Updating preliminary study of multiphase diet for dairy beef cattle

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The new way of understanding research on livestock

It is necessary to **improve feed efficiency** in animal production because of the **environmental impact** and the **low economic profitability** *Makkar & Webber, 2012*

Especially in ruminants => Low FE *Tolkcamp et al., 2010*

Genetics → **1,3% improvement in CH4 emissions after 2 generations** *Arthur et al.,2001*

Nutrition → **Machine learning and Precision nutrition (PN) techniques**

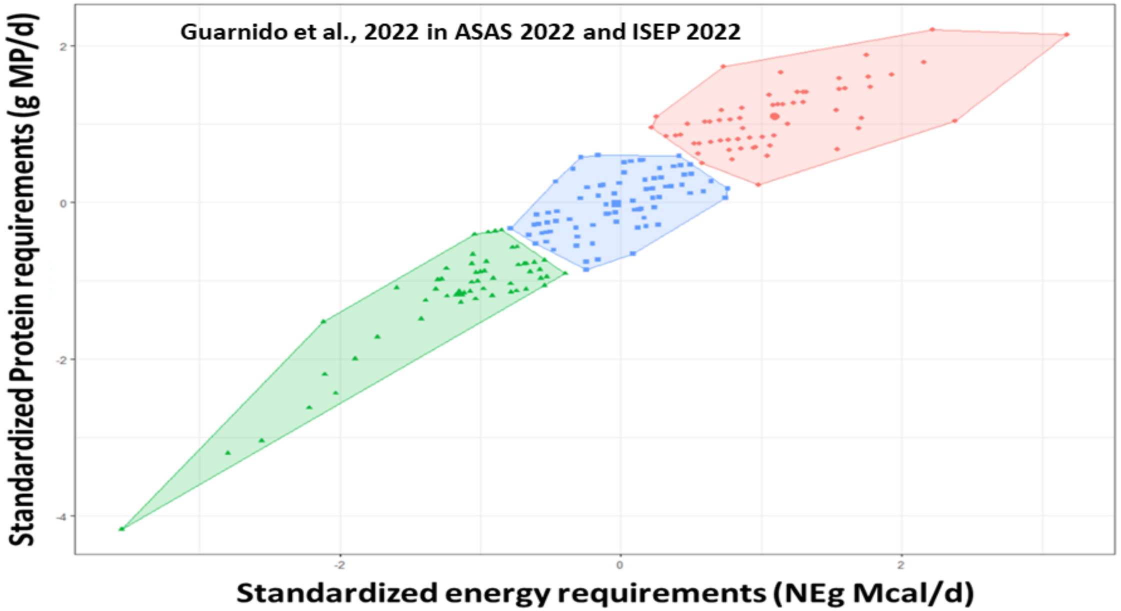
- **Grain processing**
- **Additives**
- **Forage genetics**
- **Rations formulation**
- **Animal' requirements**

PN techniques to improve feed efficiency

PN techniques consist of the use of new technologies (electronic devices, sensors, eartags…) to **characterize animals** in order **to adjust their ration** more accurately *Rowe, 2004 ; Broderick, 2016*

=> **Nutritional grouping:** Groupe animals to feed them according to their animal requirements (**NEg, MP…**) (Cabrera et al., 2014; 2020; 2021)

- Change bulls between pens may generate **dominance problems**, decreasing efficiency (Grant and Albright, 2001)
- **Mid-low repeatability** between clusters across the whole fattening period (r=0.42)



=> **Multiphase diet:** Change dietary characteristics according to changes in animal requirements during the whole growing period (Pomar et al., 2007; Andretta et al., 2014)

Multiphase diet to improve feed efficiency

<u>Daily multiphase diet</u> demonstrated an economic **(-3% production cost)** and an environmental improvement **(-23% N2O emissions)** in pig production (Pomar et al., 2007; Andretta et al., 2014)

Hauschild et al., 2012

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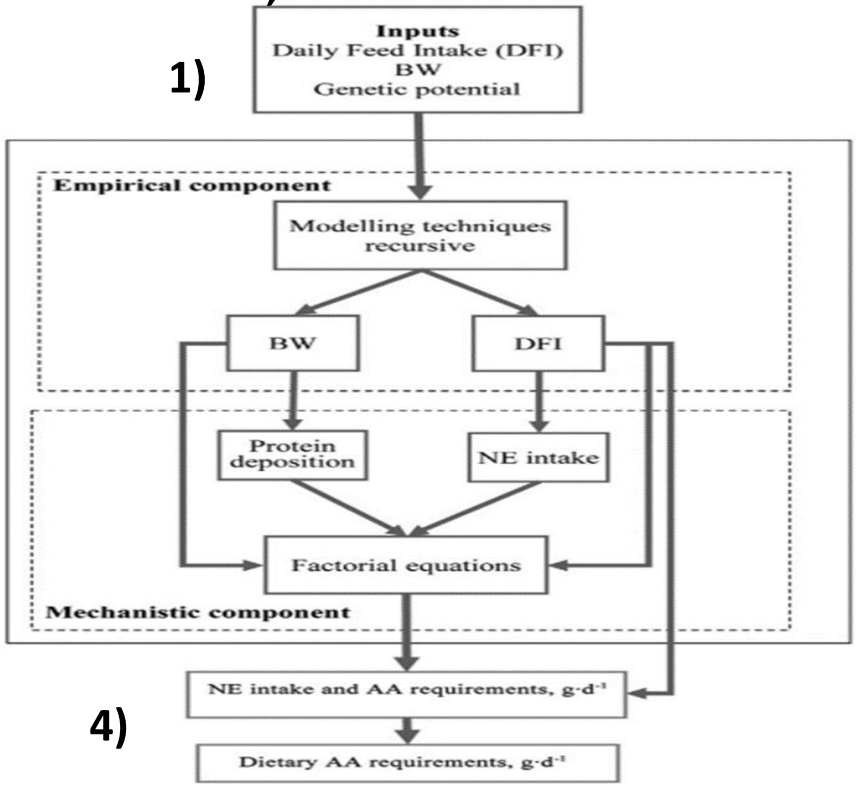
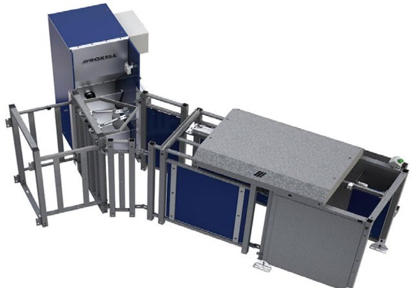


1) **Collection of individual (or by pen) animal performances (BW, ADG and DMI if possible)**
2) **Modelling energy and protein requirements (NRC, INRA…)**
3) **Modelling animal requirements daily and predicting future requirements (forecasting models)**
4) **Calculation of daily dietary energy and protein concentration and its individual (or by pen) distribution**

