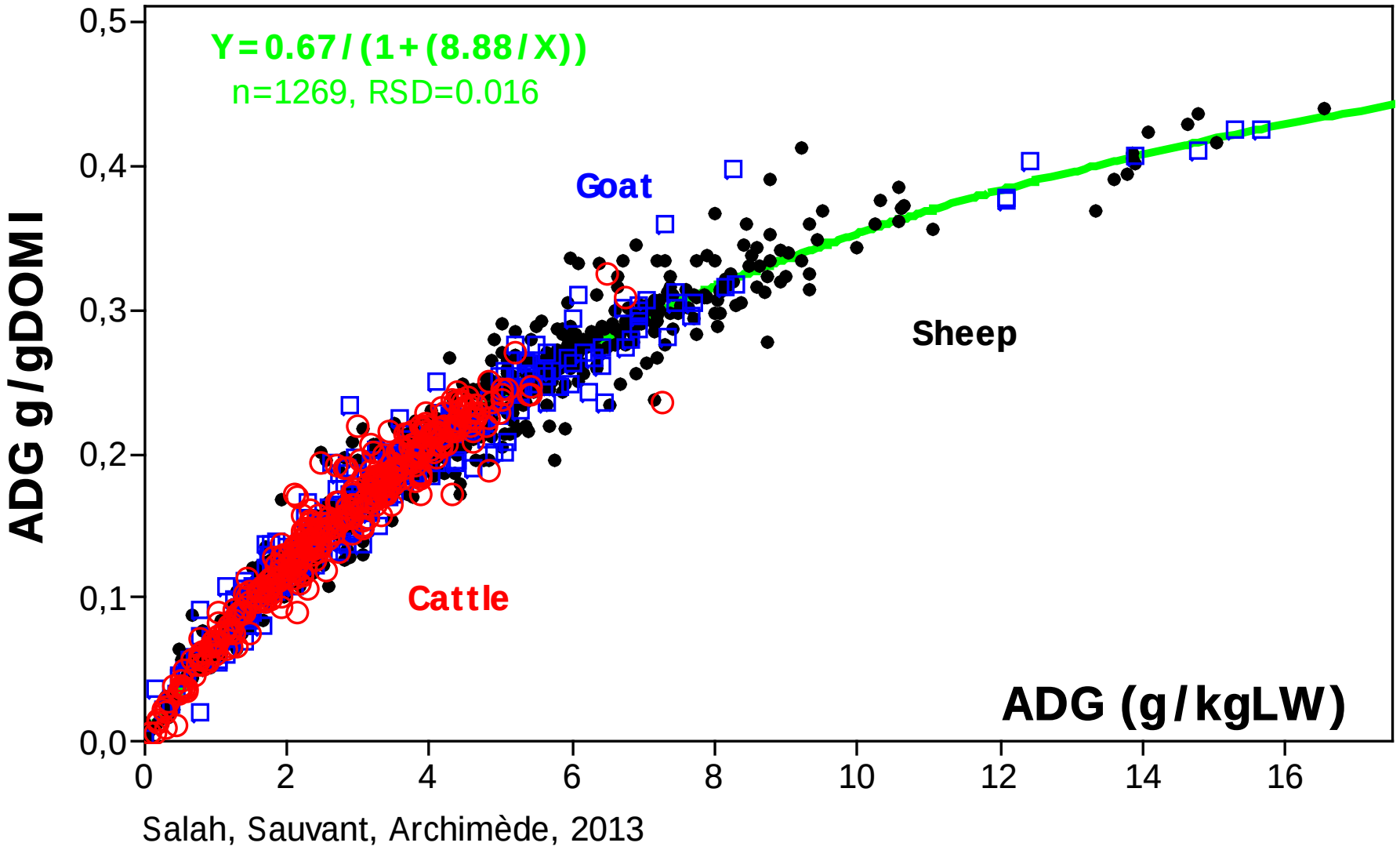




➔The race to high level performance
➔Indirect role in responses to diets

3.2.1.

Intra-experiment influence of ADG/LW on metabolic efficiency in growing ruminants



Salah, Sauvant, Archimède, 2013

Residues negatively related with of the protein content of the gain

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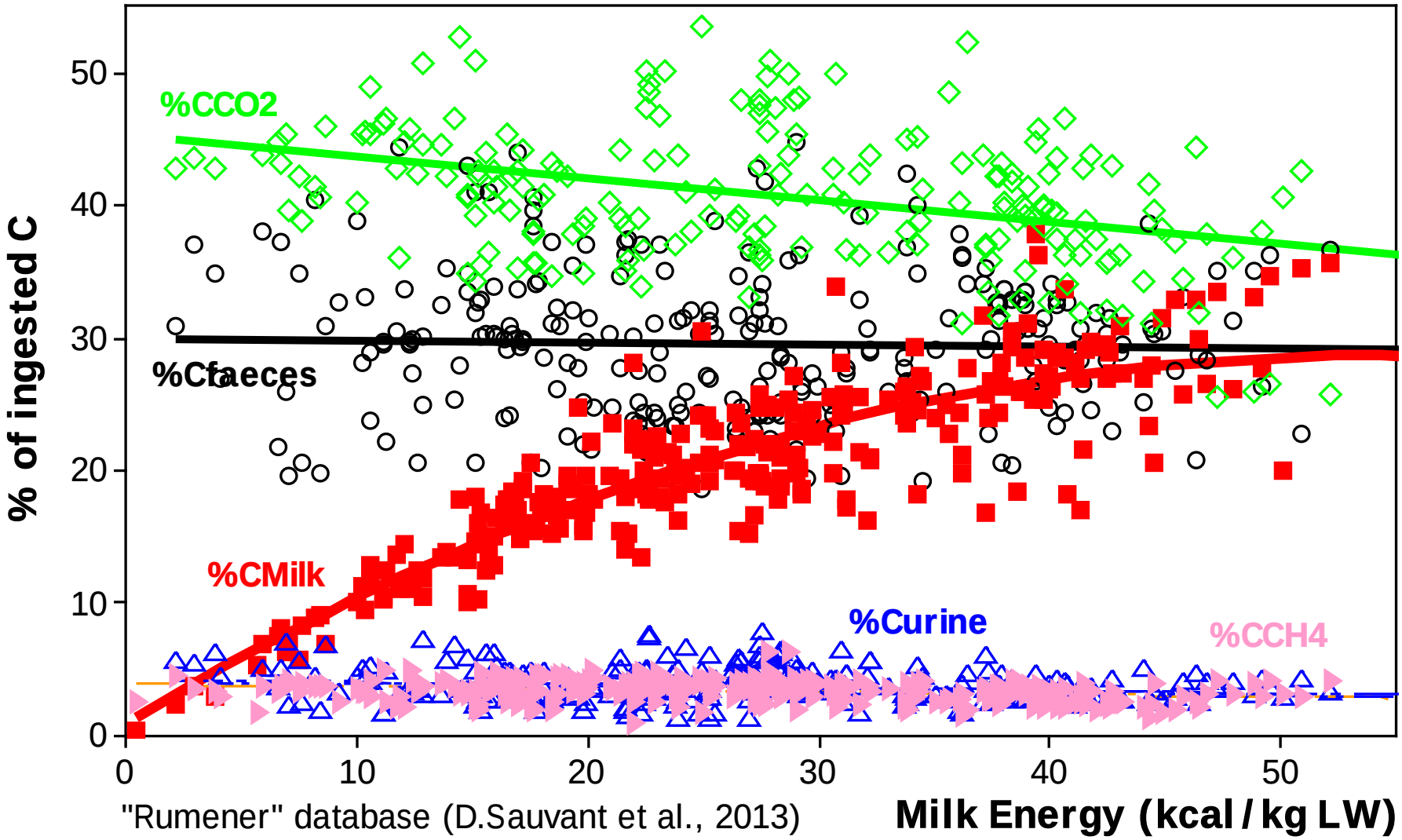
3.2.1. Partition in excreted carbon in dairy cows and goats



No difference between cows and goats
Maximum efficiency of ingested C into milk C = 30%
Maximum efficiency of metabolisable C into milk C = 50%

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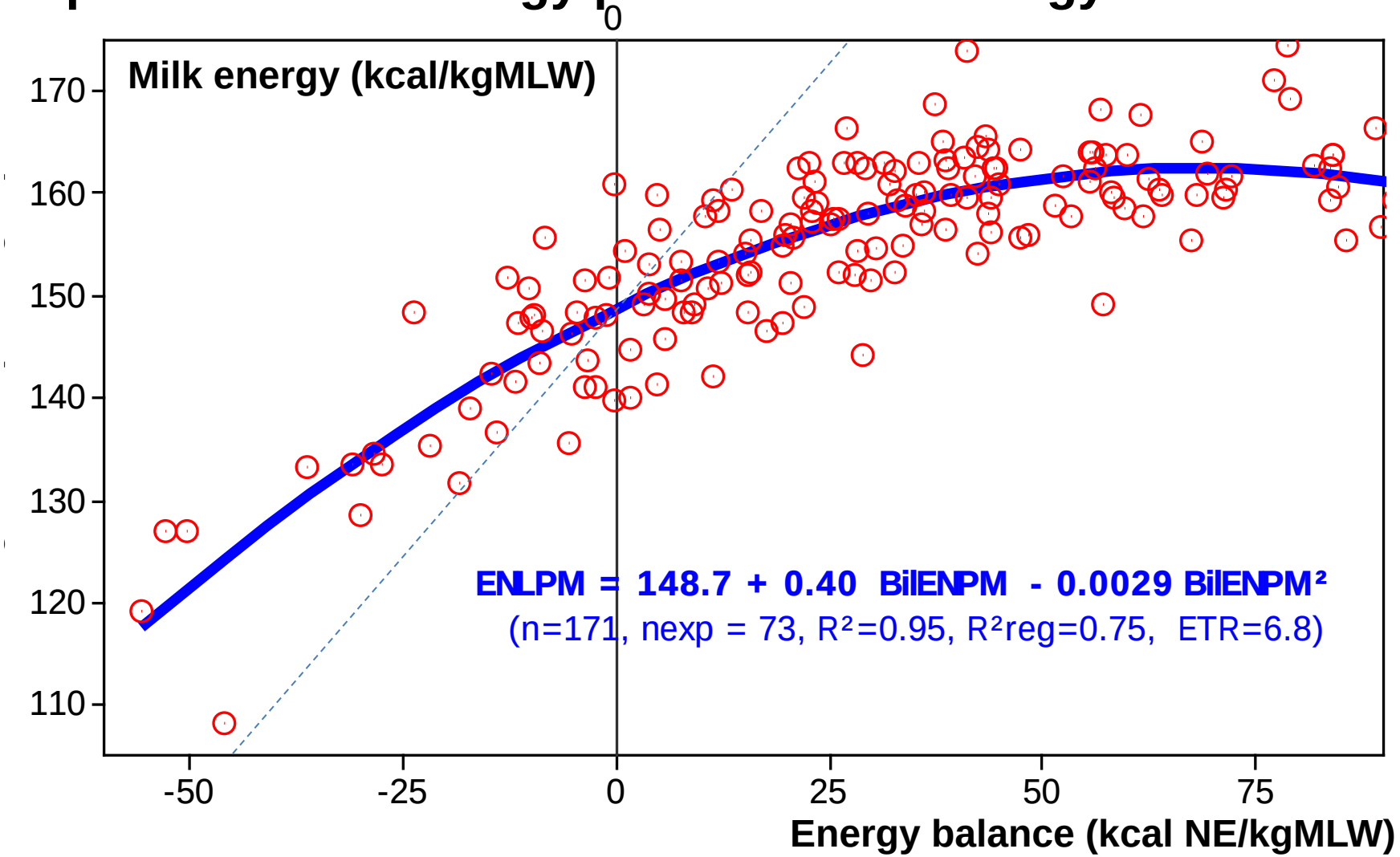
3.2.2.

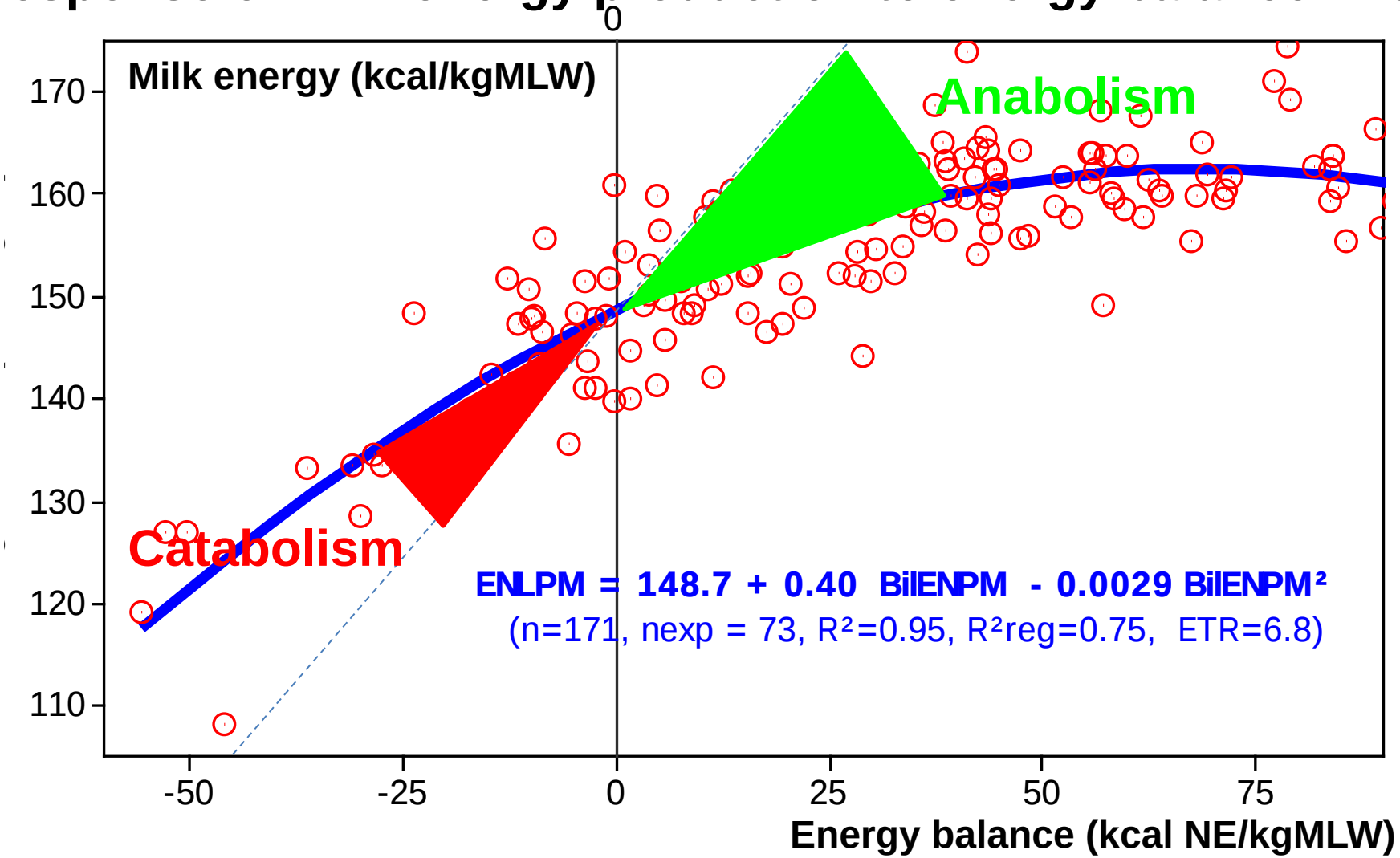
Response of milk energy production to energy balance in cows



NEBal = -50, 0 and +50 ➔ marginal efficiencies of NE 69, 40 and 11%
Bovidig database, exp with measured OMD and focused on concentrate supply

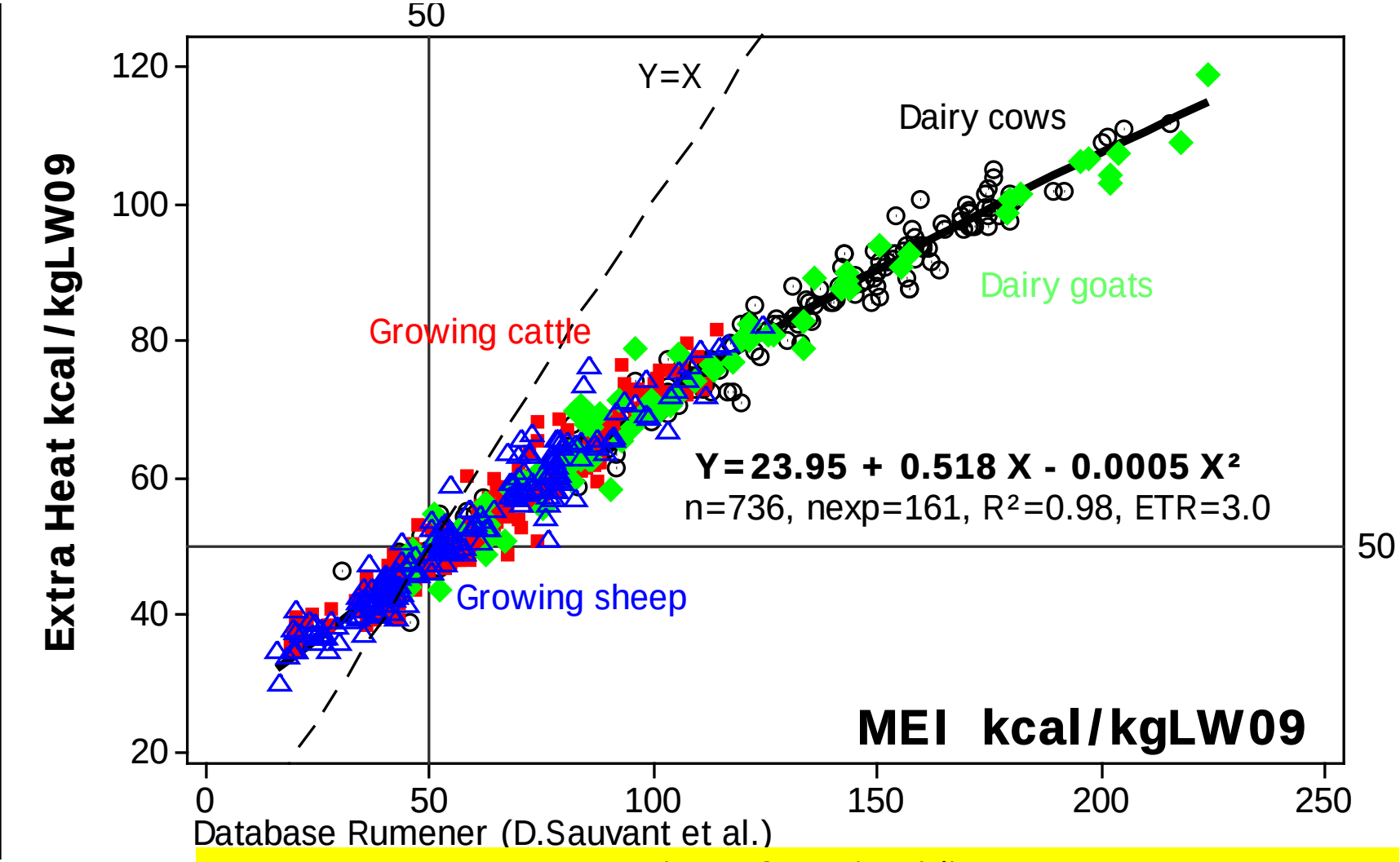
3.2.2.

