Ruminant Farm Systems Model

Animal Module (Dairy feed ration)

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Two directions of the model

Undefined diet

Input:

- Animal state
- Feed (On farm)
- Feed (Purchased)

→

Output:

- Nutrient requirement
- Feed intake
- Feed formula
- Manure production

Defined diet

Input:

- Diet
- Animal state

→

Output:

- Growth
- Milk production
- Manure production

Materials and Methods

- The new NRC is the foundation of the ration formulation module
- Minimum feed cost is the objective
- Linear programming (LP) is used in current simulations (lpSolve package in R)
- An attempt on non-linear programming (NLP) is made (nloptr package in R)

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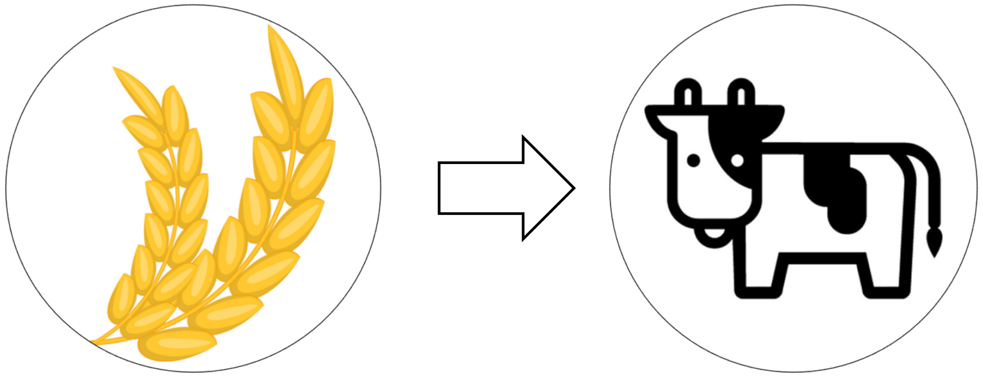
Nutrient supply & requirement

Supply (Feed)

- Feed table from NRC (peNDF from CNCPS feed library)
- Digestibility calculation



Requirement (Animal)

- Energy (New NRC)
- Protein (New NRC)
- peNDF (CNCPS)
- Forage NDF (NRC 2001)
- Ca (NRC 2001)
- P (NRC 2001)
- Other constraints (fat, forage, DMI)

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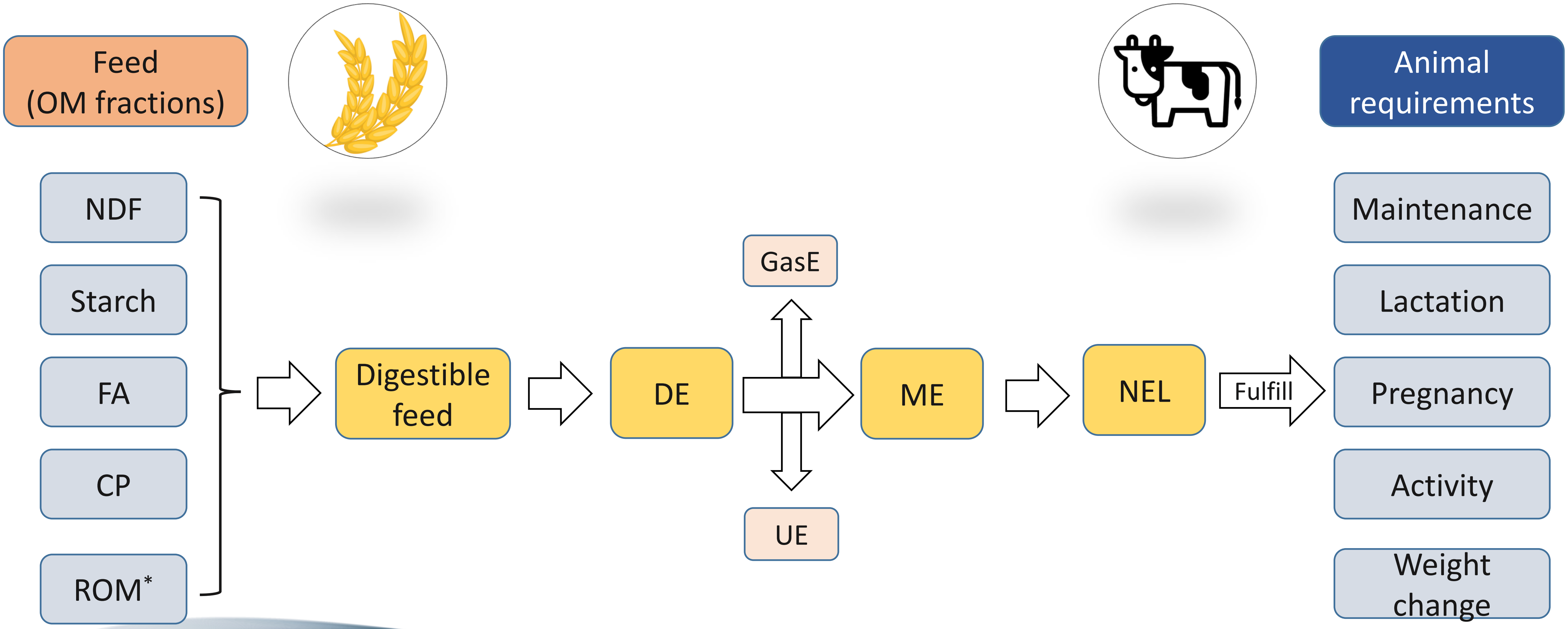
Energy