<u>Smart electronic feeders</u>

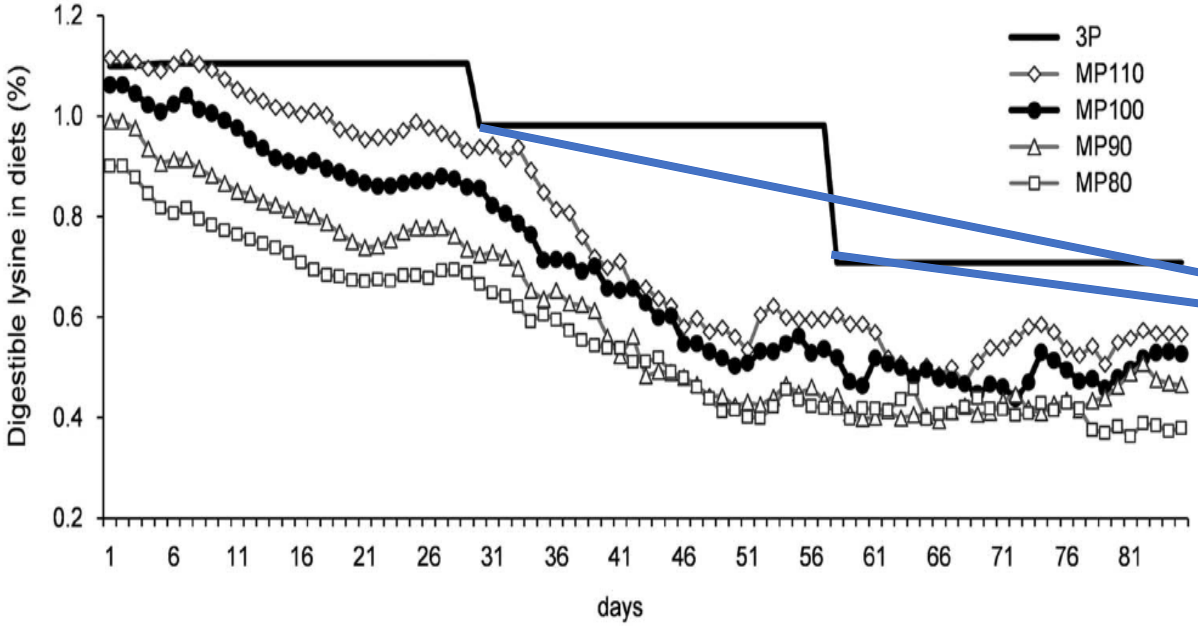


Developing multiphase diet in cattle

Electronic feeders are not totally working on cattle → **Not daily Multiphase diet**

- Ration is daily prepared
- Dietary composition have much more fiber (TMR) than in pigs
- Cost

$$\textbf{Regular Multiphase diet} = \frac{\text{Energy and protein requirements}}{\text{Dry matter intake}} = \textbf{Dietary energy and protein concentration required}$$



Determining **main switching points** could help decision-making of beef cattle farmers **to change the diet and improve feed efficiency** (Andretta et al., 2014)

Objective

Simulate the implantation of a multiphase diet in beef cattle

- Evaluate animal **requirements over intake**
- **Model individual animal requirements** during the whole growing period
- **Determine main switching points** of animal requirements during the whole growing period

Material and methods : Database

To accomplish our objectives we conducted a retrospective study:

- We used **342 growing bulls ;** *dairy crossbred with Angus, Limousine Charolais or pure Holstein*

- Animals were **conventionally allotted in pens by BW** (197±39.5 d and 269±70.9 kg BW)

- Animals were weighed every 2 weeks (n=9) during **126 days**

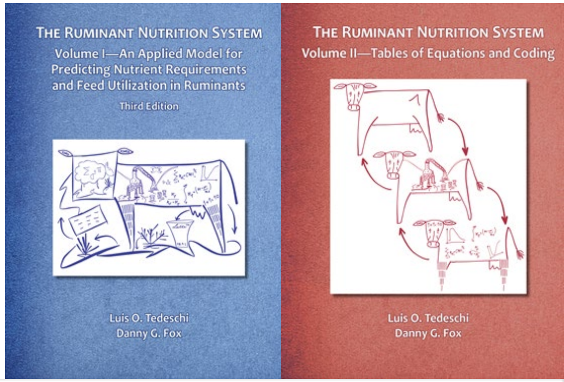
- **Daily DMI** was measured through **electronic feeders** (GEA Surge, Westfalia)

- Animals were fed **a high-energy diet**

-1.94 Mcal NE/kg DM
-89g MP/kg DM

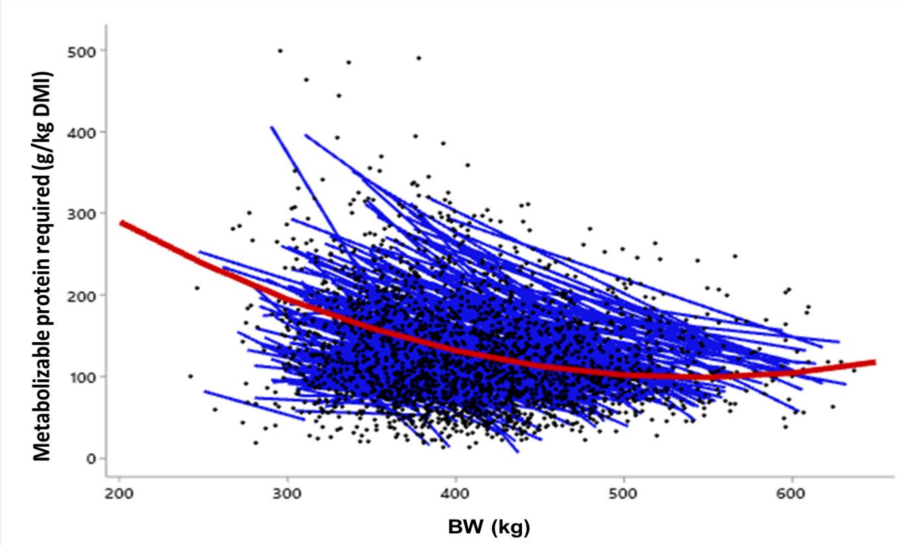
Material and methods : estimation of animal requirements and dietary needs

1. **Animal requirements** [Net energy for gain (Mcal/d) and metabolizable protein (g/d)] were **estimated following the ruminant nutrition system®** guidelines by using measured BW and ADG



2. **Dietary energy and protein concentration** required was evaluated by dividing energy and protein requirement by their respective DMI observed during the whole fattening period