Response of milk energy production to energy balance in cows



NEBal = -50, 0 and +50 ➔ marginal efficiencies of NE 69, 40 and 11%
Bovidig database, exp with measured OMD and focused on concentrate supply

3.2.3.
Intra-experiment generic equation between MEI and extra heat in ruminants



Common maintenance value of 50 kcal/kgLW0.9
MEI=50 kcal ➔ meanNEr/ME=0, margNEr/ME=53.2%,
MEI=200 kcal ➔ meanNEr/ME=46.2%, margNEr/ME=68.2%
Is km>kl>kf still valuable ?

Part 3: partial conclusions

Digestive eff. is mainly driven by dietary factors *(major role of the cell wall , of the rumen & digestive interactions)*

Metabolic eff. is largely influenced by maintenance requirements.

Beyond maintenance, dietary level of ME or NE has a positive influence on Met.Eff. but a negative influence on the ME or NE partition to milk

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4. FE and multicriteria responses to diet:

Example of concentrate supply in dairy cows (similar results for dairy goats)

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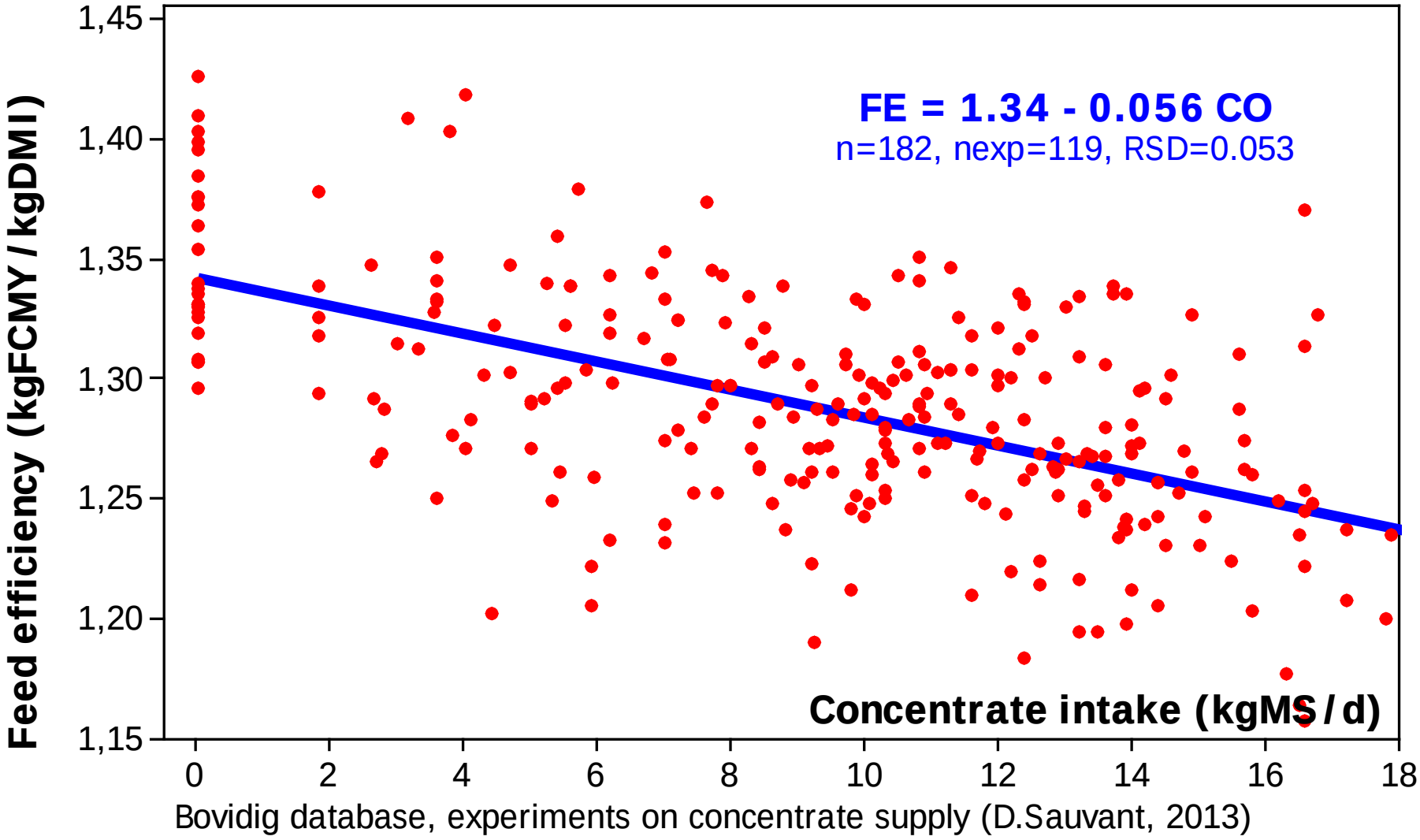
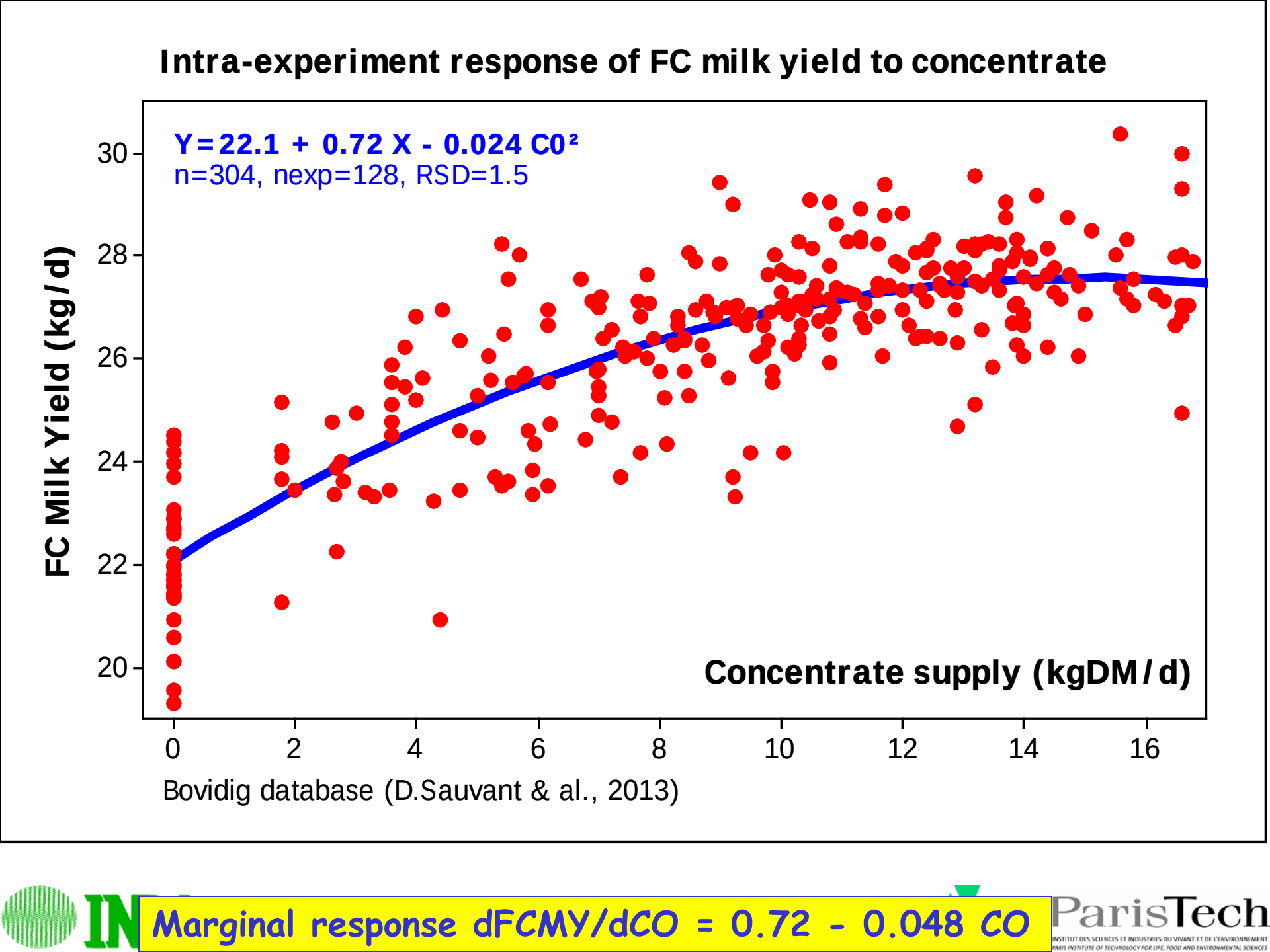
Intra-experiment response of FE to concentrate supply in dairy cows



Bovidig database, experiments on concentrate supply (D.Sauvant, 2013)

Partition of FE according to forage and concentrate intake ?


Intra-experiment response of FC milk yield to concentrate
Y = 22.1 + 0.72 X - 0.024 C0²
n=304, nexp=128, RSD=1.5
FC Milk Yield (kg/d)
30
28
26
24
22
20
Concentrate supply (kgDM/d)
0
2
4
6
8
10
12
14
16
Bovidig database (D.Sauvant & al., 2013)
Marginal response dFCMY/dCO = 0.72 - 0.048 CO
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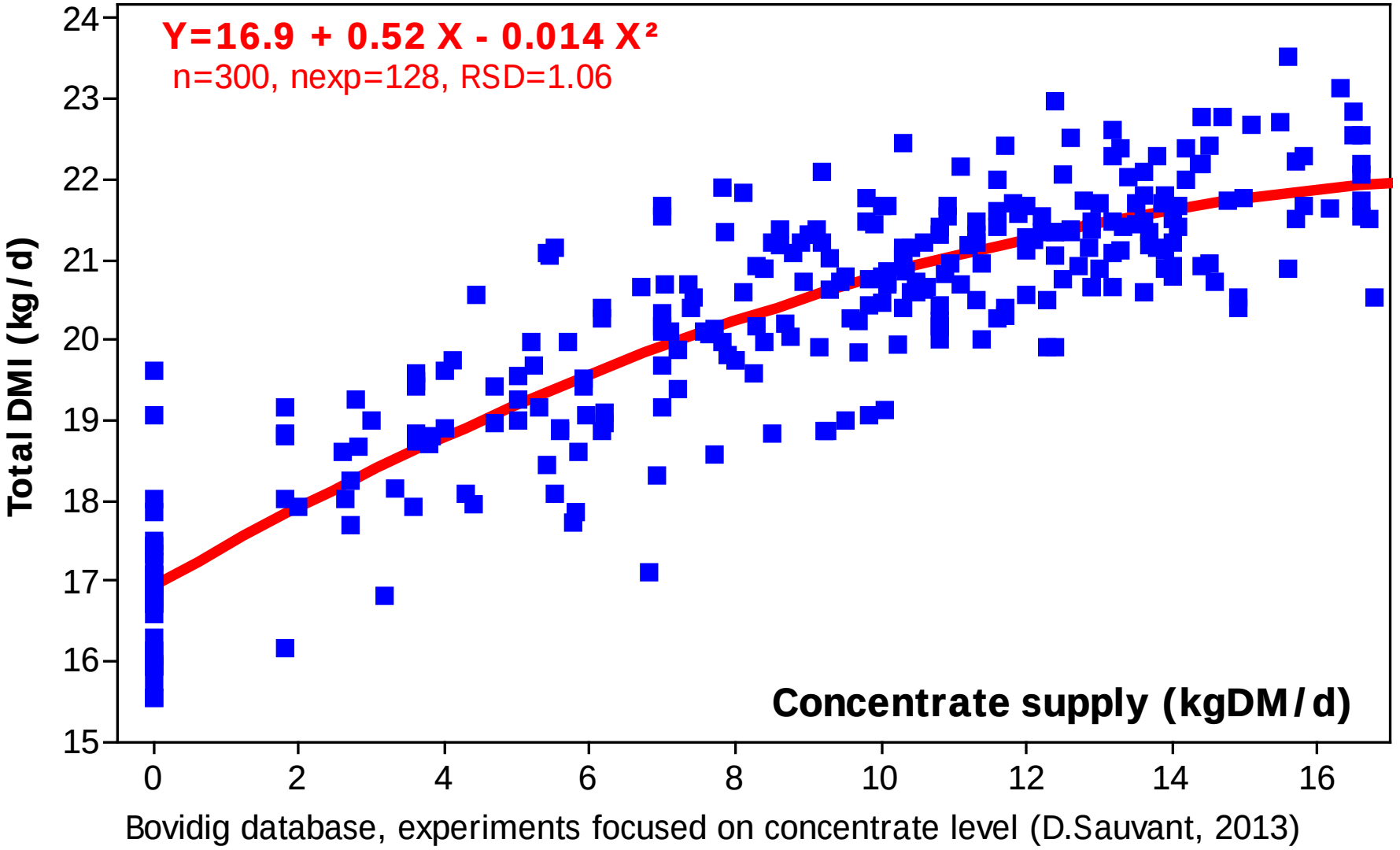
Intra-experiment response of dry matter intake of dairy cows to concentrate



Bovidig database, experiments focused on concentrate level (D.Sauvant, 2013)

FO ⇔ CO marginal substitution dFO/dCO = - 0.48 - 0.028 CO

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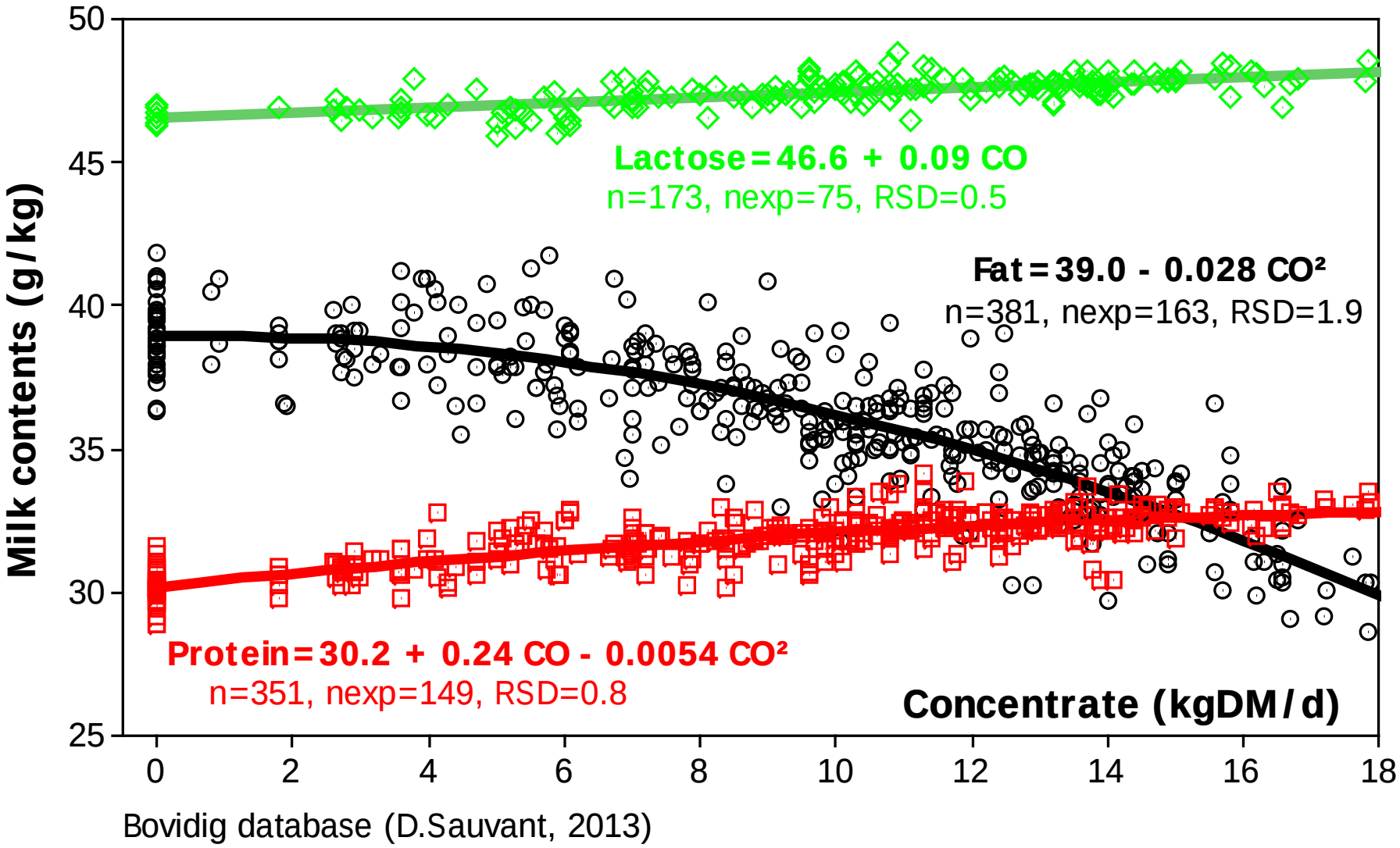
Influences of concentrate supply on fat, protein and lactose content of milk



