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Effect of early life nutrition on the growth, metabolic and carcass characteristics of beef cattle

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Big picture…

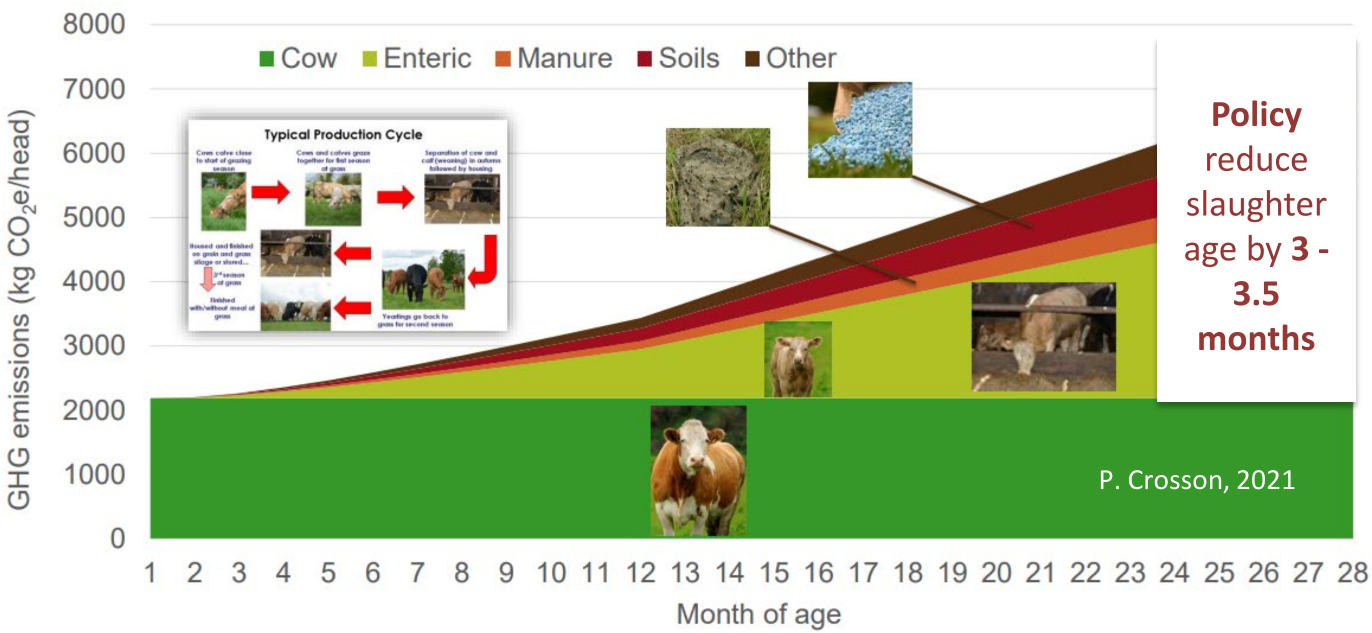
- **Demand for beef is increasing globally**
- **Beef industry facing many unprecedented challenges**
    - Environmental impact and legislation
    - Economic viability of beef production farm systems
    - Feed-food competition
    - Need more efficient use of resources
    - Biodiversity loss and environmental degradation
    - Negative publicity about beef production

Ultimately: Population growth and environmental constraints will continue to pressure beef producers and wider industry

to improve productivity, efficiency and sustainability

Sustainability in pasture-based beef production systems

Future/on-going work *age at slaughter*



Methane (CH_4) = 64%

Nitrous Oxide (N_2O) = 21%

Carbon dioxide (CO_2) = 15%

Challenge: Optimising slaughter age, carcass weight and fatness to **achieve earlier slaughter** and lower the carbon footprint of pasture-based beef systems

Importance of Early life Nutrition

"Growing area of interest"

I. Metabolic programming

The metabolism of mammals can be programmed

„fetal programming“

„metabolic imprinting“

„fuel mediated teratogenesis“

Early adaptations to a short nutritional perinatal stimulus permanently change the physiology and metabolism of the organism and continue to be expressed even in the absence of the stimulus that initiated them.