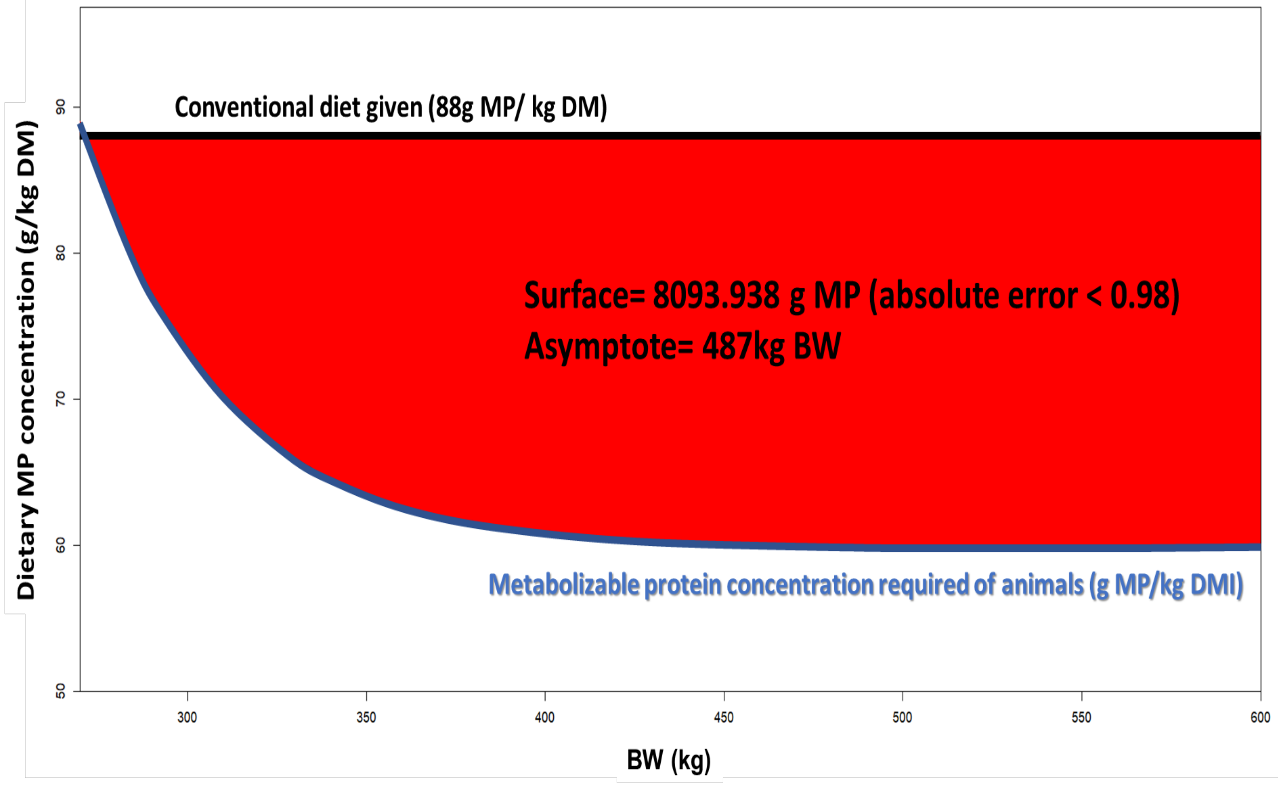
3. *Crossbreed effect* was considered



Material and methods : Determining changing points to propose dietary changes

We calculated **the area between two curves**:

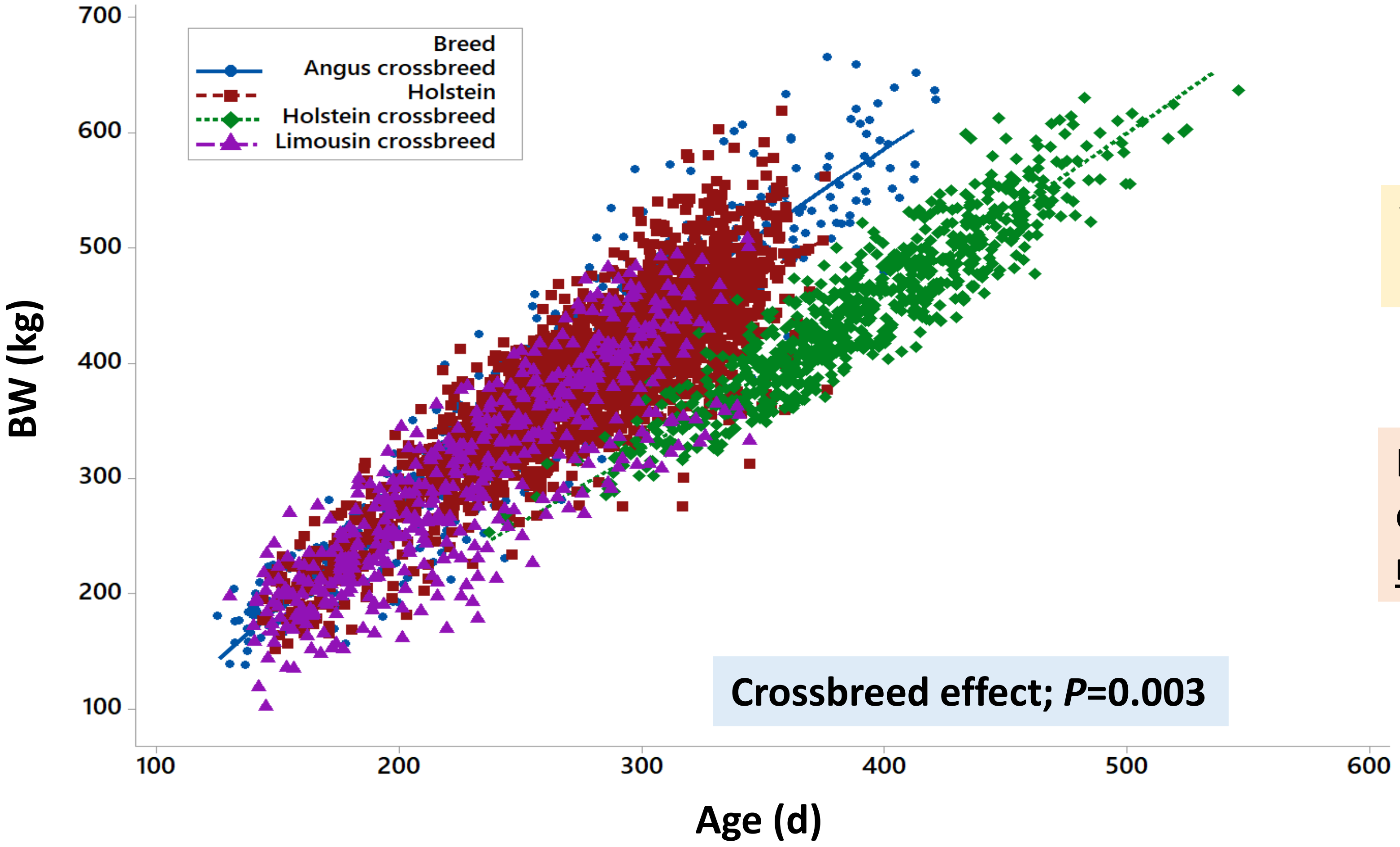
1) **The horizontal line** of the conventional diet given (gMP/kg DM)
2) **The curvilinear line** which represents the estimated energy or protein concentration required across the whole fattening



Area under the curve was calculated in R Studio

- We determined this area using the **function "integrate"** (Piessens and Branders, 1983) in R through an iterative process (loop For), the function "integrate" searched the X point (BW) across Y values (dietary NE and MP concentration required)
- Changing points were determined the area between curves was minimized.