Bovidig database (D.Sauvant, 2013)

Opposite responses of fat and [lactose + protein] contents

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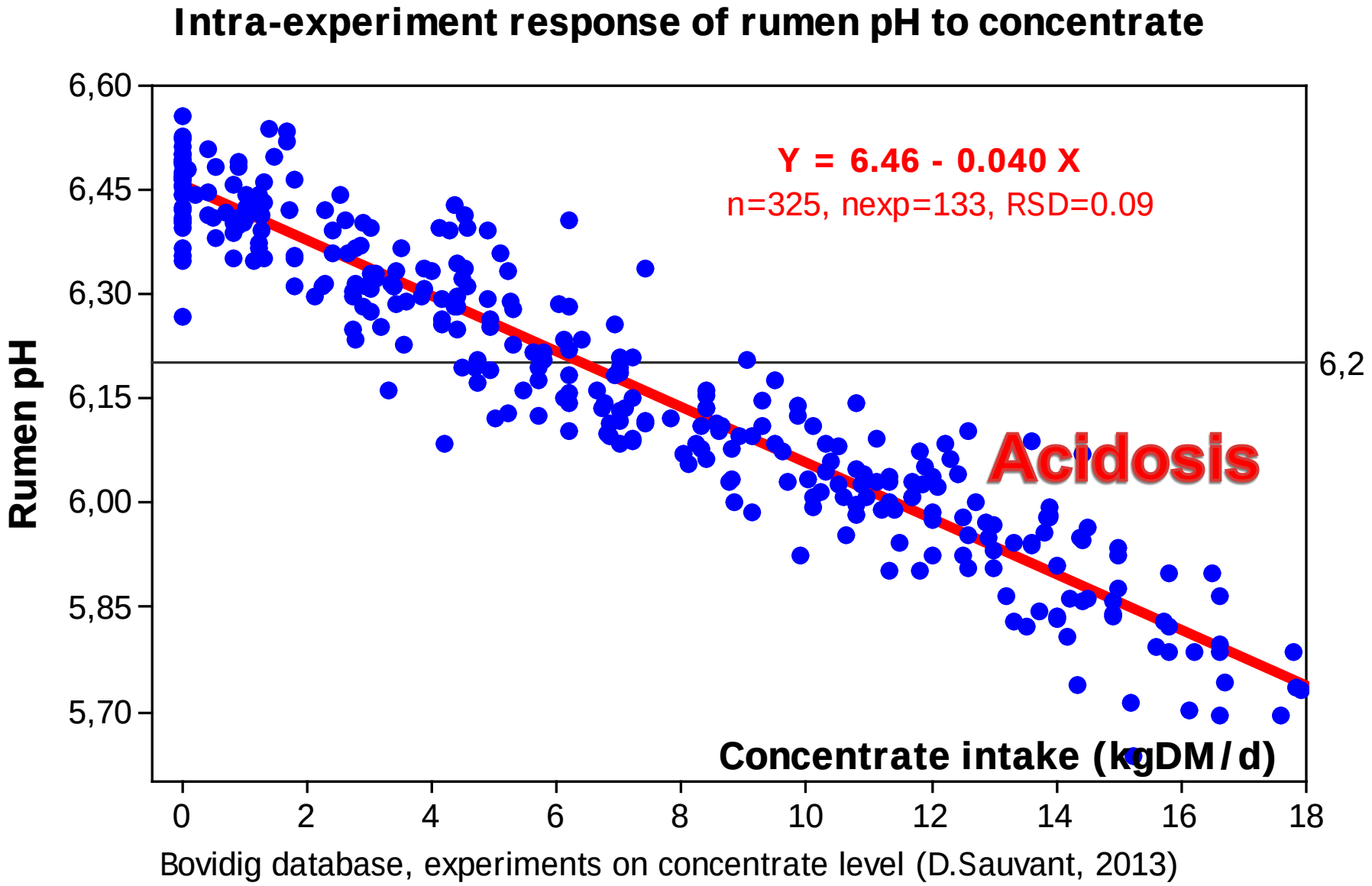

Increased risk of acidosis with CO intake

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Part 4: partial conclusions

FE is only one of the animal multicriteria responses to feeding practicies

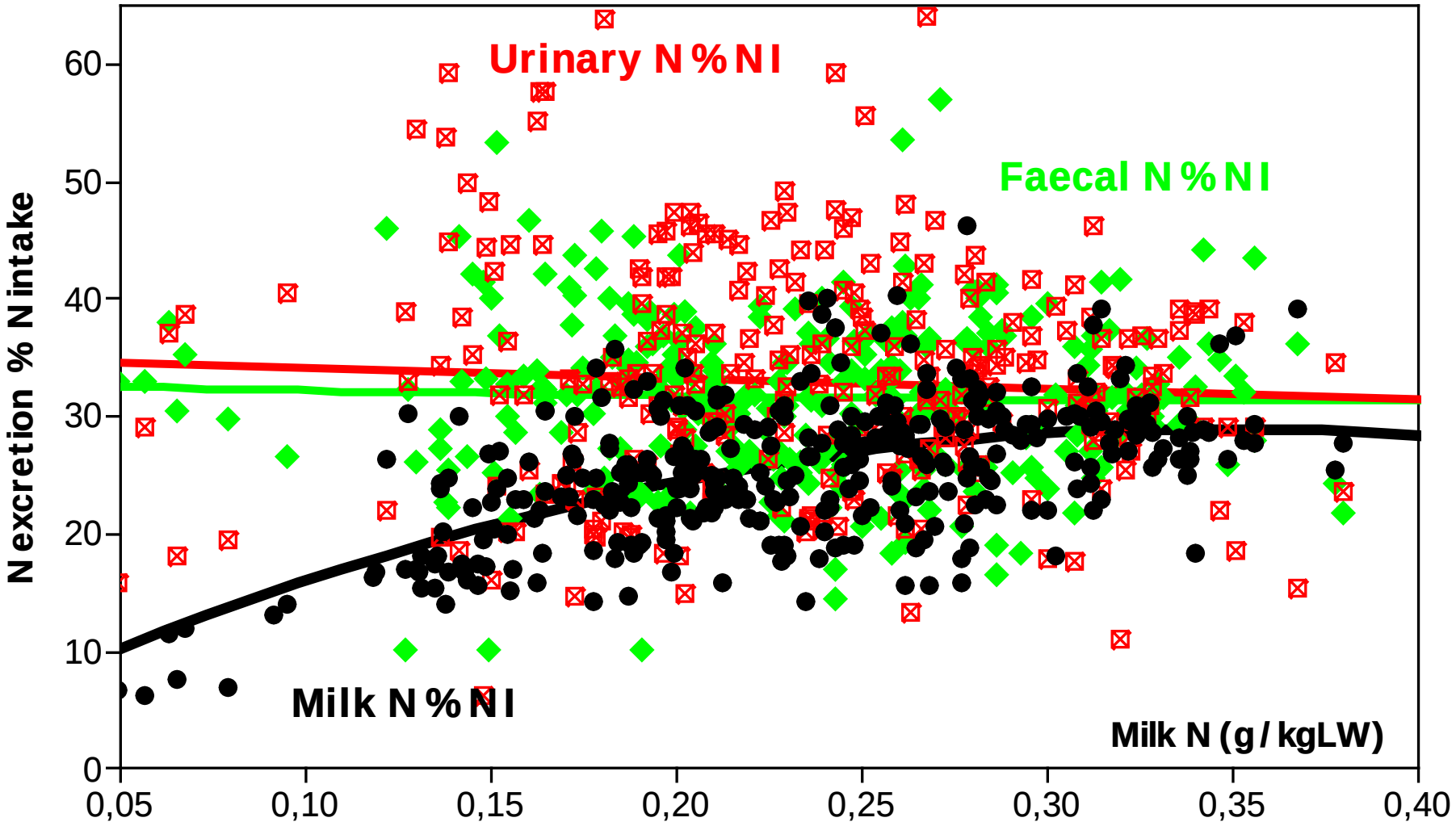
➔ It cannot be considered alone

5. Feed Protein Efficiency

5.1. Influence of level of production
5.2. Influence of rumen protein balance
5.3. Efficiency of MP into milk
5.4. Link between FPE and FE

5.1.

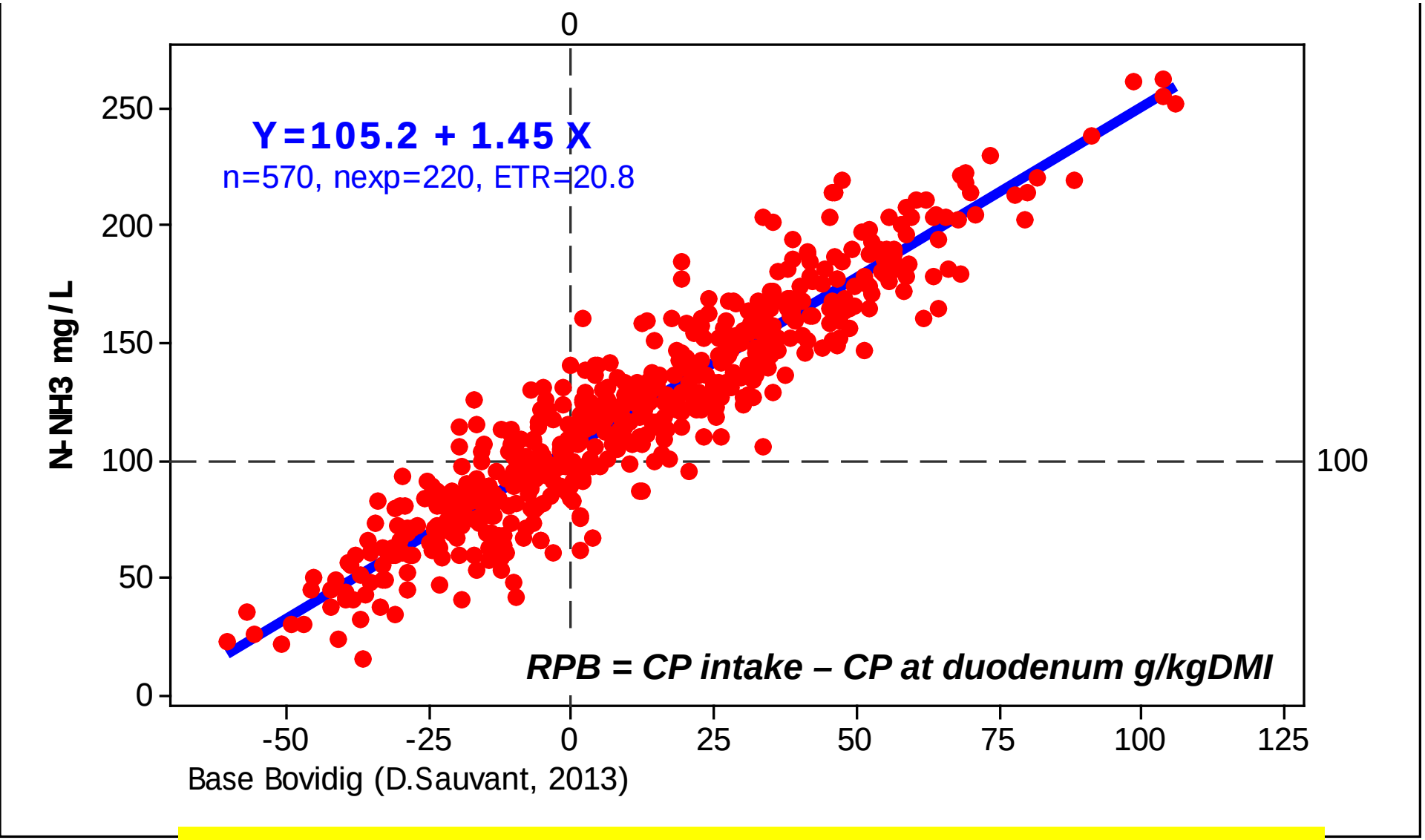
Partition of N excretion in cows and goats



Data bases Bovidig and Caprinut (D.Sauvant & al., 2013)

Maximum efficiency of ingested N into milk N = 30%
No difference between goats and cows
Large variations of FN/NI and UN/NI: Role of the rumen ?

Relationship between Rumen Protein Balance and N-NH3 of rumen juice



➔ **Consequences on ammonia and urinaryN excretions ?**

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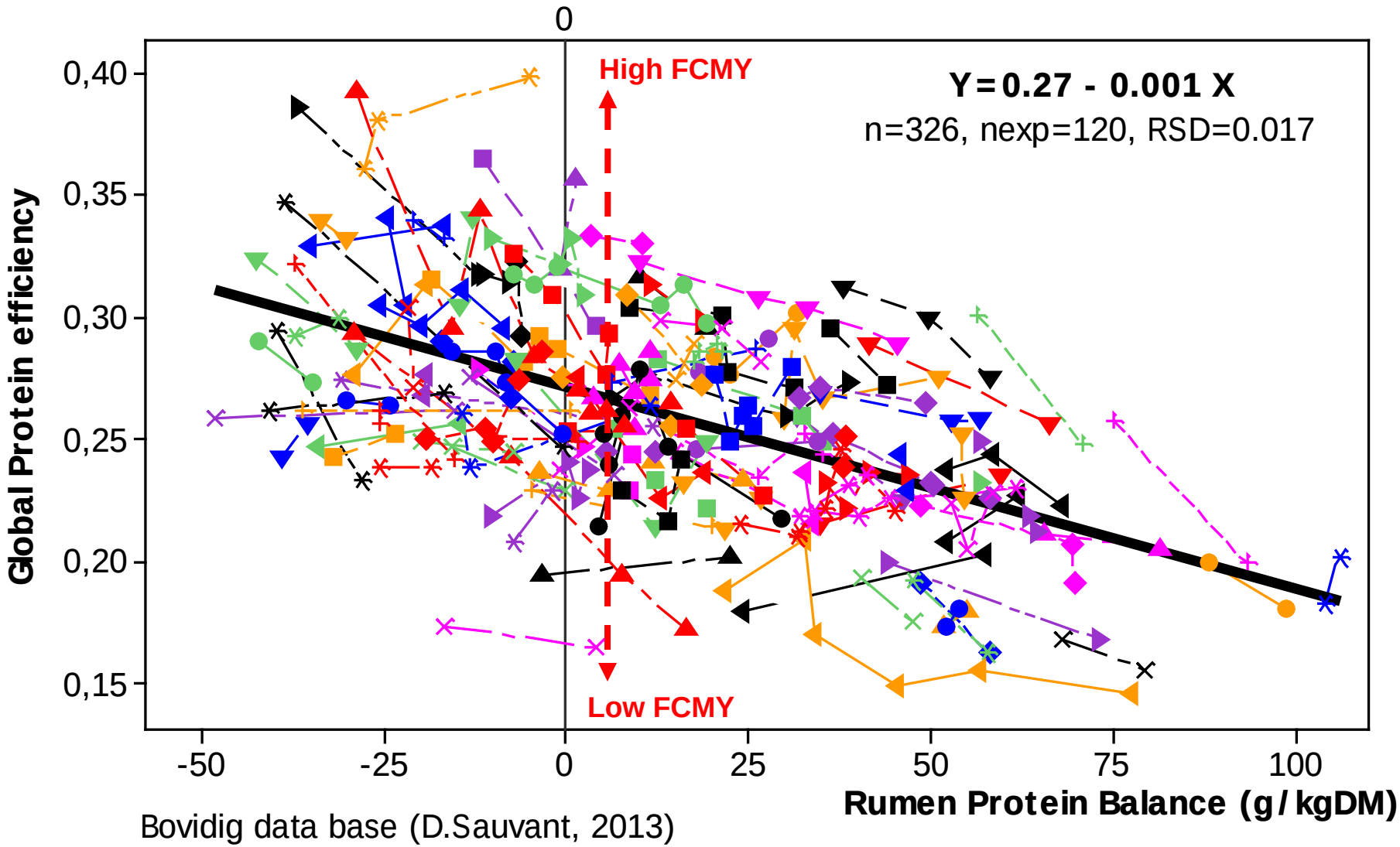
5.2.