„perinatal programming“

„developmental programming“

„fetal imprinting“

„nutritional programming“

Importance of Early life Nutrition

"Growing area of interest"

"Management of calves during the first 6 months of life offers potential for improving production efficiencies"

Growing evidence of effects of **early-life nutrition** on key **profit traits** in cattle

Early life Nutrition

- Growing evidence of effects of early-life nutrition on key profit traits in cattle
- Pre-natal *v* **post-natal effects on tissue growth/composition**
- Does nutrition at **different stages of development** influence final carcass composition?
  - Lack of **long-term studies** available – latent effects?
- Latent effects on functionality of important biological processes?
- Complement progress in genomics

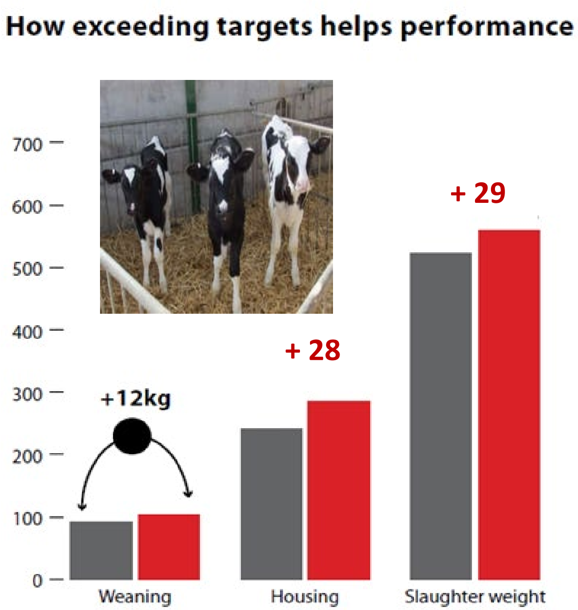
Evidence: Performance from weaning to slaughter of steer progeny of Charolais and Beef x Friesian cows

	Charolais	Beef x Friesian	Difference
Cow milk yield (kg/day)	7.3	11.1	+3.8
Liveweight gain to weaning (kg)	1.05	1.20	+0.15
Weaning weight (kg)	301	330	+29
Slaughter weight (kg; 25 months)	697	720	+23
Carcass weight. (kg)	383	395	+12

Source: Drennan et al (2005)

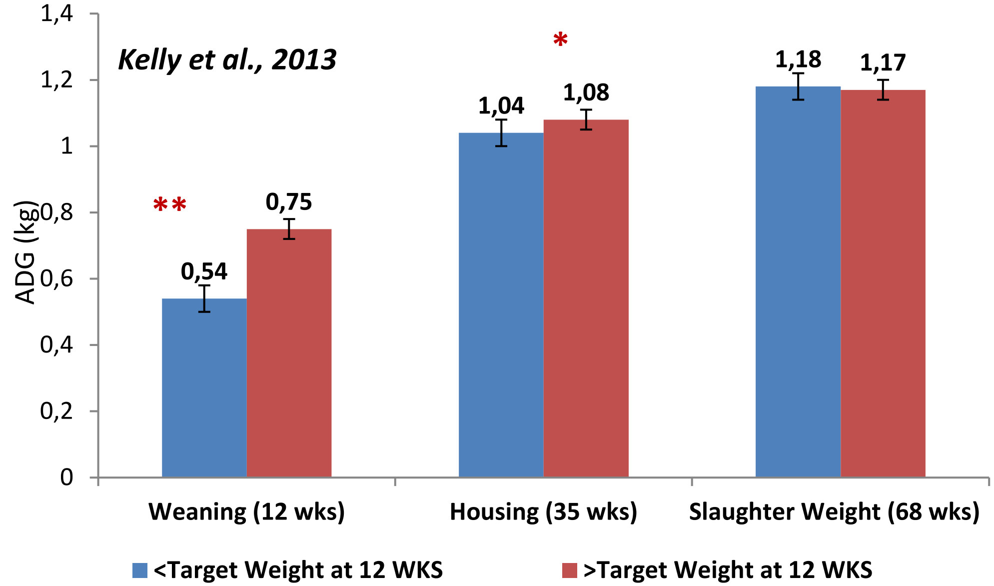
Every additional kg of milk resulted in

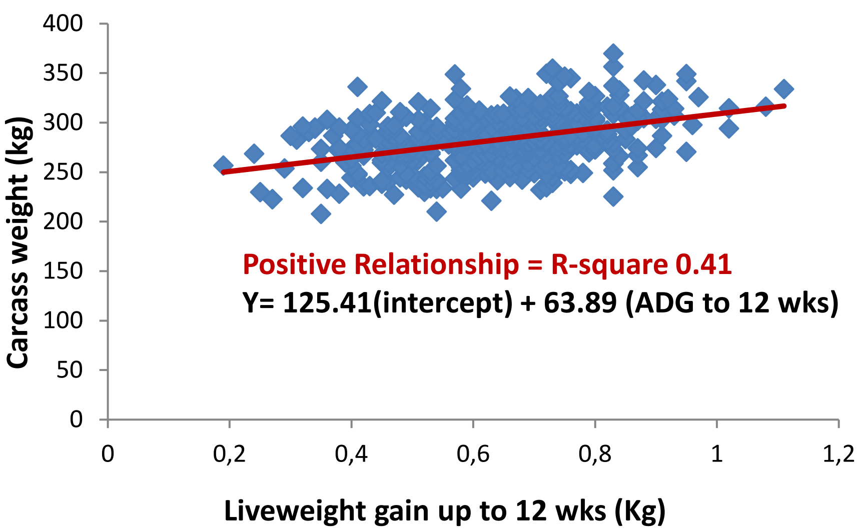
- **+6.5 kg** in weaning weight
- **+ 5.2 kg** in slaughter weight
- **+2.72 kg** in carcass weight