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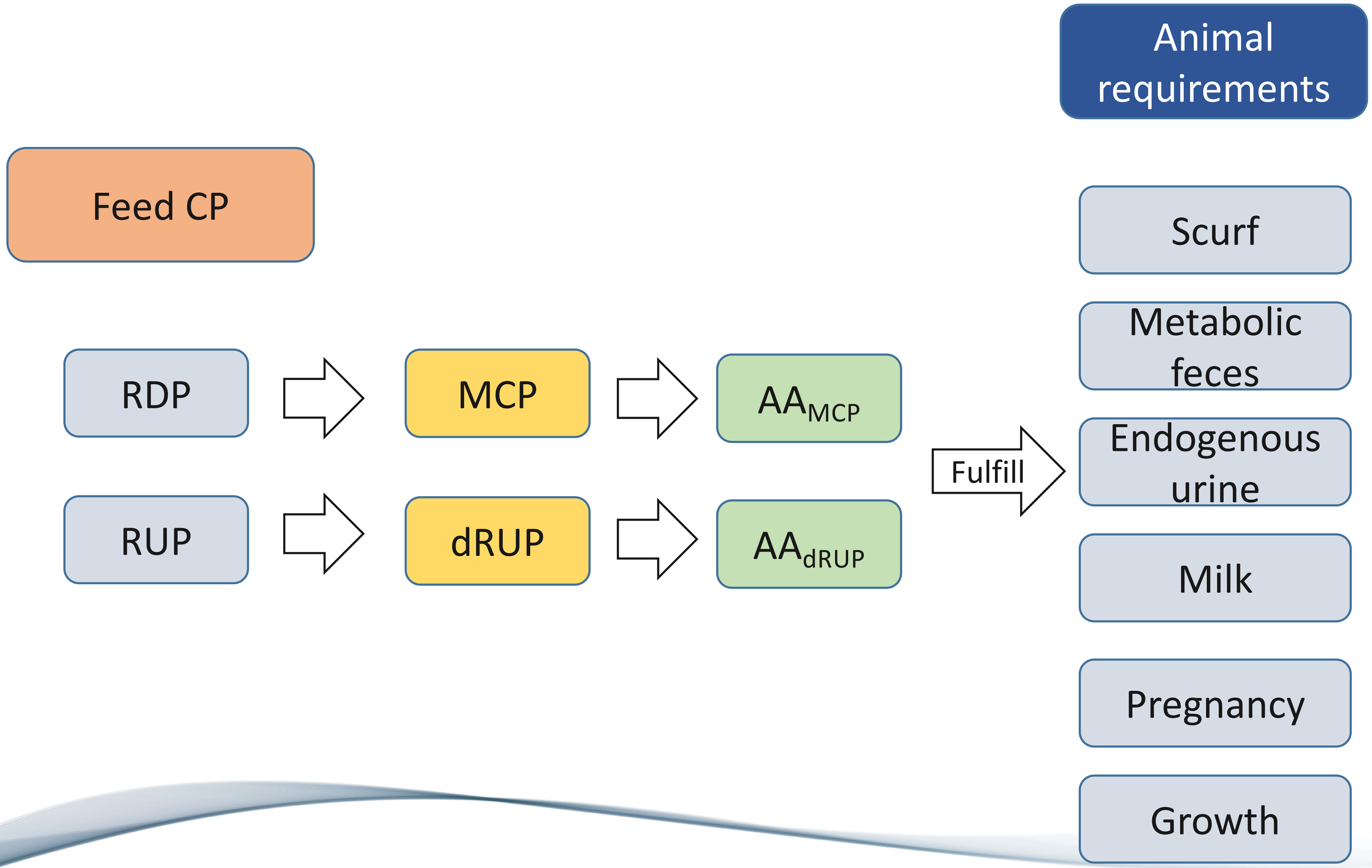
* Residue organic matter: ROM = 100 – Ash – NDF – Starch – FA / Fat Factor – CP