Influence of Rumen Protein Balance on protein efficiency in dairy cows



Bovidig data base (D.Sauvant, 2013)

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5.2. Equation of prediction of protein efficiency in dairy cows

Global:

EffProt% = 29.2 – 0.09 RuProtBal + 0.25 FCMY – 0.015 LW

n=214, R^2=0.42, RSD=3.5

Intra-publication:

-Similar coefficients for FCMY and RuProtBal
-No effect of LW
-Significant increase of precision: RSD=1.6

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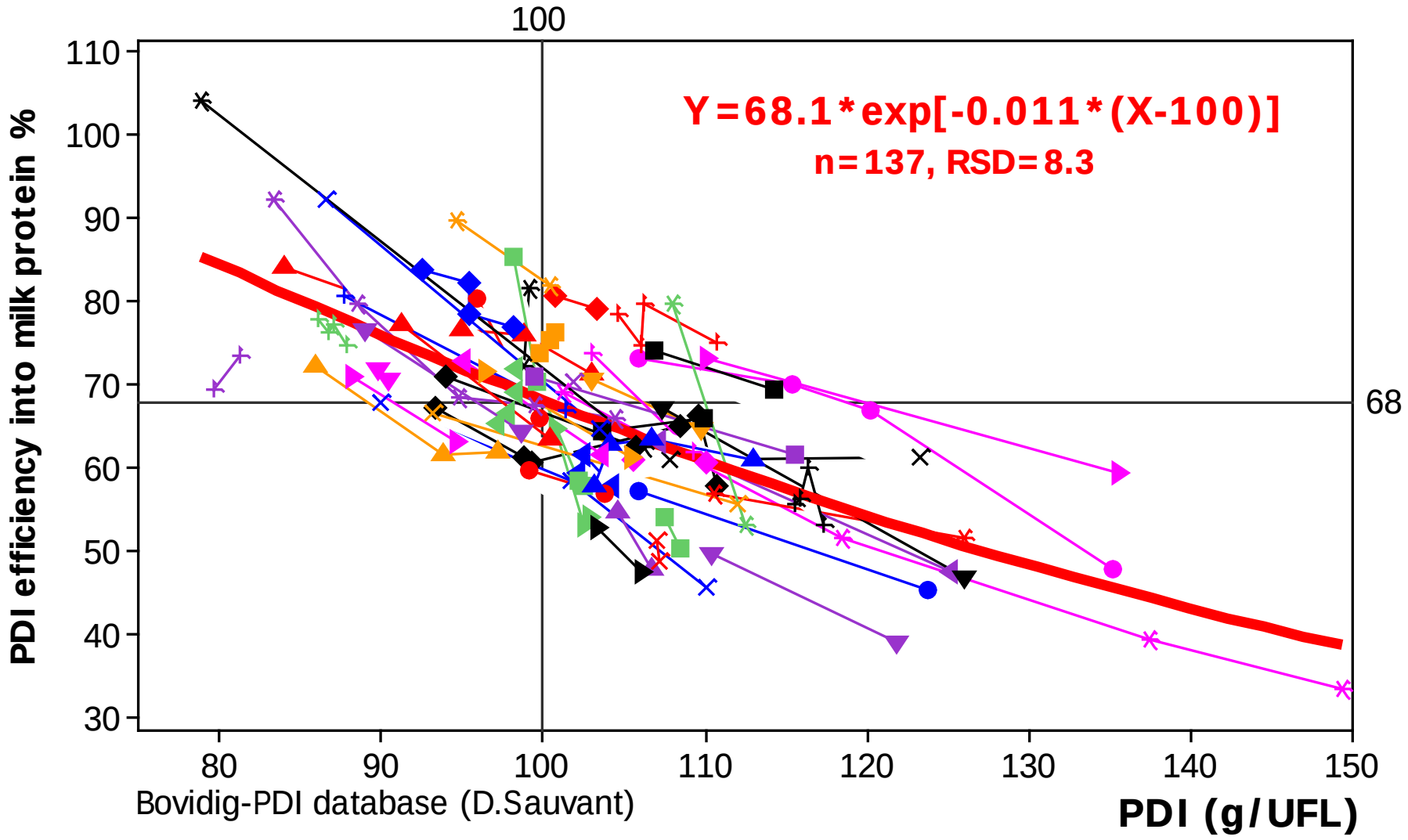
5.3.

Influence of MP / energy ratio on MP efficiency in dairy cows



Same relationship in g/DM
Interfering factors ?

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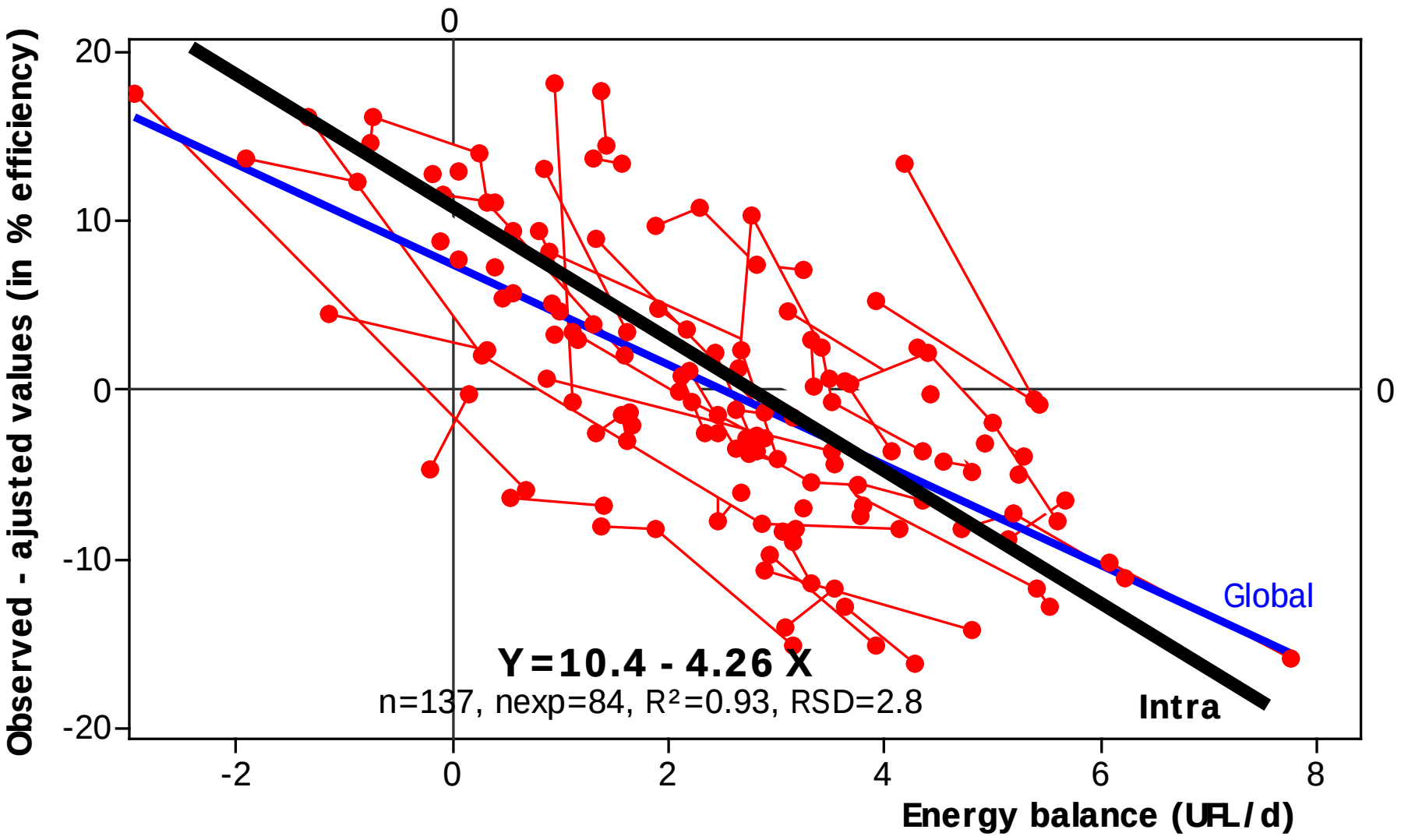
Interference of energy balance with efficiency response to MP/enegy ratio



1 MFU = 1.7 Mcal = 7.1 MJ

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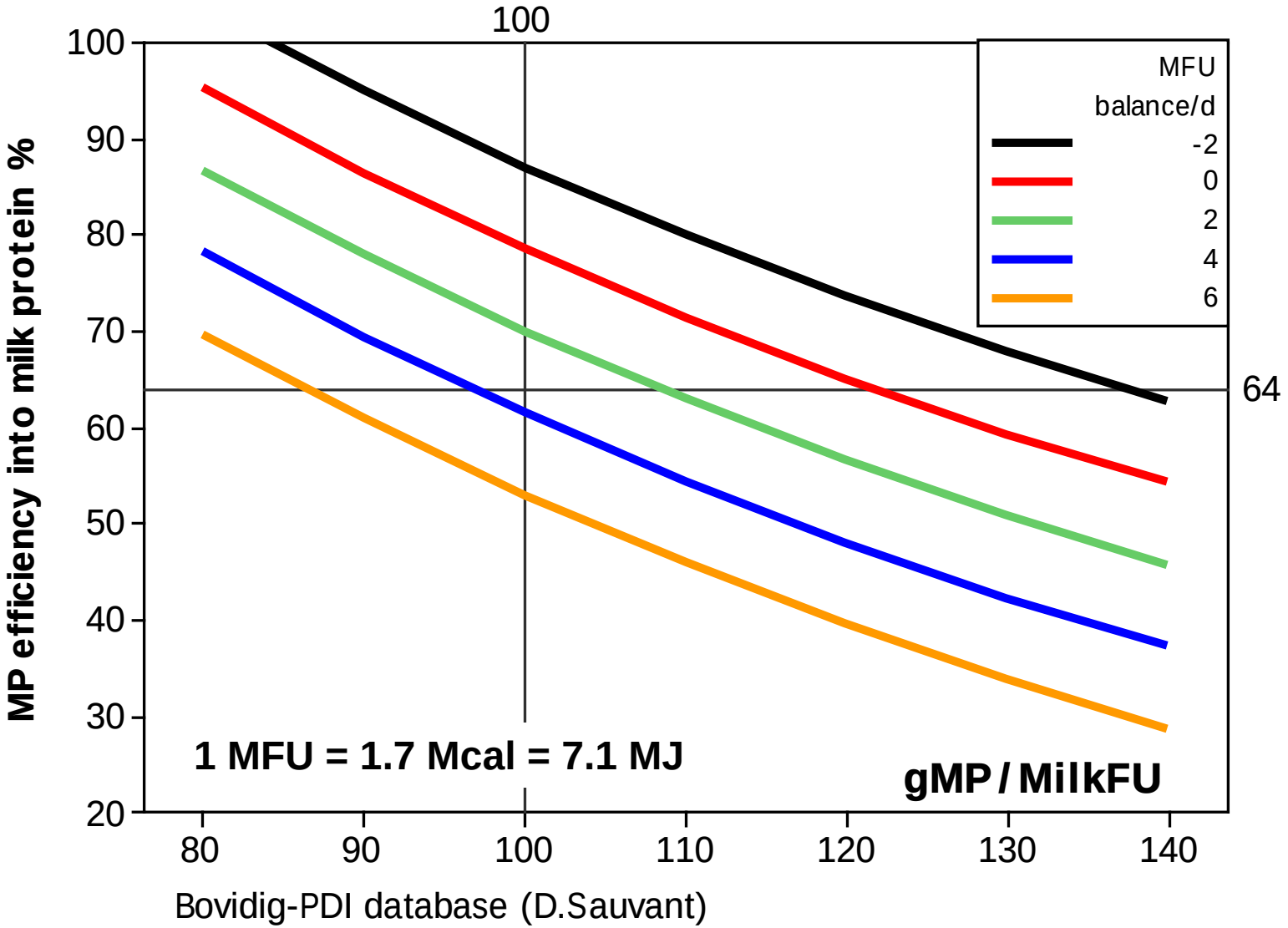
Influence of energy balance on MP efficiency in dairy cows



= outcome of nutrient partition between reserves and udder

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MP efficiency into milk protein previous proposals

Subnel et al., 1994 → NL system

MP Eff. = 117.6 – 3.04 MP/NEL (g/MJ) – 0.23 FCMY (kg)

Rico-Gomez et Faverdin, 2003

MP Eff. = 119 – 0.65 MP/UFL – 3.1 En. Bal. (UFL) + 0.35 FCMY (kg)
(no trial effect, R^2adj. = 0.90, RSD=2.6)

Volden et al., 2010 → NorFor system

MP Eff. 189.4 – 11.14 MP/NEL + 0.21 MP/NEL^2

Amino acid balance and Metabolizable Protein Efficiency (Rulquin & Faverdin, unp.)

- Curvilinear response of MP efficiency with an increase of essential amino acids content in proteins (+0.02 to +0.06 increase in MP efficiency)

MP efficiency = 0.71 - 0.0048 PDIE/UFL- 0.031 DMI+ 0.01 MY
+ 0.139 LysDi - 0.0082 $LysDi^2$ +0.038 MetDi

(no trial effect, R^2adj. = 0.85, RSD=0.041)

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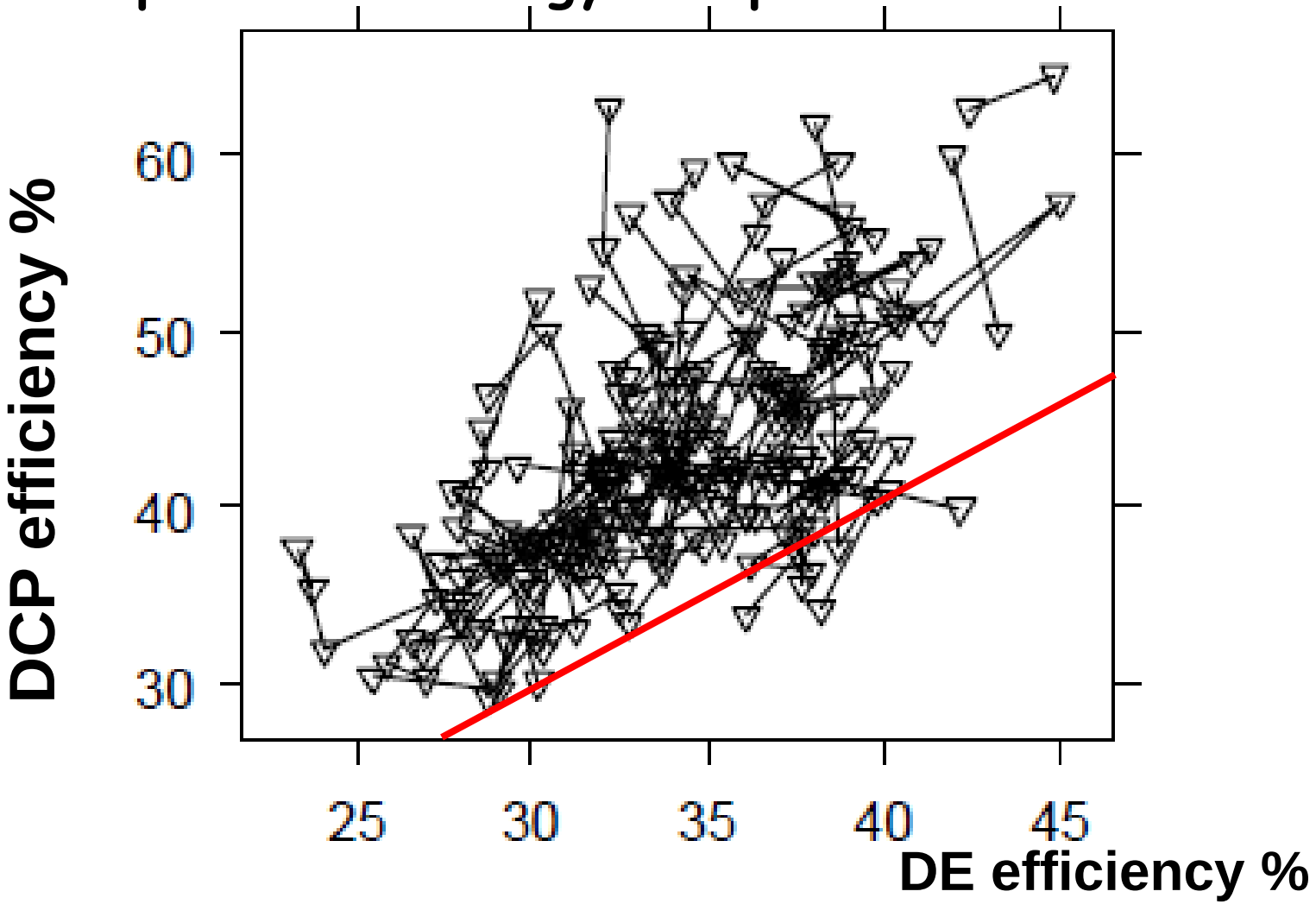
5.3. Relationship between Feed Protein Efficiency and Feed Efficiency ?

5.3.1. Variations across experiments
5.3.2. Influence of dietary CP
5.3.3. Influence of dietary concentrate
5.3.4. sub-relationship between CH4 and Nurine

Relationship between energy and protein efficiencies in cows



Phuong et al, 2013

N=253, Global R=0.62, Intra R=0.30
Influences of maintenance ? Of feeding pratices ?