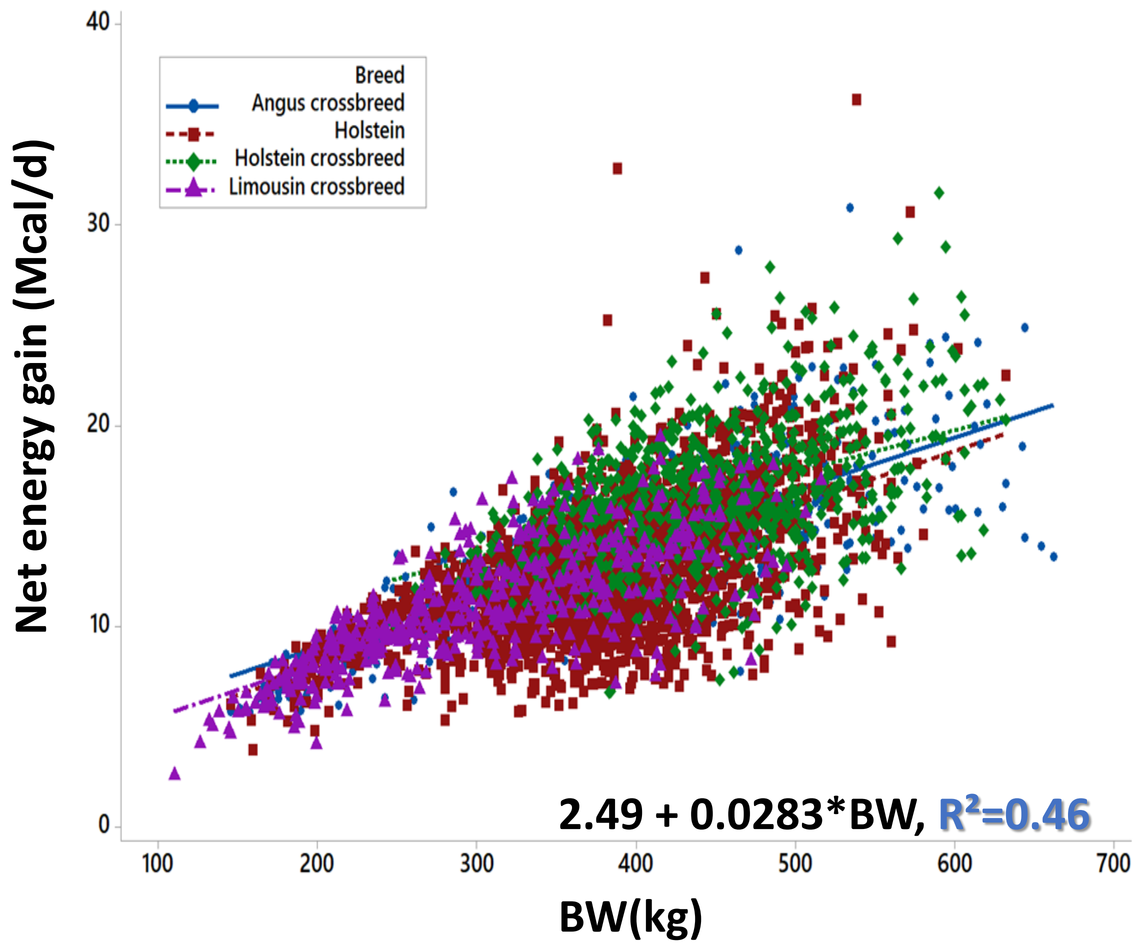
First preliminary analysis: growing curves of different crossings of Holstein resulted different