Protein



- Amino acids (AA) requirements are used instead of protein requirement
- 9 essential AA requirements are specified: His, Ile, Leu, Lys, Met, Phe, Thr, Trp and Val, with each having 6 components
- The AA profiles of MCP, RUP and the 6 components are also specified by NRC

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The challenge when applying LP

The nutrients of feeds (input) are affected by DMI and dietary information (output)

e.g.: $\mathbf{dNDF_i = dNDF\_base_i - 0.43 \cdot (Starch\_Diet / 100 - 0.26) - 3.0 \cdot (DMI / BW - 0.035)}$

$\mathbf{dStarch_i = dStarch\_base_i - 1.0 \cdot (DMI / BW - 0.035)}$

Strategy:

- Replace dietary information with feed information (Starch_Diet → $Starch\_DM_i$)
- Iterate for DMI

Iteration

- 3 feeds: A (x_1), B (x_2), C (x_3)
- Estimated DMI (DMI_{est})

LP

Actual values of x_1, x_2, x_3

The actual DMI (DMI_{ac}) = $x_1 + x_2 + x_3$
(not equal to DMI_{est} in general)

If | DMI_{est} - DMI_{ac} | > 0.5

Yes: Replace DMI_{est} with DMI_{ac} → LP

No: Outputs of x_1, x_2, x_3

Iteration

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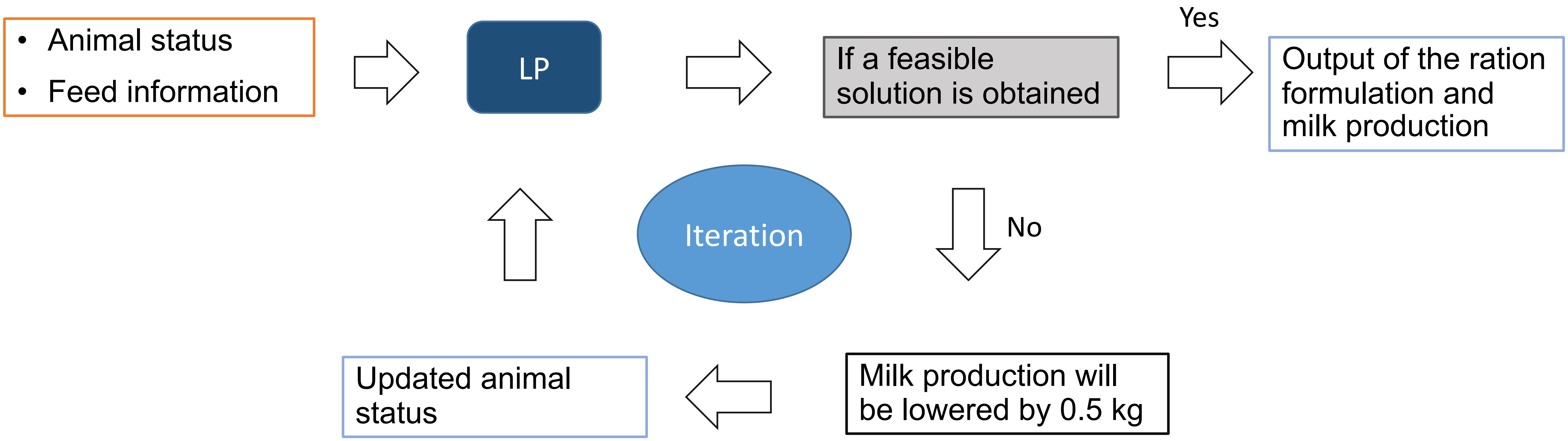
LP flowchart