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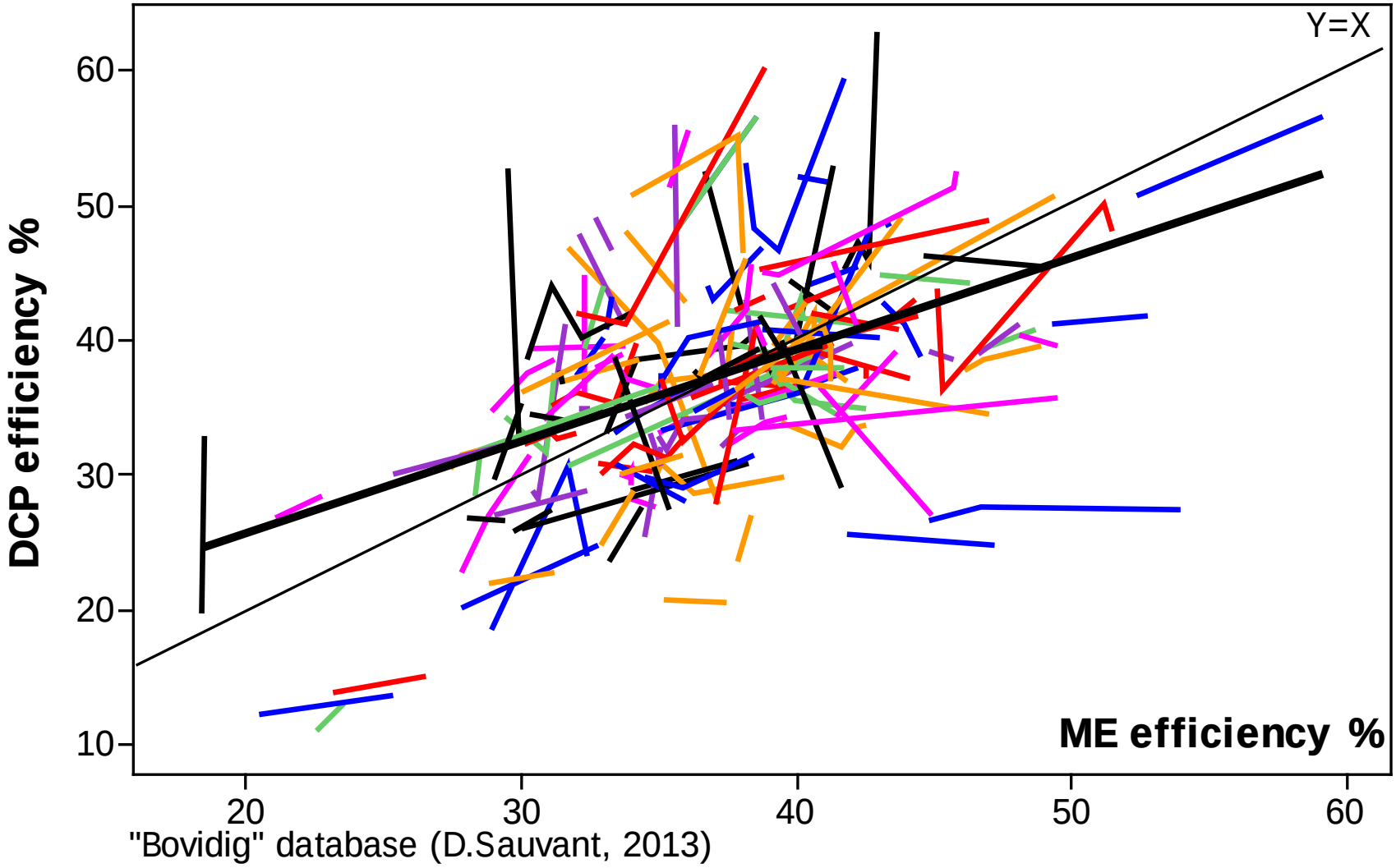
Inter and intra experiment relationship between protein and energy efficiency in dairy cows



n=354, Global R=0.49, Intra R=0.37, Tr with measured digestibilities
Large diversity of the intra-experiment relationships

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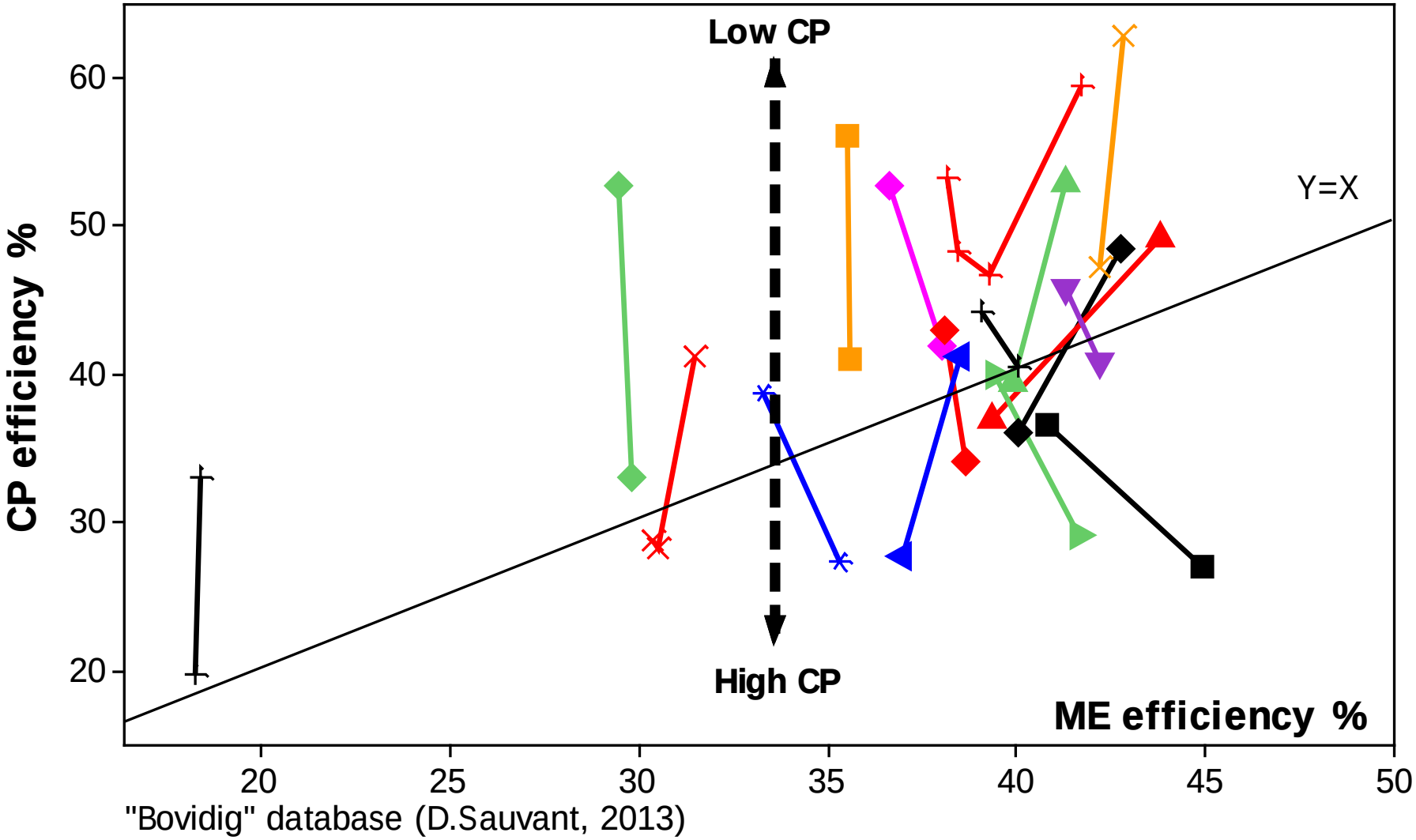
Influence of dietary protein on protein and energy effciency in dairy cows



Experiments focused on CP effect
CP level influences DCP but not ME efficiency

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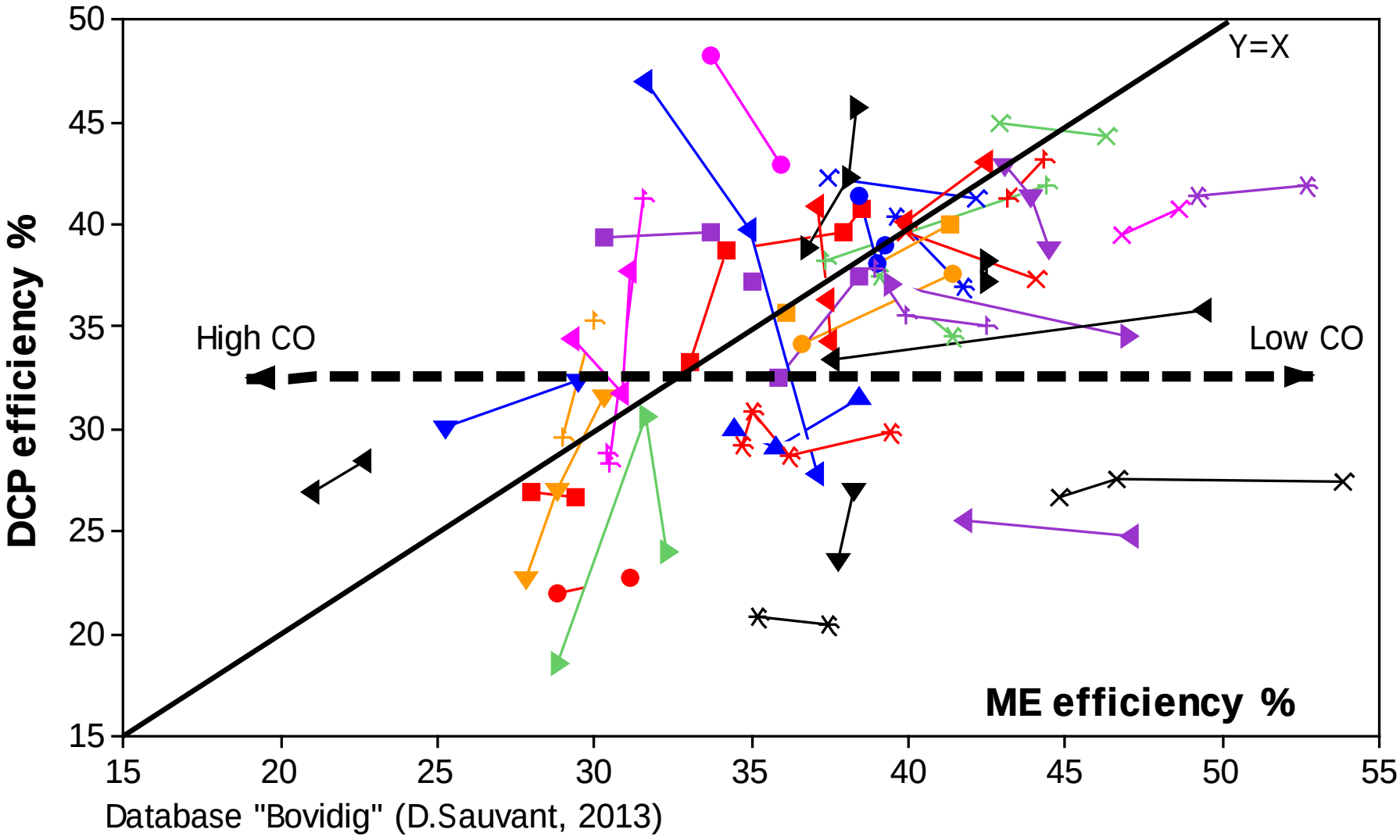
Influence of concentrate level on protein and energy efficiency in dairy cows



Experiments focused on concentrate effects
Concentrate level influences ME but not DCP efficiency

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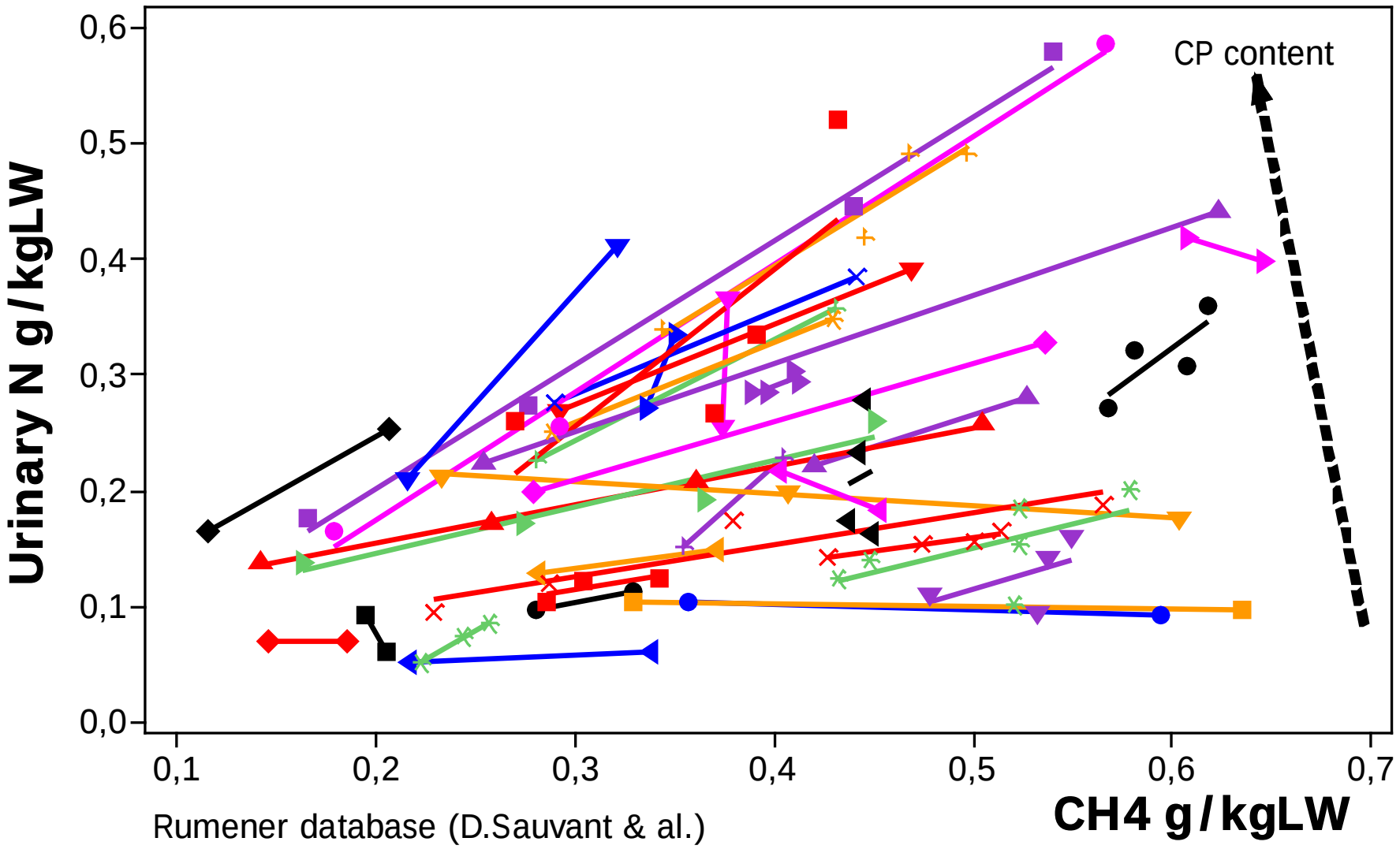

Interaction between CH4 and dietary CP

Partial conclusions on FPE ⇔ FE

- FPE and FE are >0 correlated

- Global R > Intra-exp R

Influence of maintenance more marked across exp

Intra-relationship ⇔ feeding pratices

- Relationship between CH4 and urinary N is CP dependant

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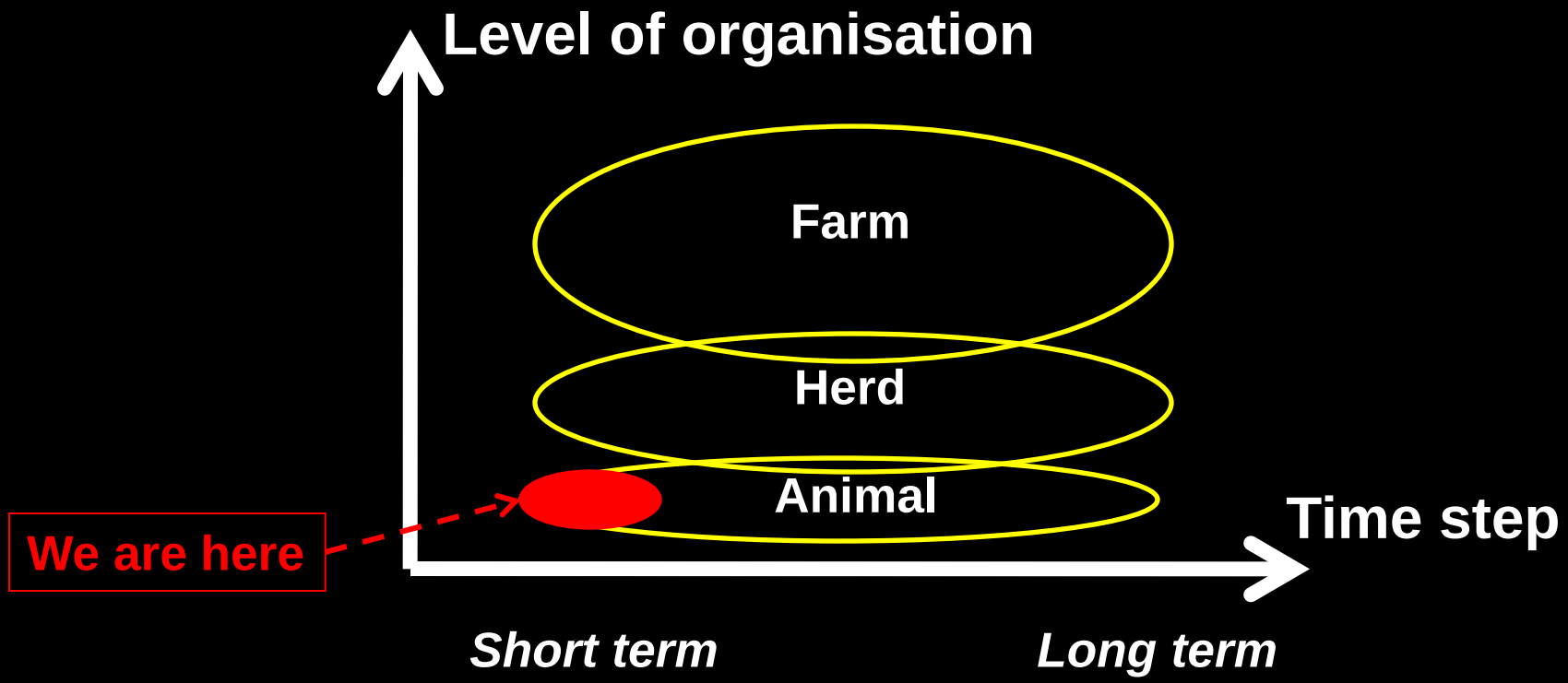
6. Toward a more systemic approach ?