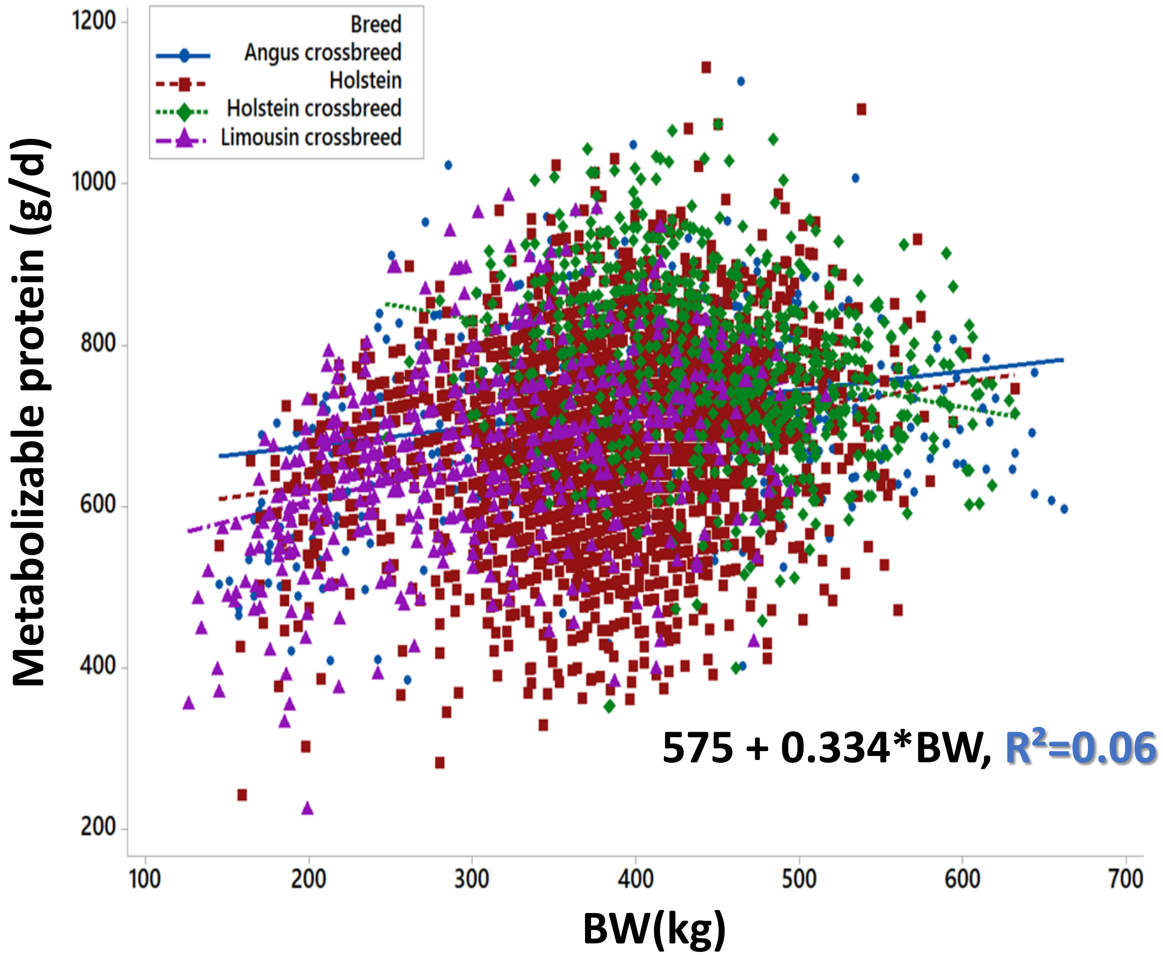


We will show graphs with the different holstein crosbreeds

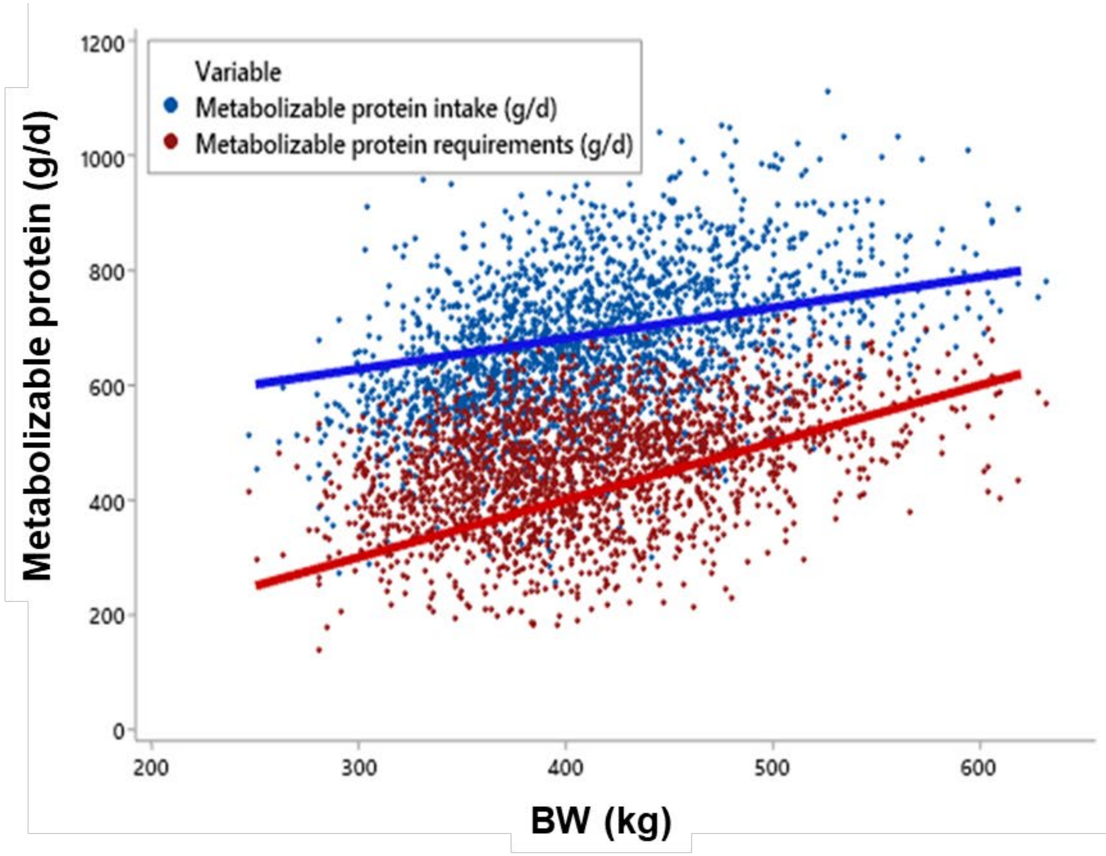
However, to develop the models we decided to correct this effect by **using residuals**

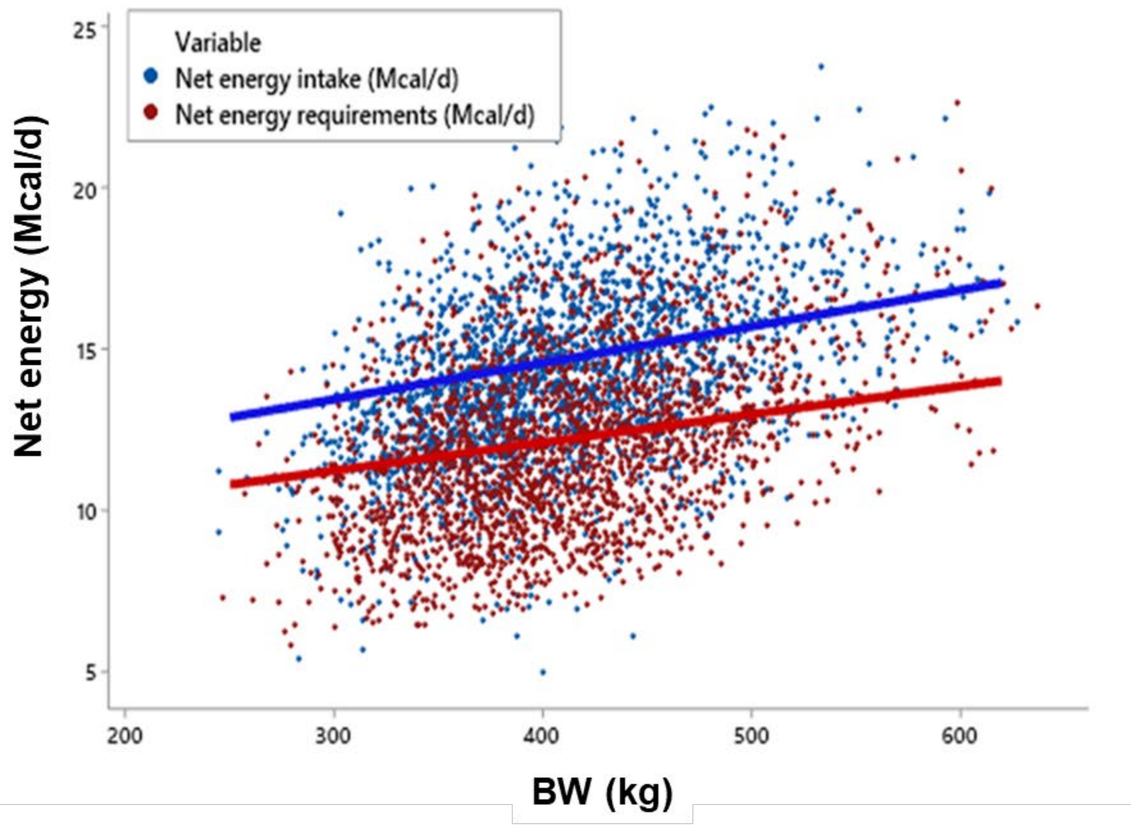
First preliminary analysis: modelling animal requirements during the whole fattening period