+ €55

Margin Per head



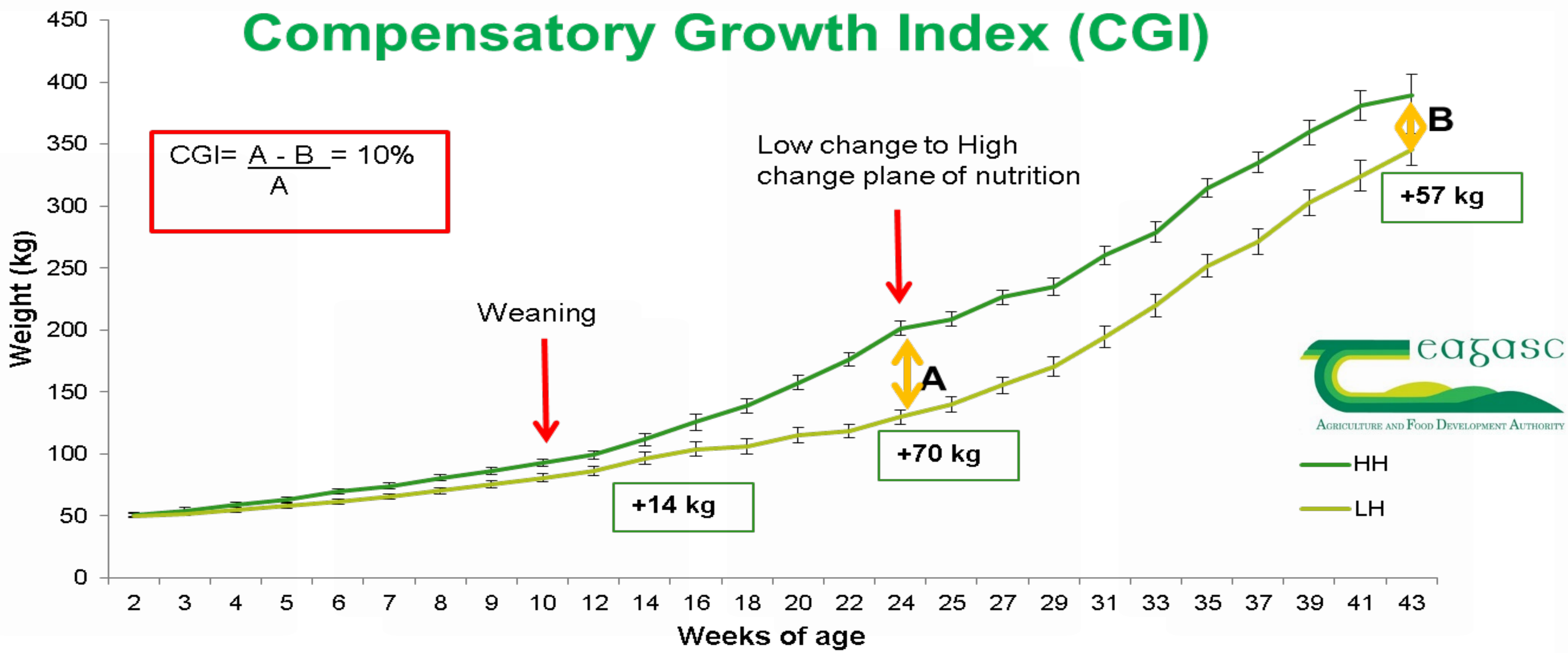


Evidence:

Early life growth and relationships with carcass weight

- **Calf ADG** (up to 12-15 wks) **R-square = 0.41**
- Adding ADG from 12-15 wks to 8 months to equation R-square only increased to 0.45

Evidence: Little or no evidence for compensatory growth in calves (< 6mths)



Ultimately:

- "Failure to meet **early growth targets by weaning and housing** (7-8 months of age) results in **lighter carcasses** and/or **delayed age at slaughter**"
- "*Adversely affecting **production efficiency**, **economics**, and **environmental footprint***"

Table 2. Summary of growth parameters to weaning for each early-life treatment group within the 240 core progeny

Alford et al. (2007)