LP simulation

Animal information:

- Body weight = 600 kg
- Days in milk = 100
- Milk production = 35 kg
- Milk protein = 3.2%
- Milk fat = 3.5%
- Milk lactose = 4.85%

Feed compositions (% of DM) and prices ($/kg of DM)

Feed	DM	CP	FA	NDF	ADF	Starch	Price
Alfalfa hay	90.75	19.00	1.61	42.85	33.88	1.83	0.23
Beet pulp	92.30	9.92	0.63	46.85	28.25	0.64	0.23
Corn gluten	89.16	23.19	3.38	35.68	11.52	15.51	0.19
Corn silage	31.27	7.91	2.32	42.59	25.50	30.18	0.07
DDGS	91.07	38.99	6.56	37.60	17.71	6.20	0.16

LP simulation

Objective

$Cost_{min}$

Constraints

- ME
- Forage NDF
- 9 EAA
- Fat < 7%
- peNDF
- Forage < 70%
- Ca
- DMI
- P

$Cost_{min}$ = $3.93/cow

- Alfalfa hay = 8.91 kg
- Beet pulp = 2.45 kg
- Corn gluten = 0
- Corn silage = 7.9 kg
- DDGS = 4.75 kg
- Total = 24.01 kg

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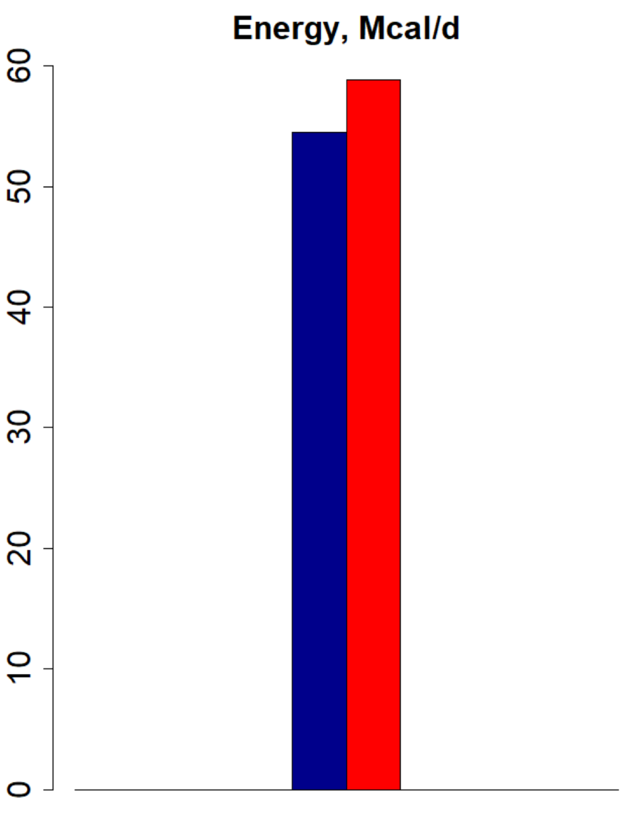
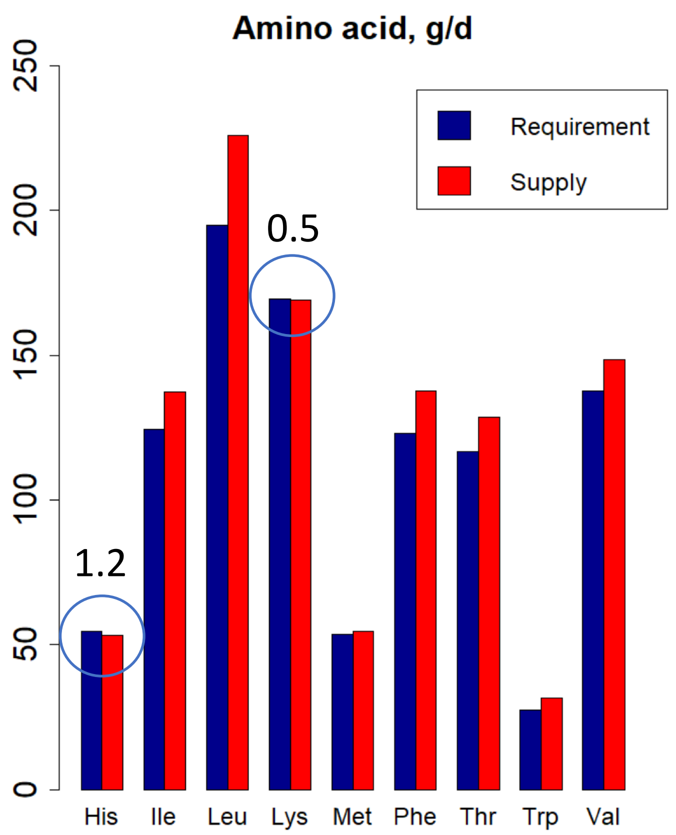
Ration evaluation