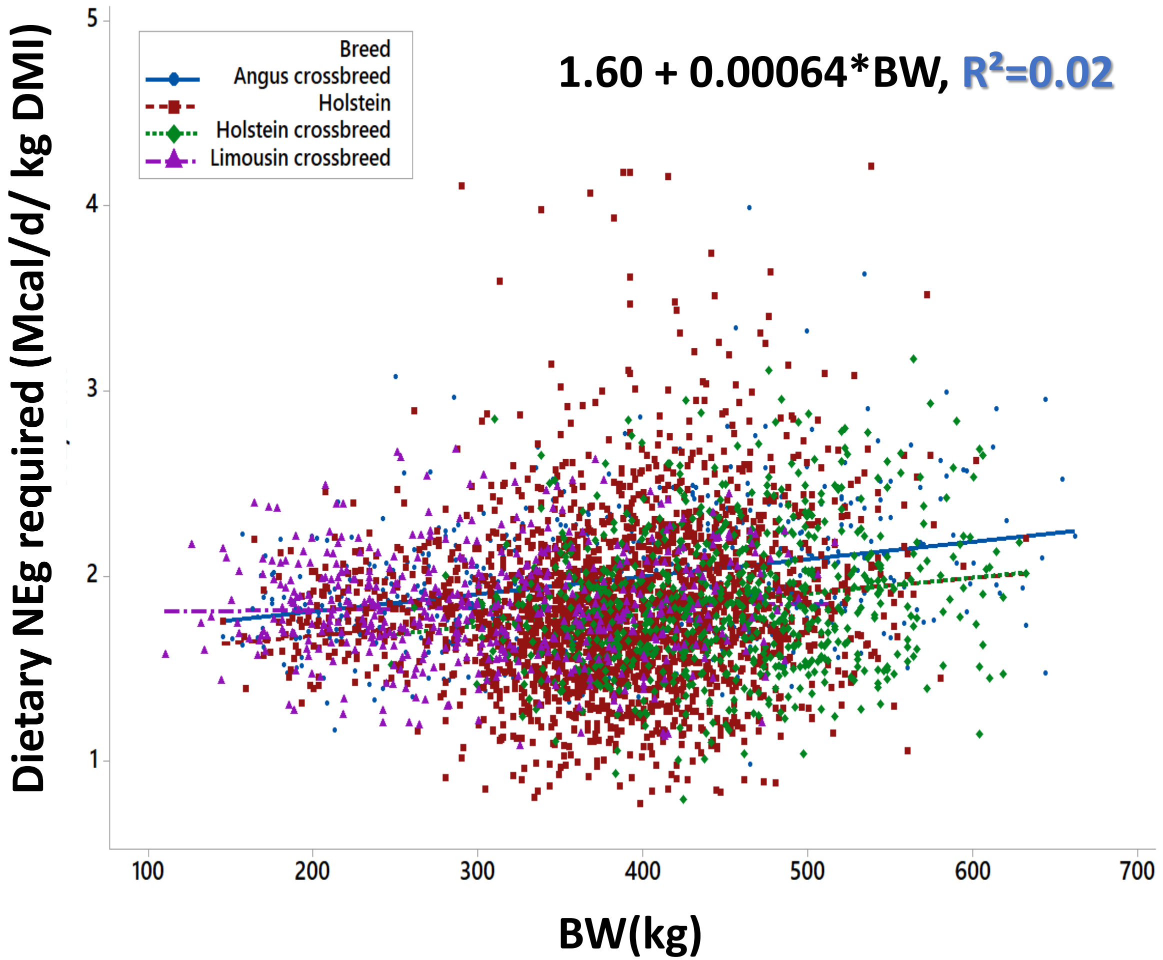


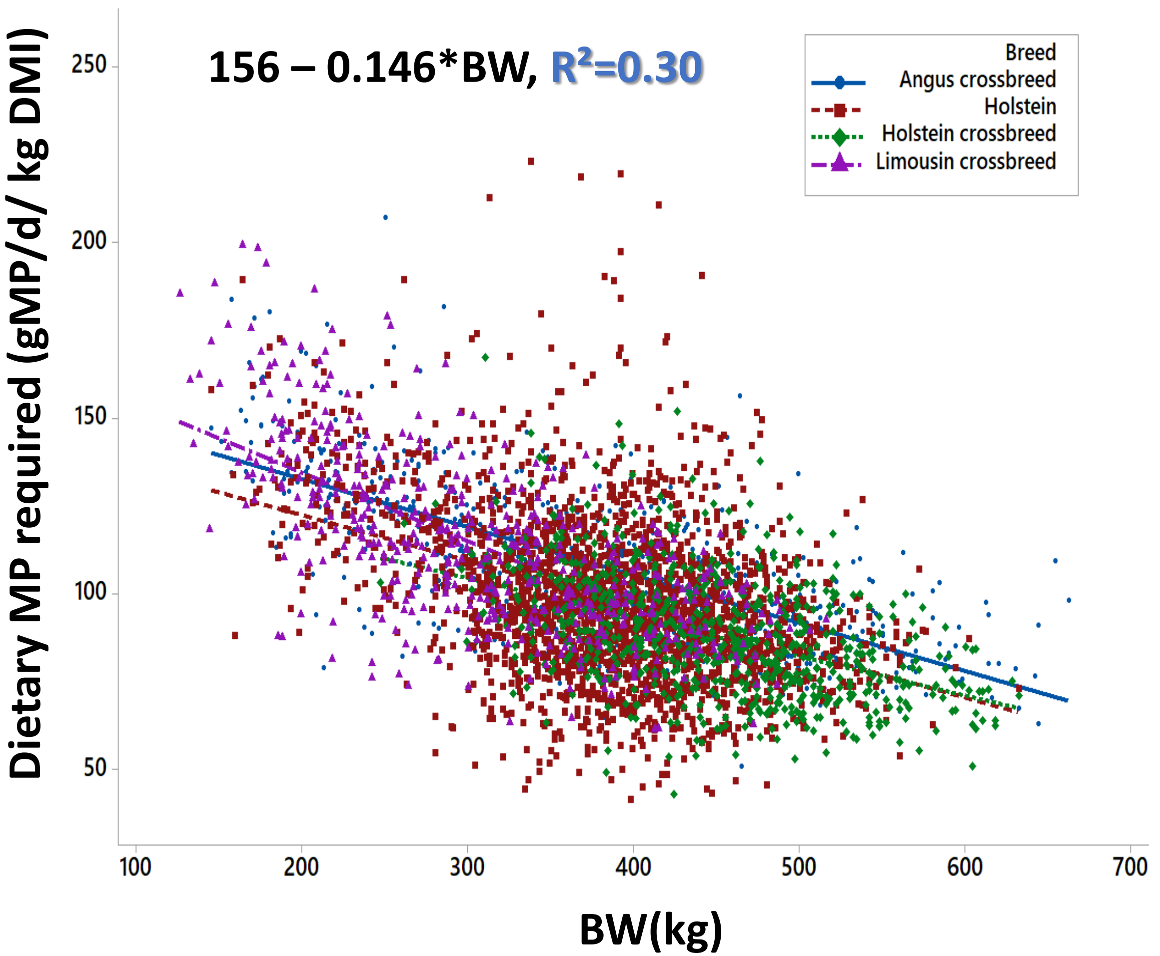
Nutrients intake were higher than required