6.1. Enlarging the levels x time scales

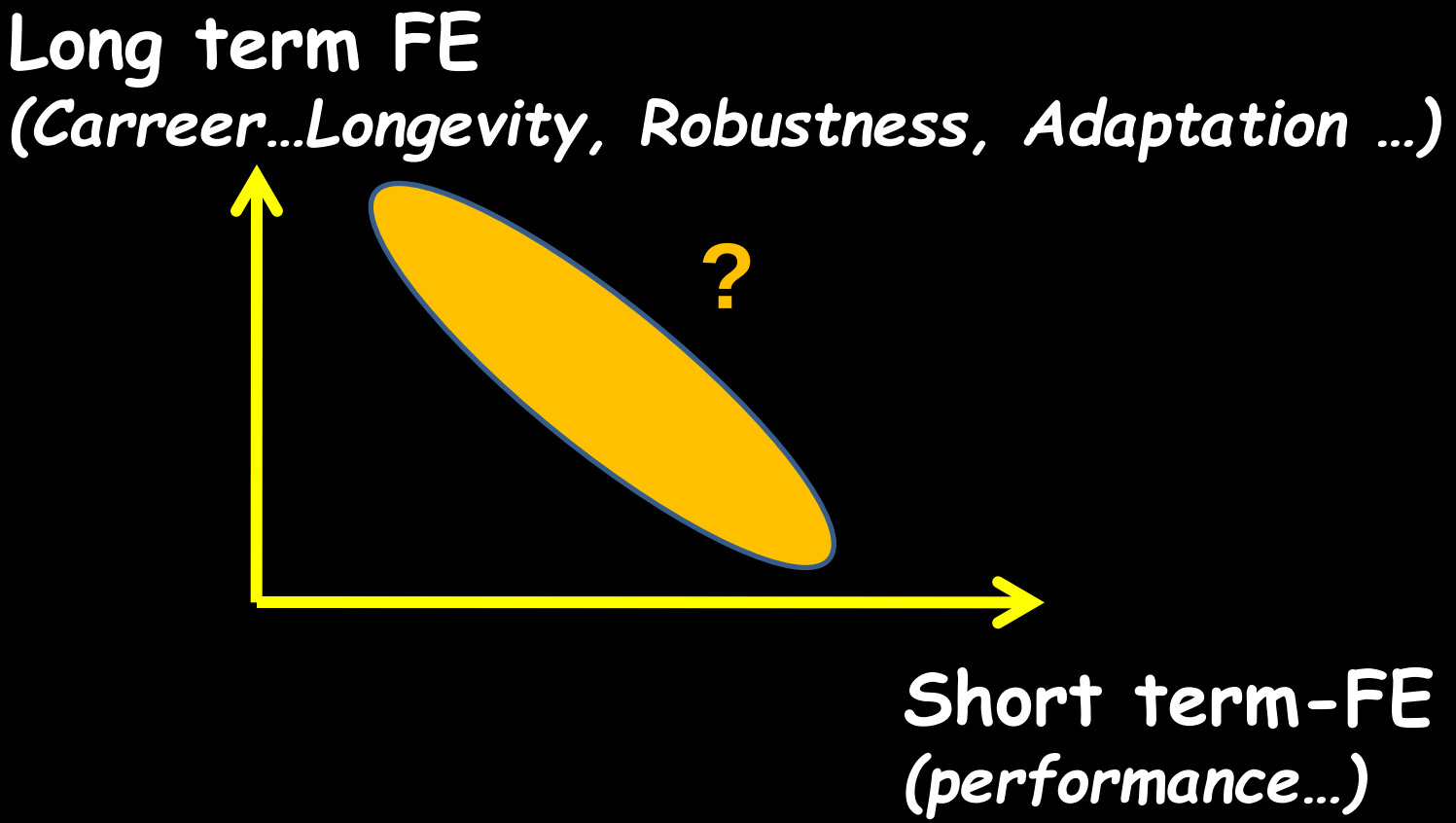
6.2. Systemic and teleonomic approach of efficiency ?

6.1. Enlarging the levels x time scales

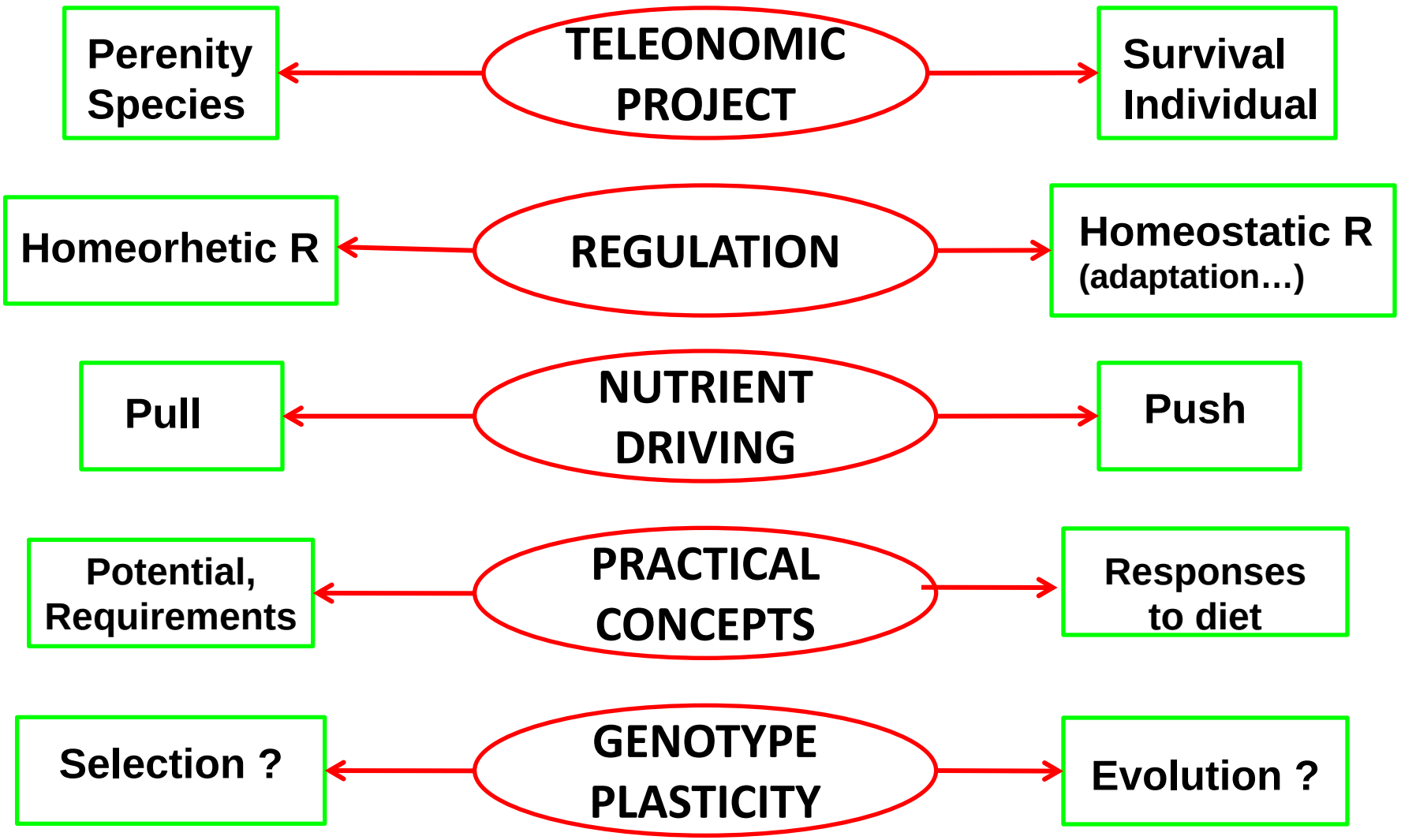


Which trade off between short term FE and other aspects ?

Trade-off between short and long term FE ?



6.2. Systemic & teleonomic approaches of Metabolic Eff.



CONCLUSIONS

Digestive Eff. > Metabolic Eff.

Digestive Eff. is mainly dependant on dietary factors

Metabolic EFF is largely dependant on maintenance requirements

Levels of metabolisable E and P over maintenance largely influence the corresponding metabolic efficiencies

Rumen is an influent organ

FE = one of the multicriteria reponses to feeding practice

Interest of a systemic view of efficiency

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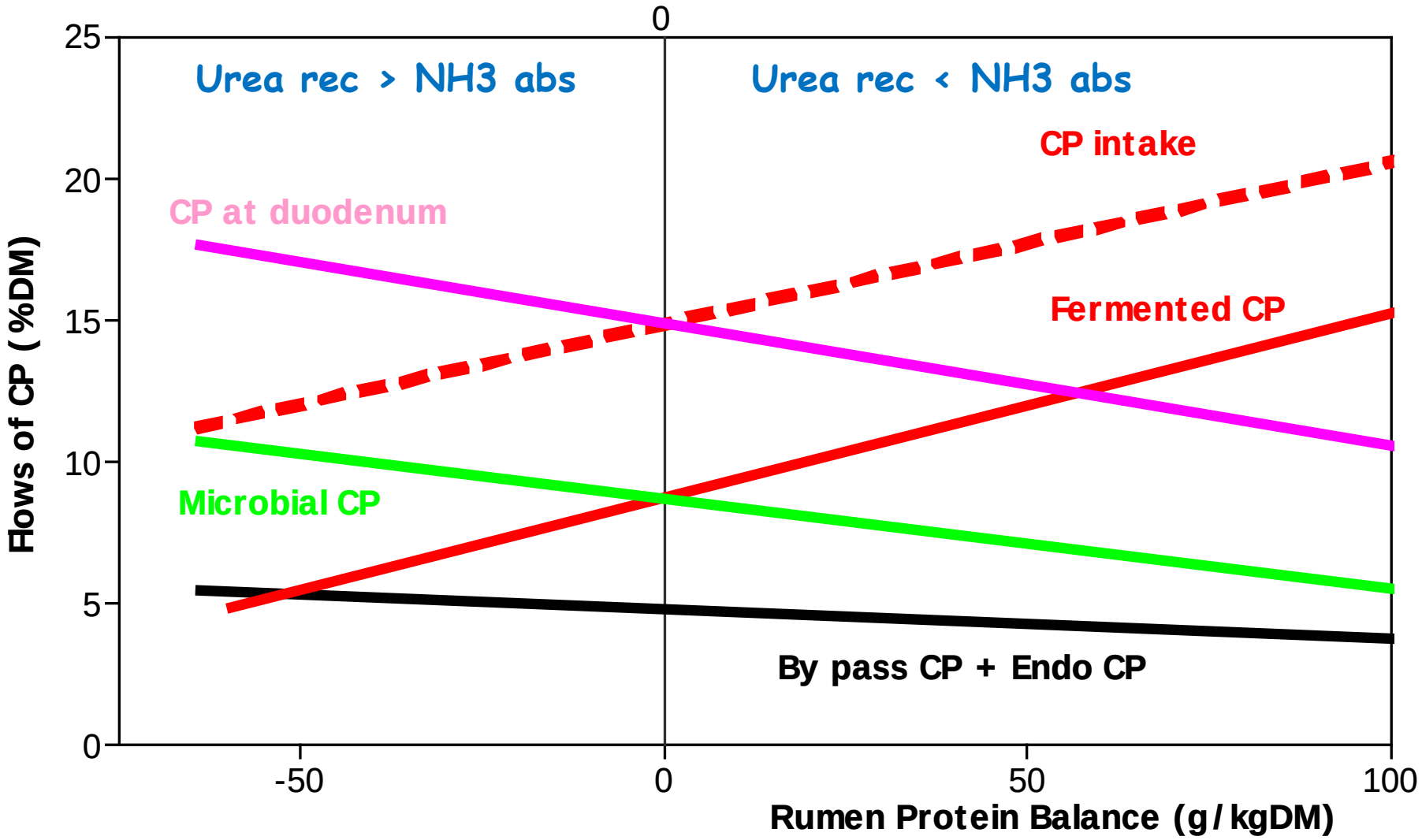
5.2.

Relationship between Rumen Protein Balance and various flows of CP in cattle



(CP intake – CP at duodenum)

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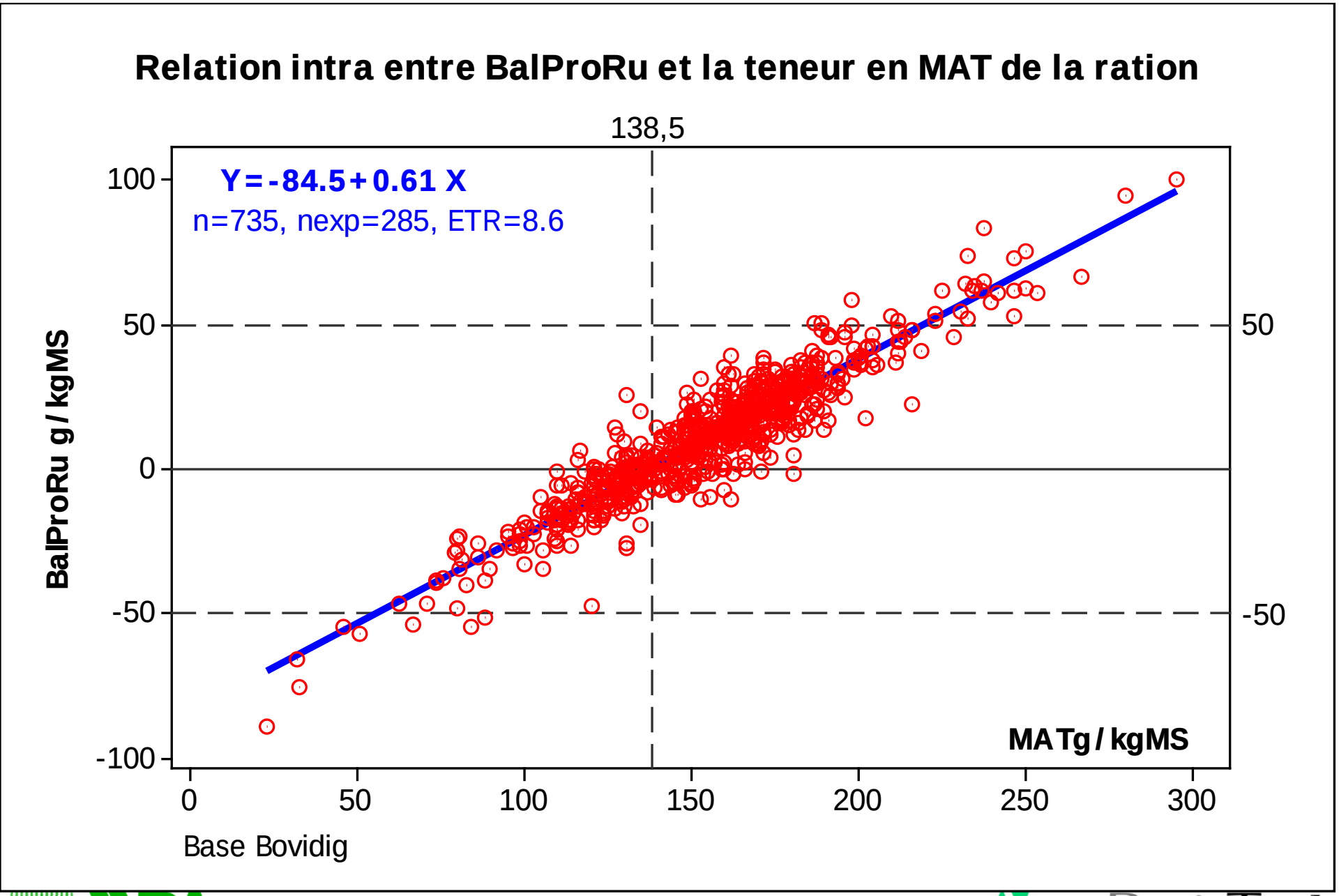
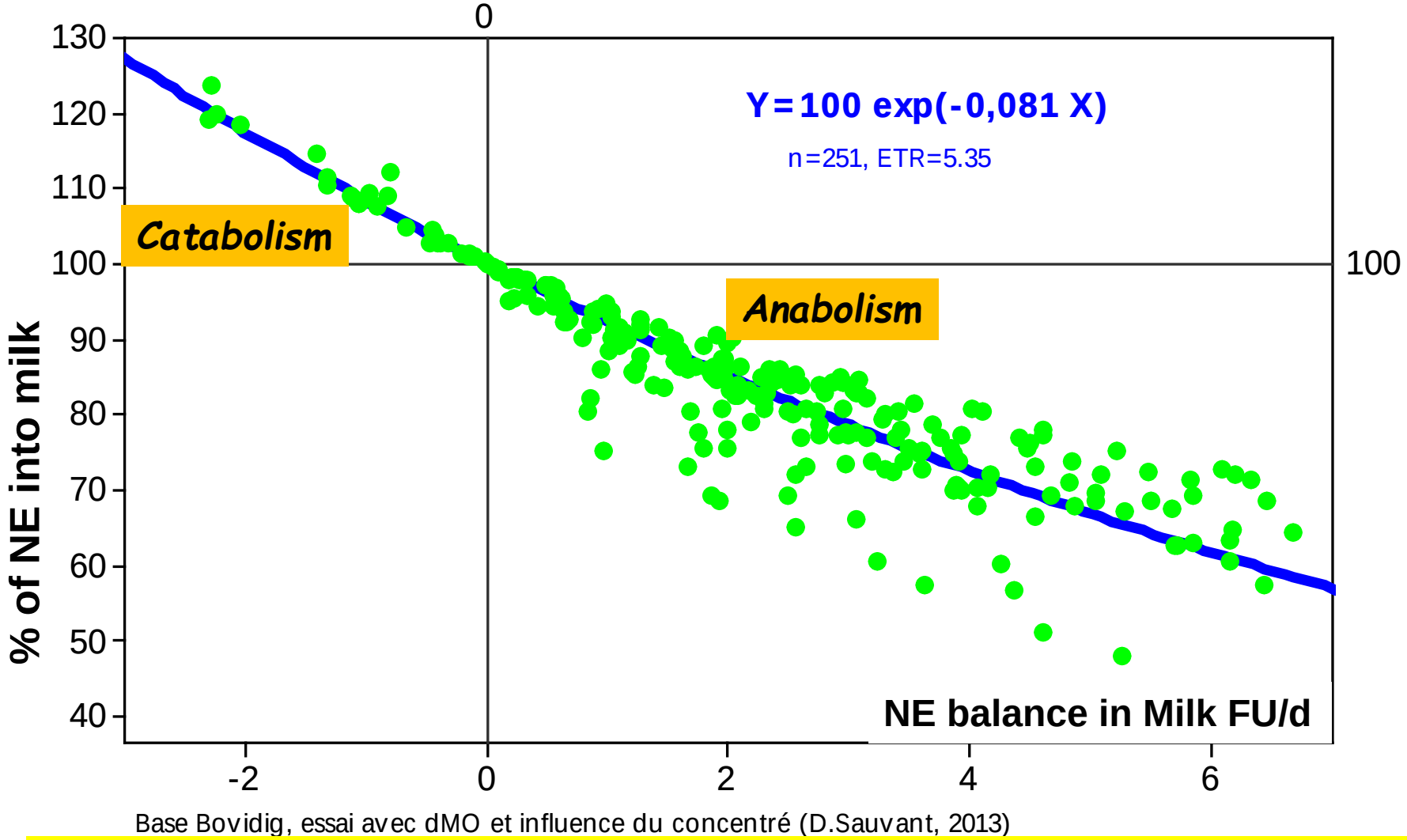
FIGURE 11


Relation intra entre BalProRu et la teneur en MAT de la ration
138,5
Y = -84.5 + 0.61 X
n=735, nexp=285, ETR=8.6
100
50
0
-50
-100
50
-50
BalProRu g / kgMS
MA Tg / kgMS
0
50
100
150
200
250
300
Base Bovidig

3.2.2.