Nutrient compositions of the diet

Nutrients	% of DM
CP	18.38
FA	2.72
NDF	42.13
Ca	0.73
P	0.31
Starch	11.90
Forage	70

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Challenge 2 when applying LP

The calculation of microbial crude protein (MCP, kg):

MCP = [110.7 + (81.6 · RDP_Diet)] / (1 + 0.0939/RDNDF + 0.0274/RDS) / 1000 · 6.25,

where RDP_Diet = Dietary RDP, kg; RDNDF = Rumen degradable NDF, kg; RDS = Rumen degradable starch, kg

RDNDF = (-31.9 + 0.721 · NDF_Diet - 0.247 · Starch_Diet + 6.63 · CP_Diet - 0.211 · CP_Diet ^ 2 - 0.387 · ADF_Diet / NDF_Diet · 100 + 1.51 · DMI - 0.121 · WetForage_Diet) · NDF_Intake / 100

RDS = (70.6 - 1.45 · DMI + 0.424 · ForNDF_Diet + 1.39 · Starch_Diet - 0.0219 · Starch_Diet ^ 2 - 0.154 · WetForage_Diet) · Starch_intake / 100

Strategy:

MCP ≈ [110.7 + (81.6 · RDP_Diet)] / 1000 · 6.25

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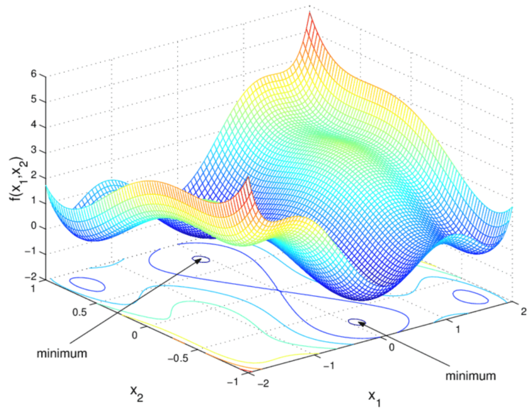
NRC structure is not compatible with LP

- Replace dietary information with feed information
- Iterate for DMI
- Take an approximation of MCP



A small deficiency of some nutrient requirements

A different tool:
Non-linear programming

Non-linear programming (NLP)

- No limitation on linearity
- Dietary information can be directly used
- No need to iterate for DMI
- Non-linear models such as the calculation of MCP can be used without taking approximation