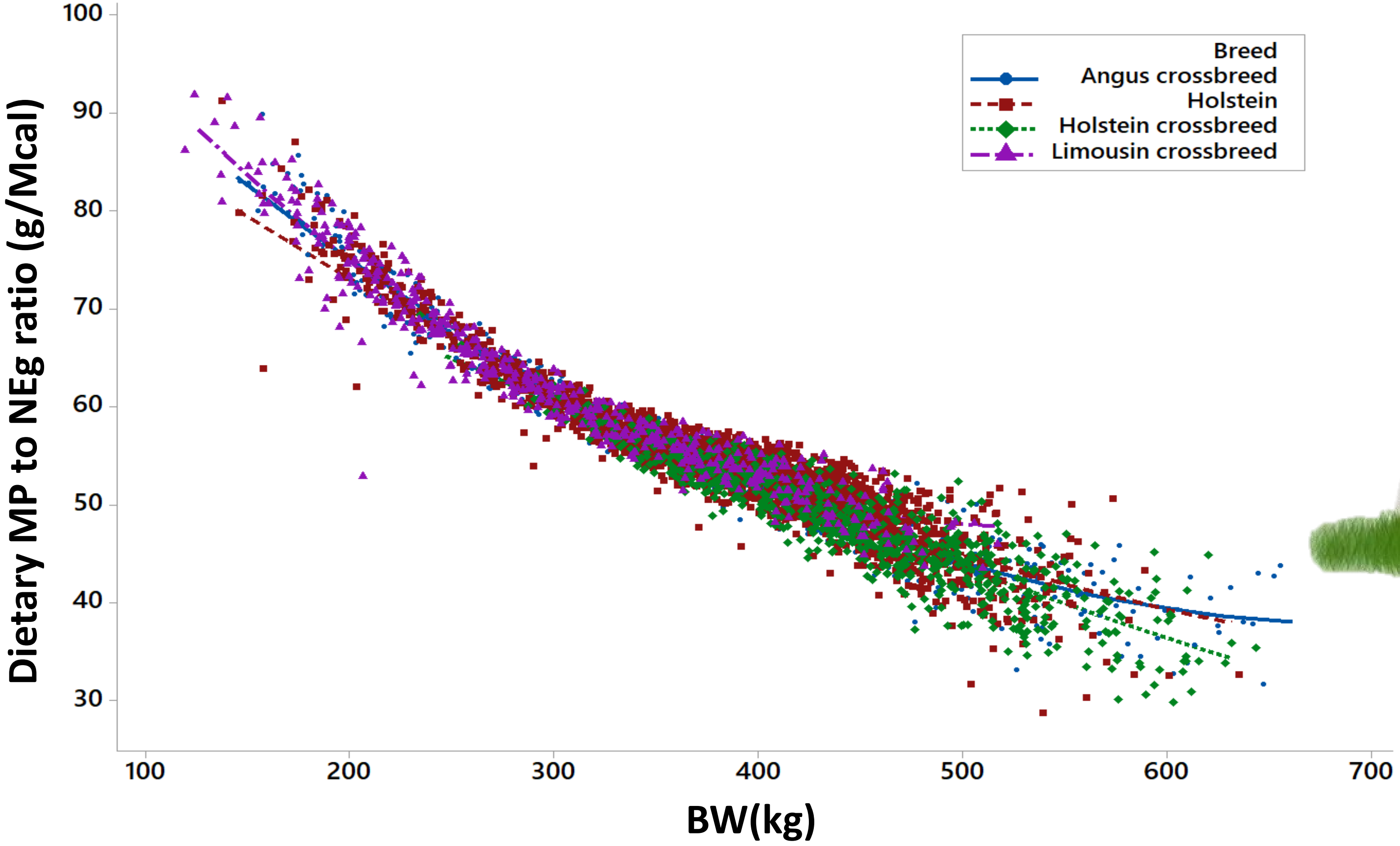


Second preliminary analysis: modelling dietary energy and protein concentration during the whole fattening period



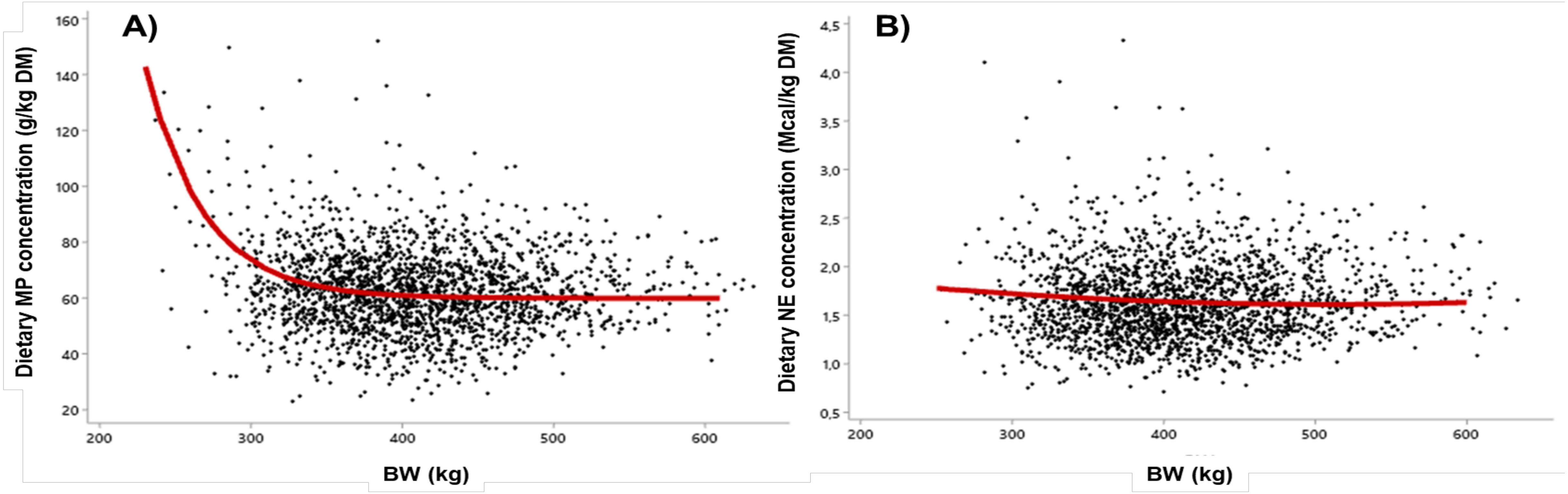


Consequently, protein to energy ratio vary across the whole fattening

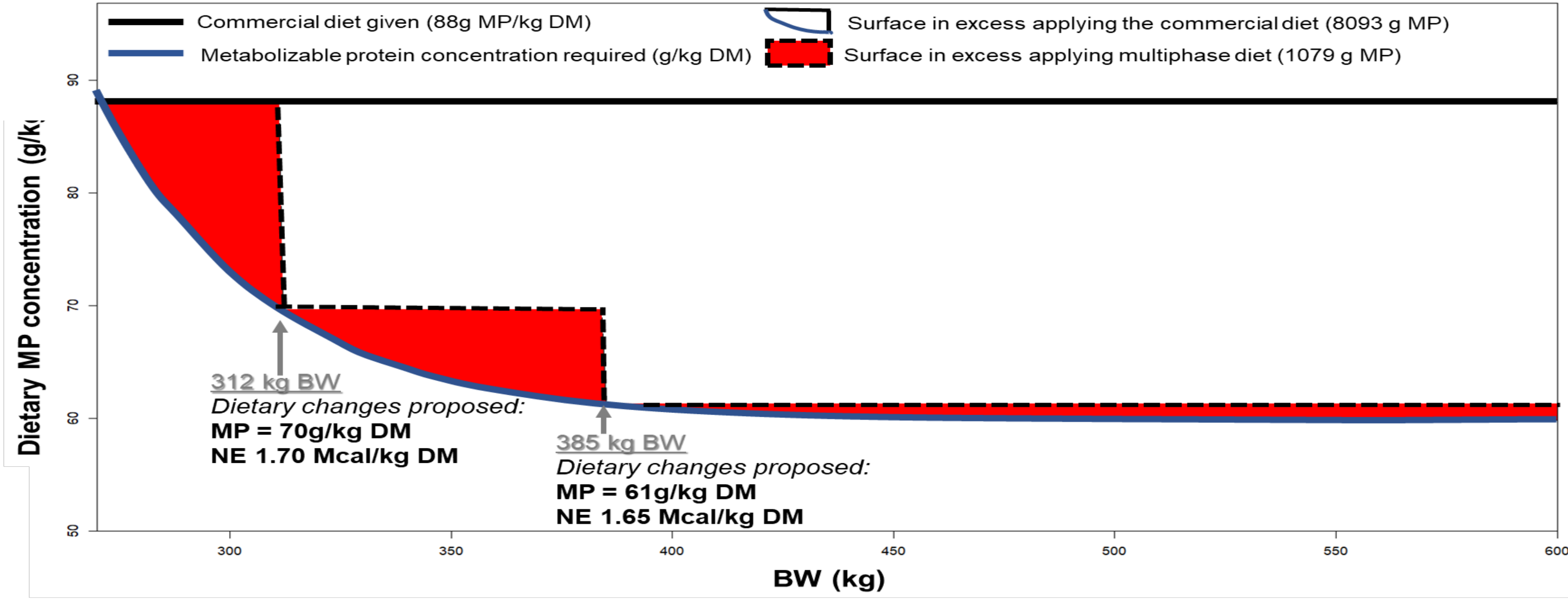


Further studies: Evaluate this relationship also at rumen level

The area under the curve did not show differences in terms of dietary energy required but did in dietary protein during the whole fattening