Relationship between NE balance and NE efficiency into milk in cows



Base Bovidig, essai avec dMO et influence du concentré (D.Sauvant, 2013)

NE Bal = 0 ➔ 100% of $NE_{milk+res}$ = NE_{milk}

Similar relationship with dairy cows and goats when NE expressed / kg LW

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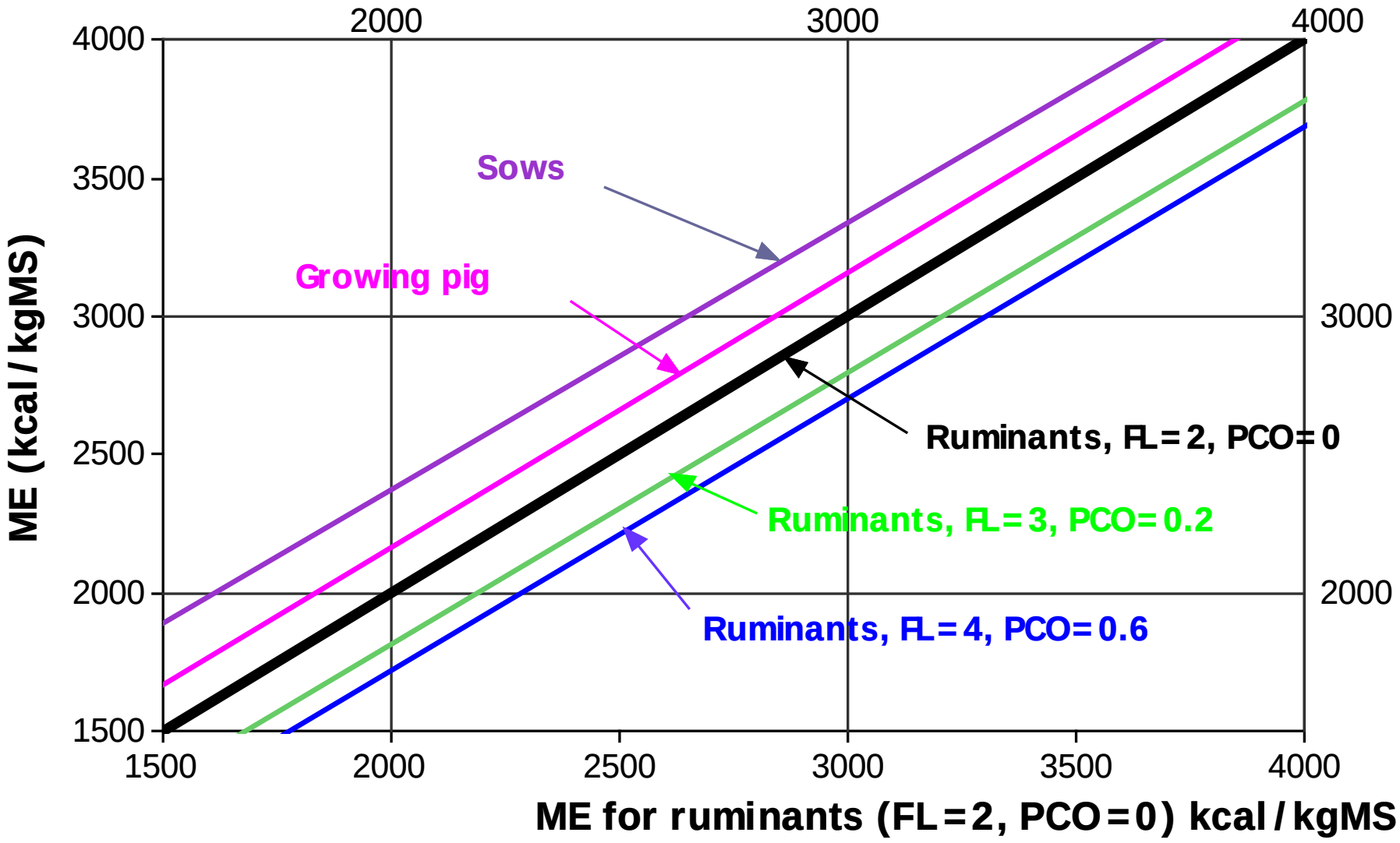
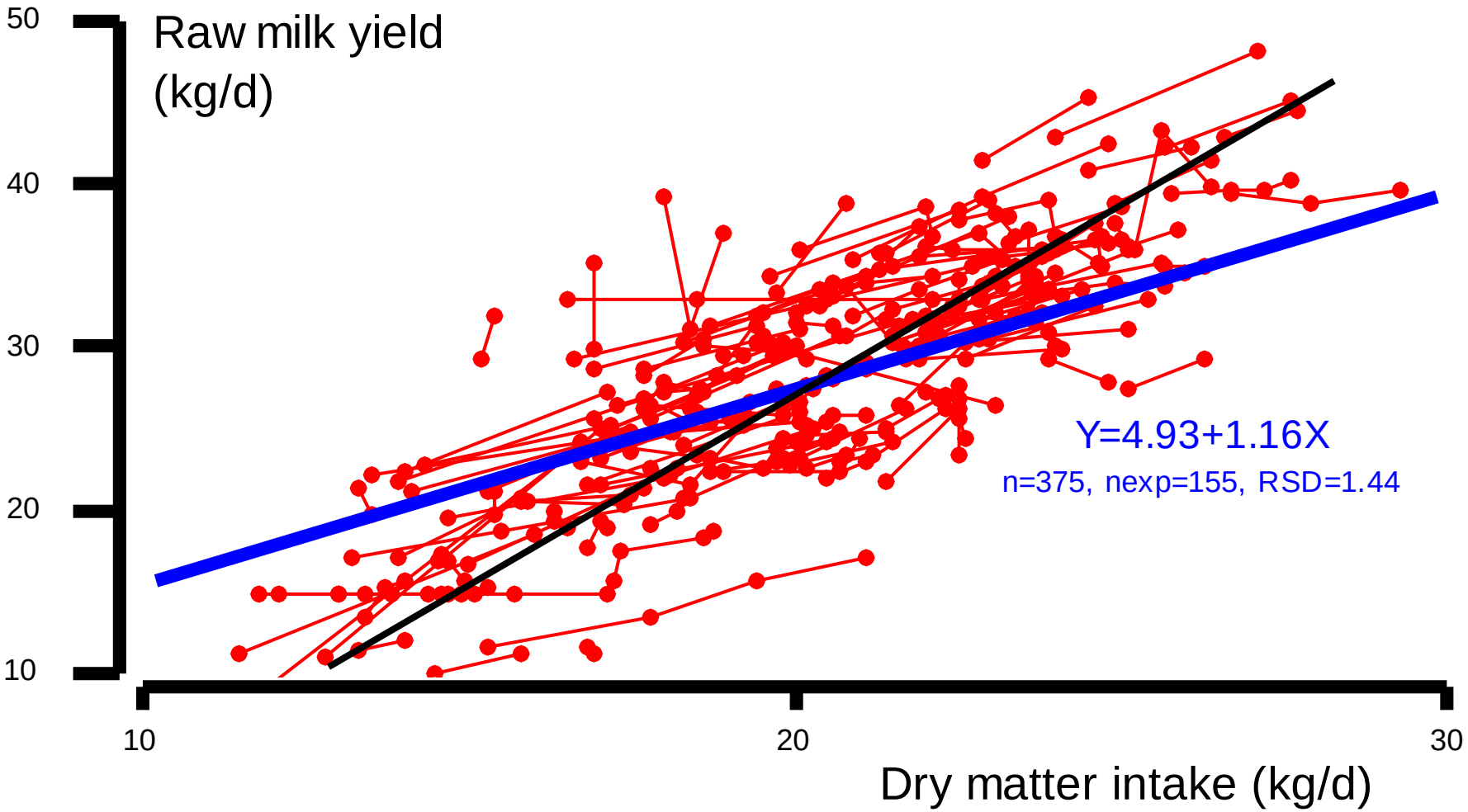
Ranking ME content of feeds according to the species and ruminant FL and PCO



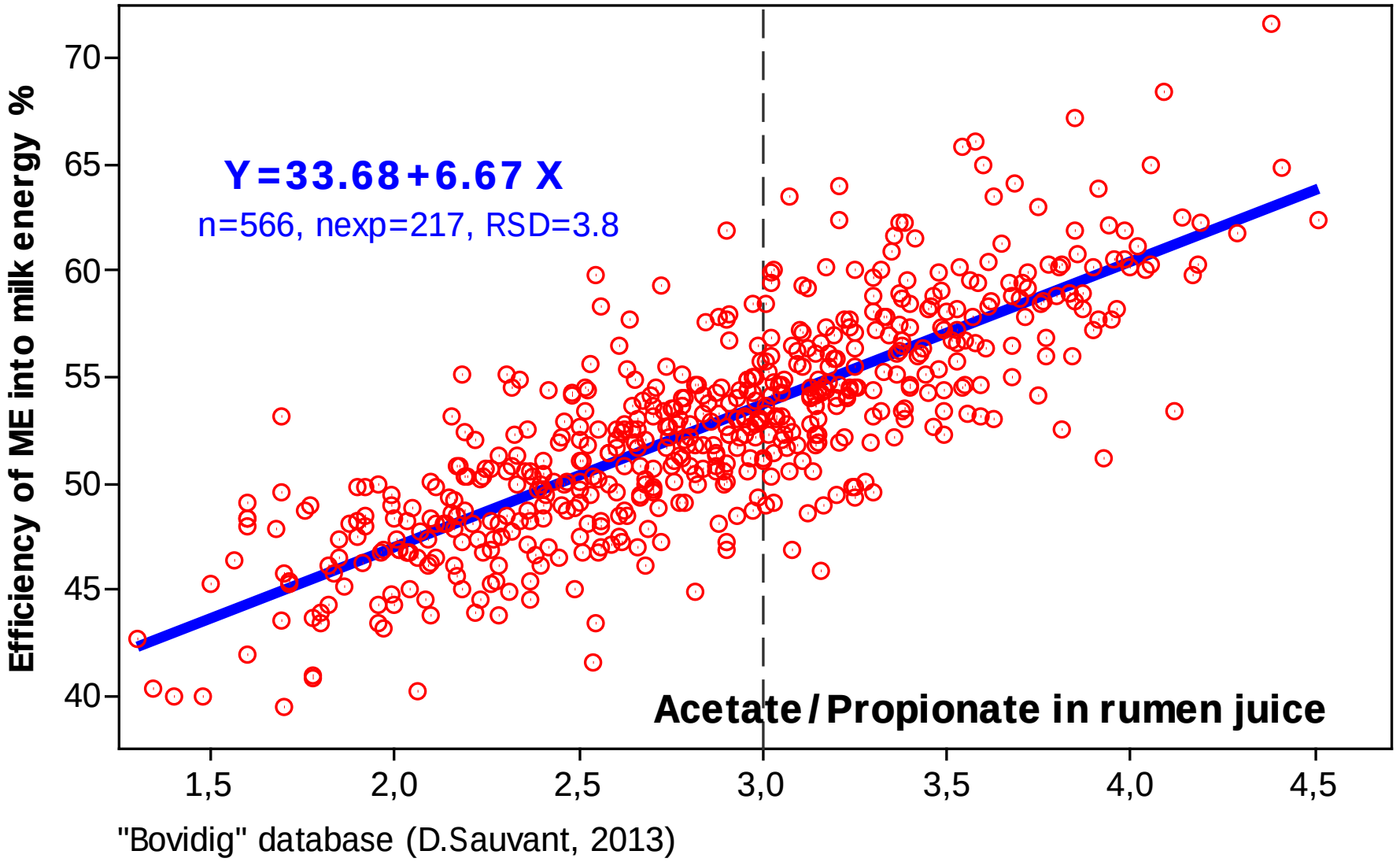
Simultaneous response of lactating cows of RMY and DMI to concentrate supply



Base Bovidig (D.Sauvant & al., 2011)

+ 1 kg MSI ➔ + 1.16 kg Lait brut

Intra-experiment influence of Acetate / Propionate on efficiency of ME into milk energy



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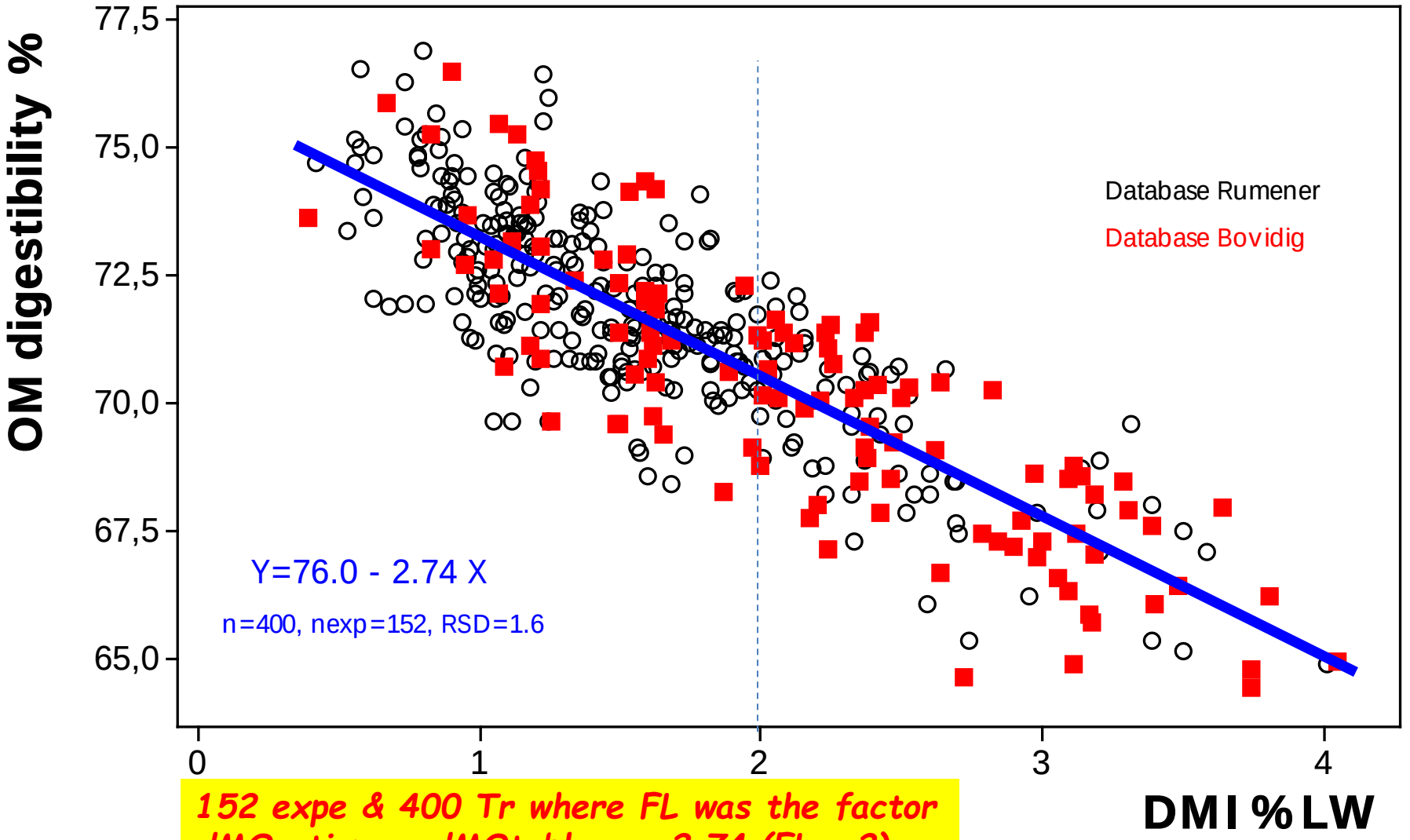
Influence of DMI %LW on the diet OM digestibility



152 expe & 400 Tr where FL was the factor
dMOration = dMOtables - 2.74 (FL – 2)