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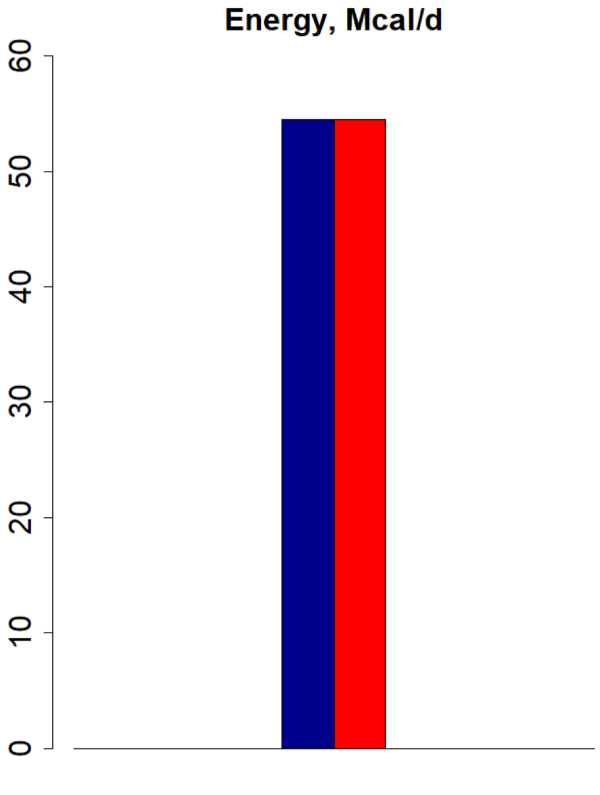
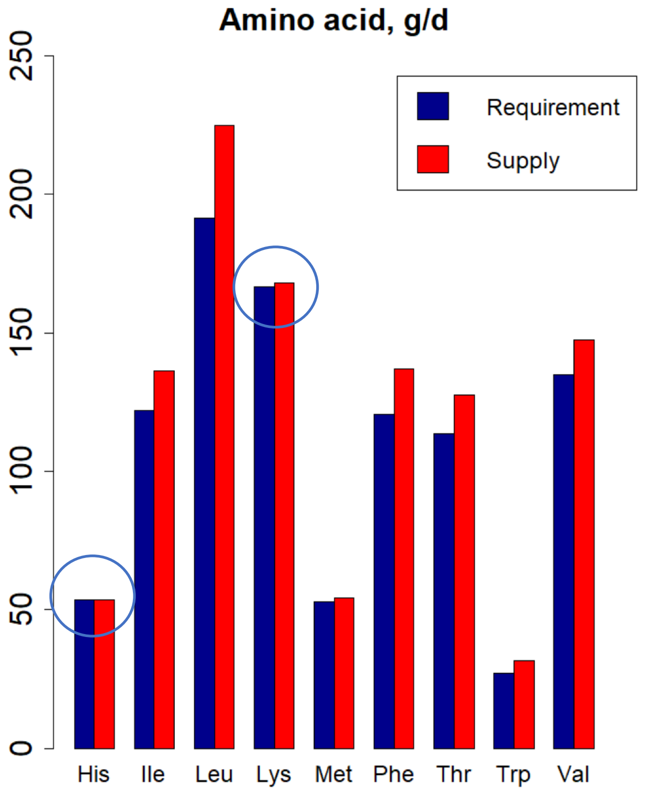
NLP simulation

- Same animal information, feeds, objective and constraints
- slsqp function in R: Sequential quadratic programming (SQP)

	LP	NLP
Alfalfa hay, kg of DM	8.91	9.38
Beet pulp, kg of DM	2.45	2.64
Corn gluten, kg of DM	0	0
Corn silage, kg of DM	7.9	4.68
DDGS, kg of DM	4.75	5.11
Total, kg of DM	24.01	21.81
Feed cost, $/cow	3.93	3.91

Ration evaluation





Nutrient compositions of the diet (% of DM)

Nutrients	LP	NLP
CP	18.38	20.20
FA	2.72	2.80
NDF	42.13	42.05
Ca	0.73	0.81
P	0.31	0.32
Starch	11.90	8.79
Forage	70	64.45