Our ML technique showed 2 different changing points in terms of dietary protein required during the whole fattening



Theoretical comparison between multiphase diet and conventional diet

Observed/estimated animal performances	Commercial diet		Multiphase diet		Anova
	Mean	CV (%)	Mean	CV (%)	
Second phase; 312 - 385 kg					
Total DMI_{av} (kg/d)	7.67	0.17	7.73	0.54	0.20
ADG (kg/d)	1.50	0.37	1.65	0.58	0.16
FCE (g:g)	0.217	0.36	0.214	0.39	0.44
CH_4 Emissions (MJ/d)	86.5[b]	0.21	140[a]	0.09	<0.001
CH_4 by intake (MJ/kg DMI)	11.3[b]	0.23	18.2[a]	0.13	<0.001
Total N excretion (g/d)	118[a]	0.16	102[b]	3.70	<0.001
N excretion by intake (g/kg DMI)	15.4[a]	0.95	13.2[b]	0.08	<0.001
Feeding cost (€/d)	2.51[a]	0.42	2.31[b]	0.08	<0.001
Third phase; 385 - 600 kg					
Total DMI_{av} (kg/d)	8.66[b]	0.17	9.53[a]	0.91	<0.001
ADG (kg/d)	1.57	0.35	1.62	0.21	0.13
FCE (g:g)	0.201[a]	0.35	0.174[b]	0.29	0.02
CH_4 Emissions (MJ/d)	101[b]	0.21	191[a]	0.21	<0.001
CH_4 by intake (MJ/kg DMI)	11.7[b]	1.19	20.1[a]	0.17	<0.001
Total N excretion (g/d)	132[a]	0.16	108[b]	9.73	<0.001
N excretion by intake (g/kg DMI)	15.2[a]	0.95	11.33[b]	0.06	<0.001
Feeding cost (€/d)	2.84[a]	0.49	2.76[b]	0.26	<0.001

Feeding costs, and therefore, economic profitability was improved in both phases

Nitrogen excretion was decreased significantly

Feed efficiency was improved in the third phase

However, **methane emissions were augmented** in both phases because of the higher inclusion of fiber

Recap of the whole multiphase diet process

1) In-vivo data collection

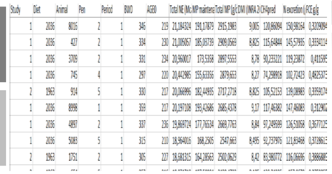
Evaluation of individual performance of 342 growing Holstein bulls during 126d

Database

DMI	BW	ADG

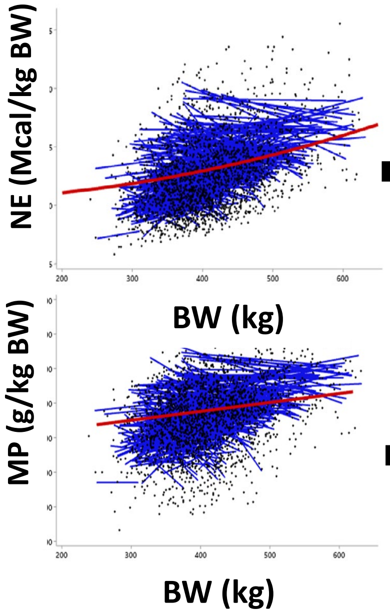
Diet A

Diet B

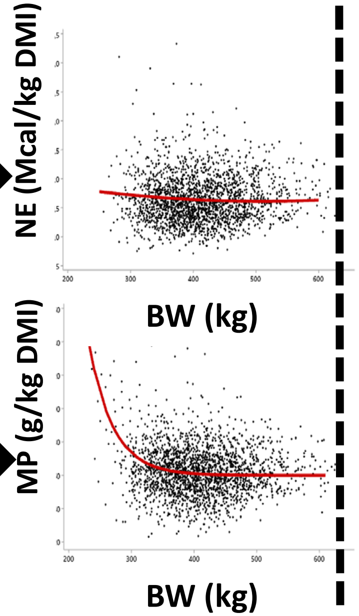


Data analysis

2) Individual NE and MP requirements estimation



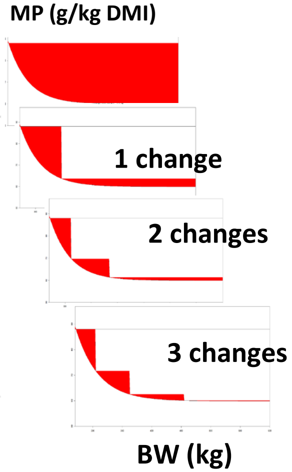
3) Calculation of Dietary NE and MP required



Dynamic modelling

4) Optimal change points

Iterative machine learning algorithm to find the optimal changing point in the curve



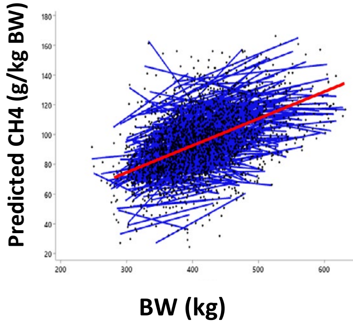
ML algorithm

5) Dietary reformulation

Adjusting diet to calculated animal requirements at minimum cost

Mathematical calculations

6) Simulation of individual animal response



Prediction of animal performance and requirements to new reformulation (response models)

7) Economic and environmental Impacts

Observed/estimated animal performances	Commercial diet	Multiphase diet	Anova
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FCE (g:g)	0,217	0,214	0,44
CH_4 Emissions (g/d)	$86,5^{b}$	140^{a}	<0,001
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Total N excretion (g/d)	118^{a}	102^{b}	<0,001
N excretion by intake (g/kg DMI)	$15,4^{a}$	$13,2^{b}$	<0,001
Feeding cost (€/d)	$2,51^{a}$	$2,31^{b}$	<0,001

Comparation between commercial vs multiphase diet in animal performance, environmental and economic terms

Prediction models

Take home message

- **Nutrients intake were higher than nutrients required, which may impact the global profitability and sustainability of the cattle sector**

- **Multiphase diet could be a strategy to improve feed efficiency in beef cattle production**

- **Dietary energy concentration could remain invariable during the whole growing period, however, protein concentration in the diet should decrease across the time**

- **We found 2 main switching points at 312 and 385 kg of BW to change dietary protein concentration (70 and 61g/kg DM) during the growing period**

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