D.Sauvant & al., 2013

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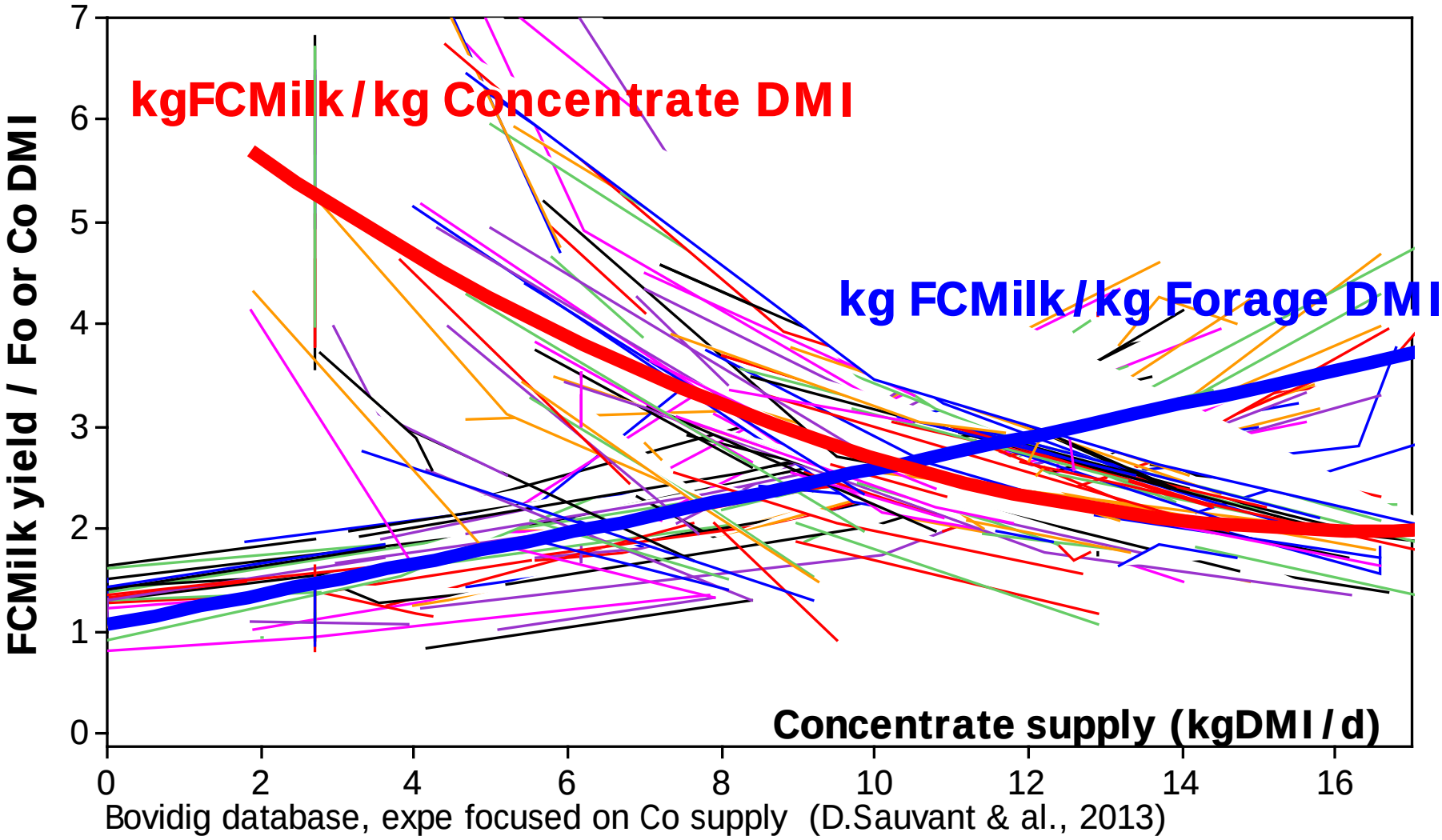
FCMilk yield / kg Fo or Co in cows in function of concentrate supply



Bovidig database, expe focused on Co supply (D.Sauvant & al., 2013)

Opposite responses of Feed efficiency of concentrate and forage

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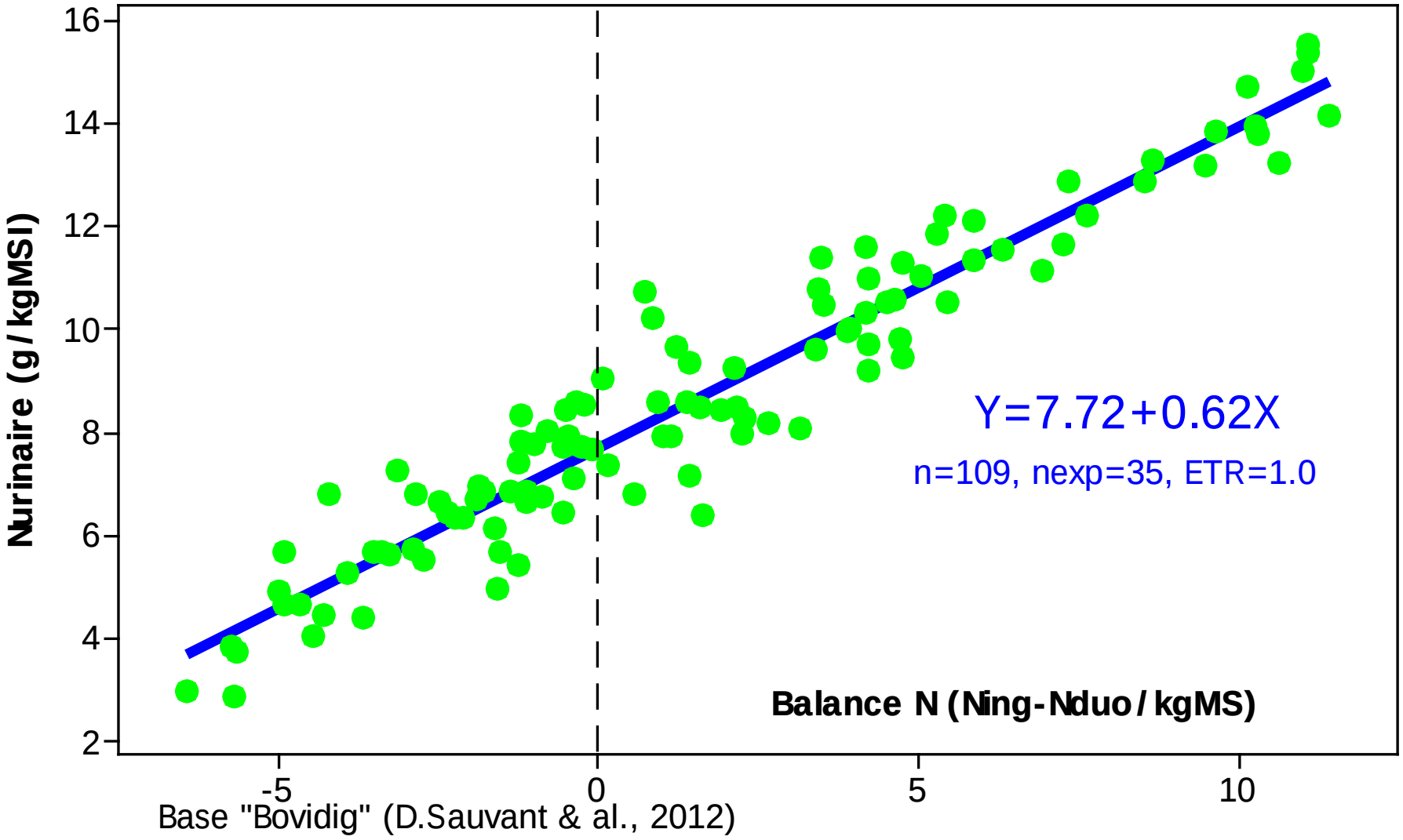
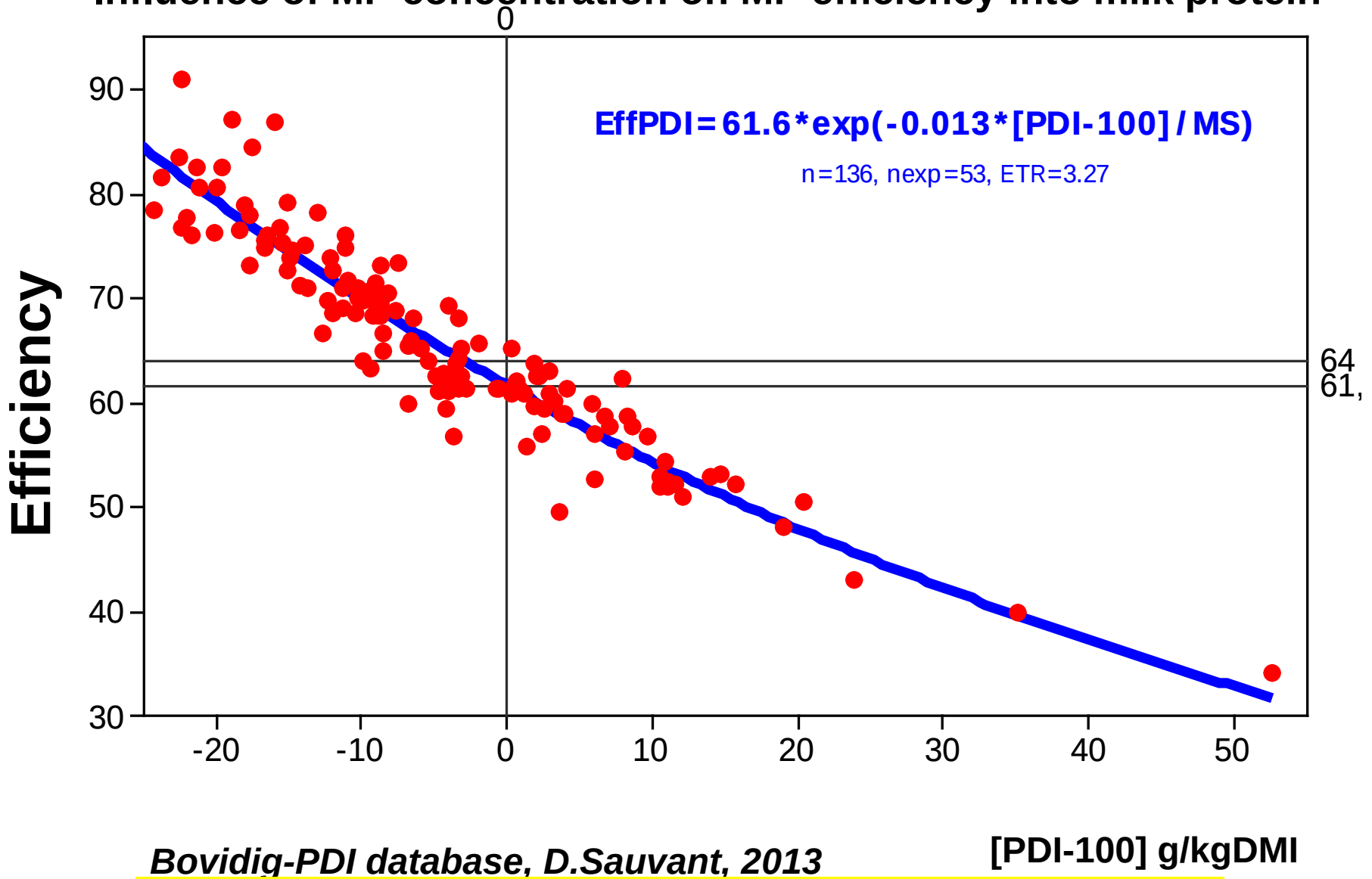
FIGURE 10

Influence des variations de la balance azotée du rumen sur les rejets N urinaires



Influence of MP concentration on MP efficiency into milk protein

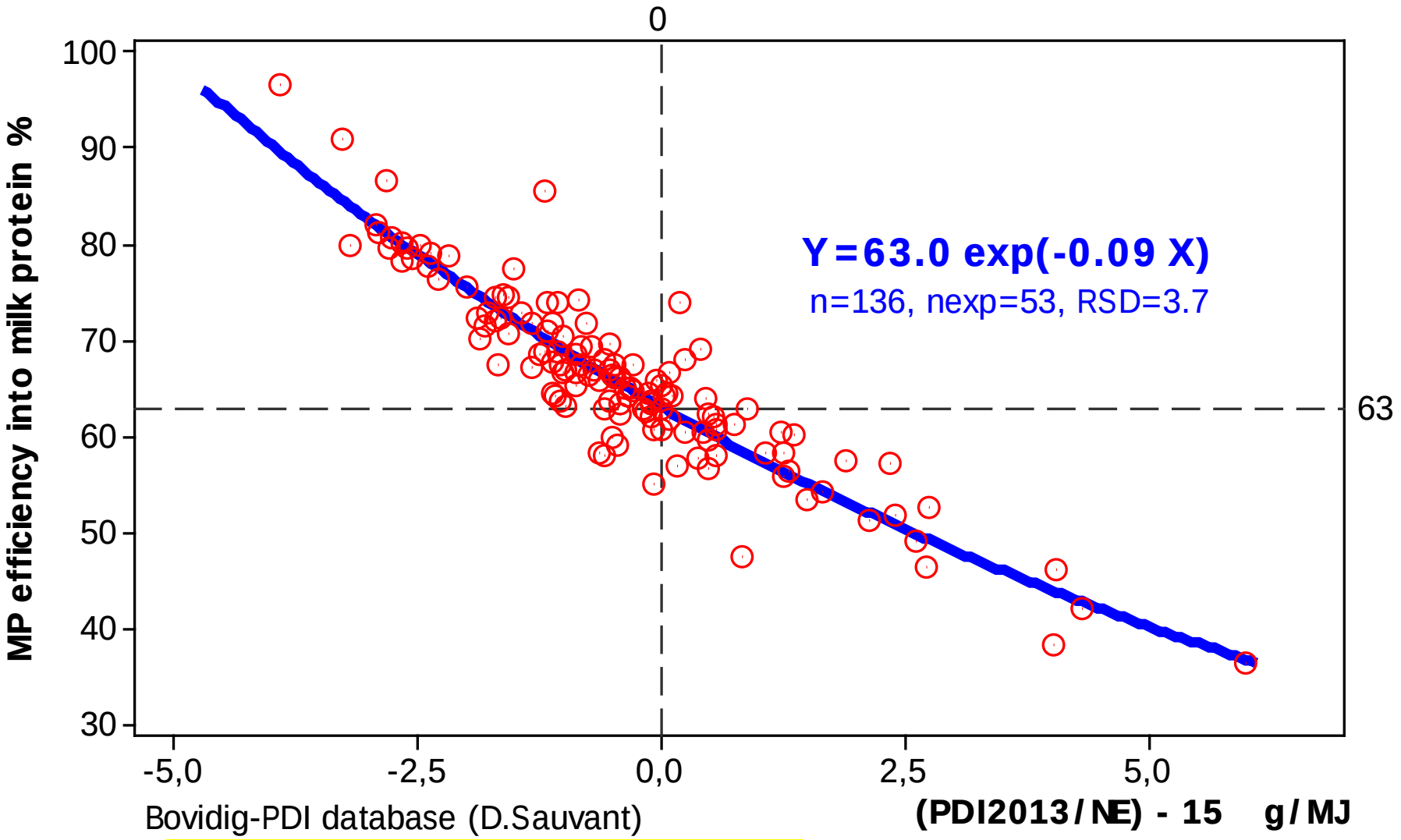


Bovidig-PDI database, D.Sauvant, 2013

[PDI-100] g/kgDMI

No better precision when MP expressed on an energy basis
No influence of FCMY and DMI%LW (as in NorFor)
Similar equation with dairy goats

Influence of MP supply on MP efficiency into milk protein in dairy cows



Similar equation with dairy goats
Other influencing factors ?

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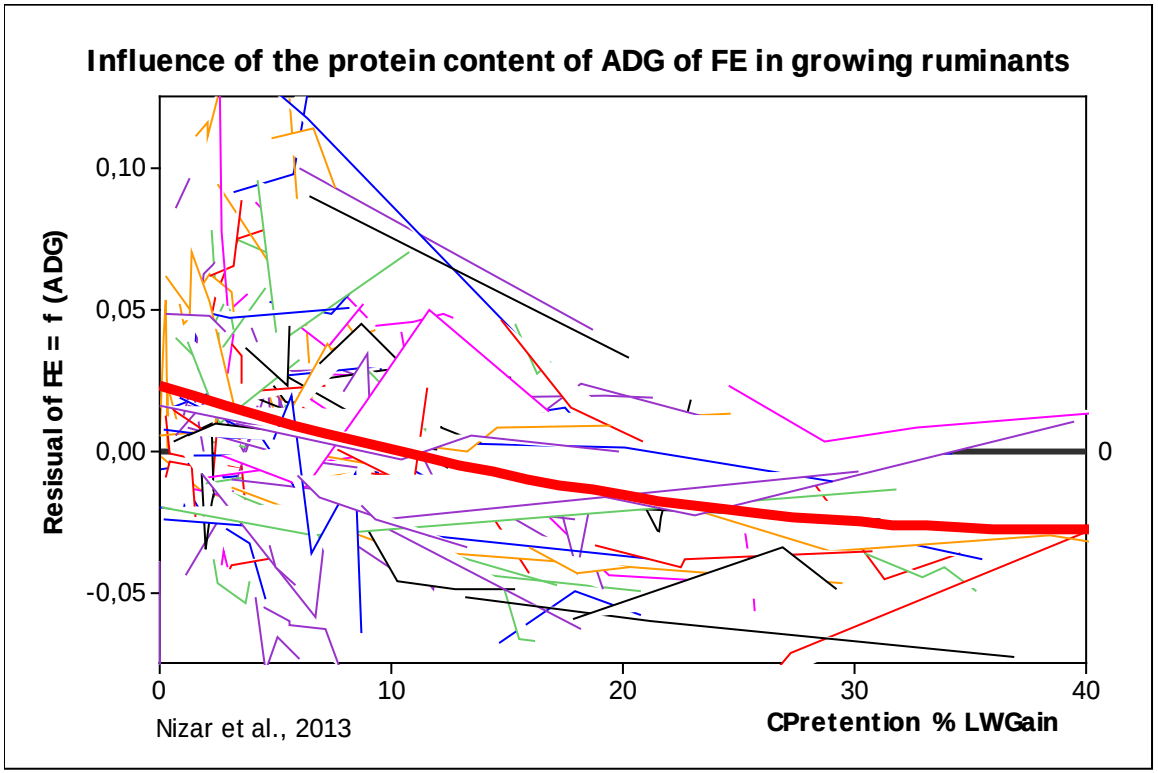
Influence of the protein content of ADG of FE in growing ruminants
Resisual of FE = f (ADG)
0,10
0,05
0,00
-0,05
0
10
20
30
40
0
CPretention % LWGain
Nizar et al., 2013