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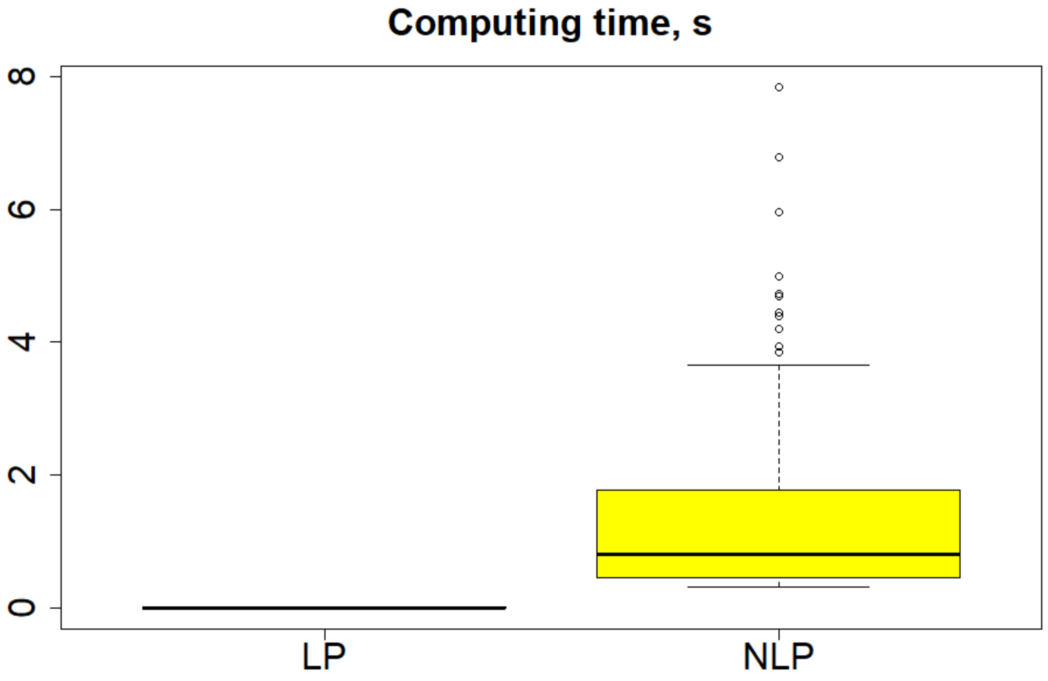
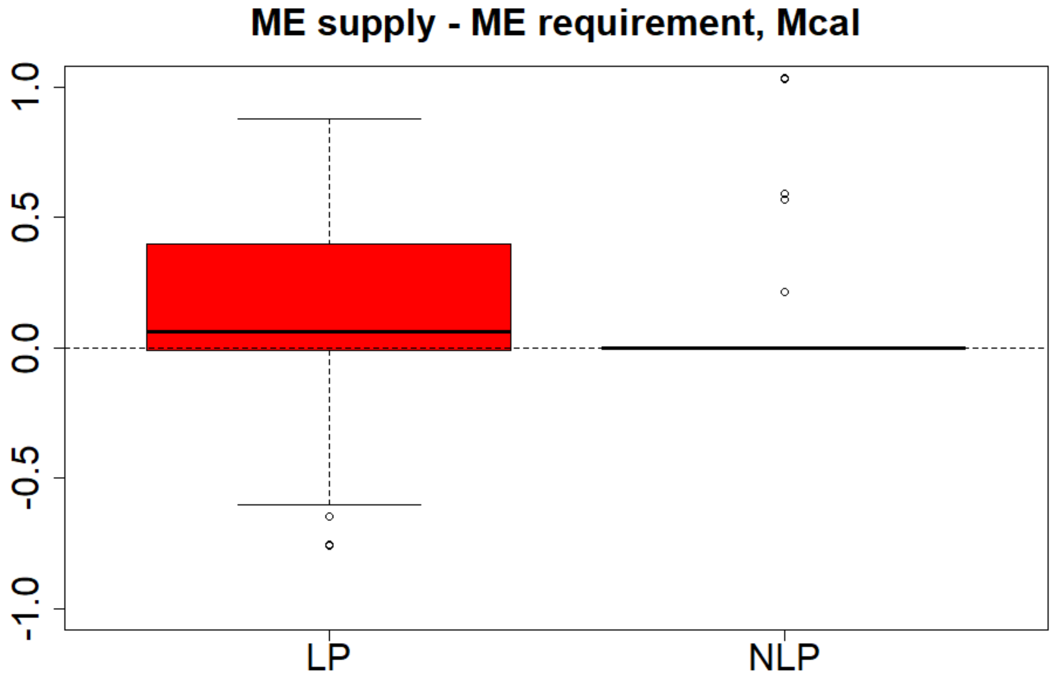
Comparison between LP and NLP

100 simulations were run, with each simulation using a randomly selected feed library (3 forages out of 6, 5 concentrates out of 14).





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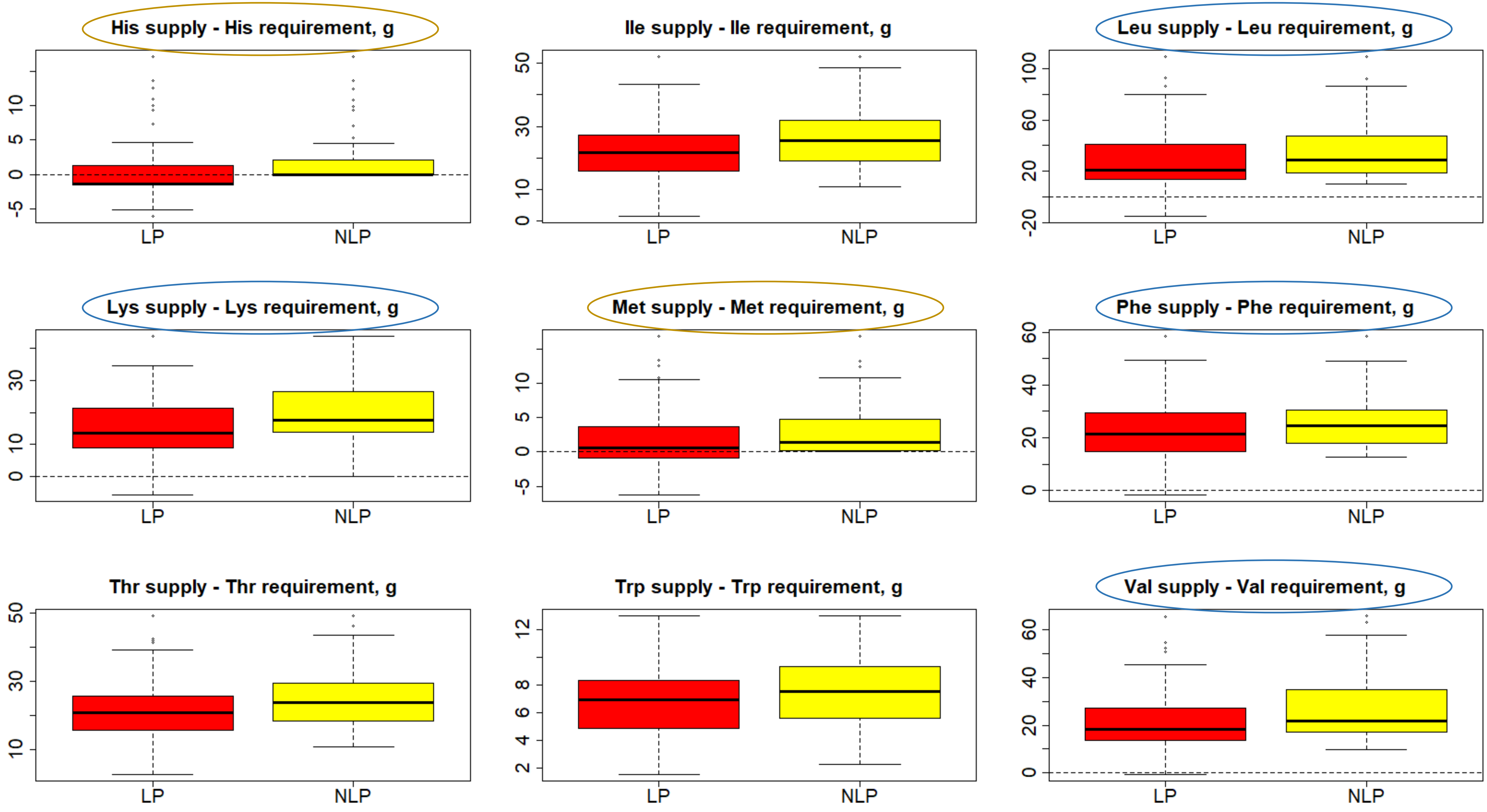

His supply - His requirement, g
Ile supply - Ile requirement, g
Leu supply - Leu requirement, g
Lys supply - Lys requirement, g
Met supply - Met requirement, g
Phe supply - Phe requirement, g
Thr supply - Thr requirement, g
Trp supply - Trp requirement, g
Val supply - Val requirement, g
LP
NLP

Next step

- Figure out how NLP works in detail
- Wait for more chapters from NRC (especially growth and body weight change)

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Thank you!