Early-life growth treatment	n	Birth weight (kg)	Weaning weight (kg)	Pre-weaning ADG (g/d)
LL	60	28.3	139	513
LH	60	28.9	210	826
HL	59	38.1	162	596
HH	61	39.5	233	923
s.e.d.		0.76	5.1	19.3

Table 5. Summary of important carcass attributes for each early-life treatment group within the 240 core progeny

Early-life growth treatment	n	Carcass weight (kg)	Hot P8 fat depth (mm)	Retail meat yield (kg/animal)	Retail meat yield (%)	US marble score
LL	60	353	19.6	234	67.4	456
LH	60	376	21.2	243	65.7	441
HL	59	383	19.2	250	66.4	449
HH	61	409	22.0	265	65.5	436
s.e.d.		7.6	1.4	5.7	0.56	22.7

Management of calves during the first 6 months of life offers potential to not only have positive effects on lifetime growth potential but also carcass composition

(Hausman et al., 2009; Moriel et al., 2014a; Scheffler et al., 2014)

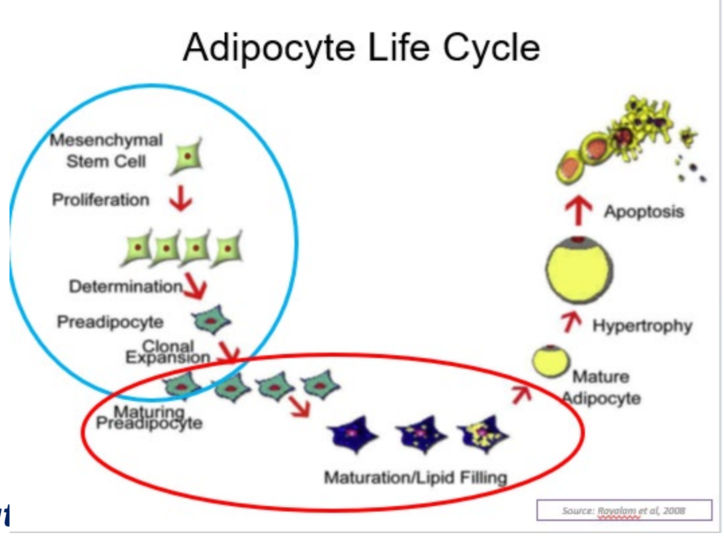
Developmental programming windows in early calf life are proposed to influence carcass composition?

-Nutritional manipulation during these windows can enhance tissue hyperplasia and hypertrophy

-Post-natal effects on tissue growth/composition

Postnatal muscle growth is dictated by an increase in muscle fiber size

Skeletal muscle targeting myogenesis—via the post-natal division of skeletal muscle satellite cells (Rehfeldt et al., 2000)



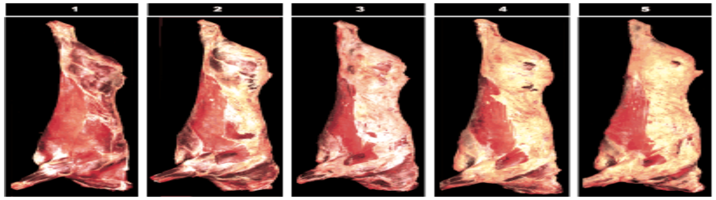
Adipocyte development, characterized by hyperplastic growth.

Dictated by differentiation of stem cells into mature adipocytes

Adiposity and cellular differentiation declines postnatally

Under correct conditions mesenchymal/pluripotent stem cells are capable of differentiating into pre-adipocytes?

This approach may alter carcass gain, adiposity, composition, and meat quality later in life ?



Du et al., 2017

Nutrient Requirement of 50 kg Dairy Calves to growth (NRC, 2021)

Rate of gain	Dry matter intake	Est intake	Metabolisable energy	Crude protein	Crude protein	Feed efficiency
kg/d	g/kg bw	g	MJ/d	g/d	g/100g DM	g gain/ g feed
0.2	10.5	525	9.8	94	18	0.38
0.4	13	650	12.1	150	22.4	0.63
0.6	**15.7**	**785**	**14.6**	**207**	**26.6**	**0.77**
0.7	**17**	**850**	**15.9**	**230**	**27**	**0.82**
0.8	18.4	920	17.3	253	27.4	0.86
1	**23**	**1,150**	**20.1**	**318**	**28.6**	**0.87**

- **Conventional feeding** systems typically support a growth rate of 0.2 to 0.6 kg/d during the preweaning period (2 to 3 mo of age)

- **Intensive enhanced feeding** programs targeting to achieve in excess of >0.8 kg/d BW gain

Factors affecting early life growth

- Health status of calf
- **Cow milk yield/quantity of CMR offered**
  - Composition of CMR
- Effective rumen development
- Integrate pre and post weaning growth potential
- Genetic potential

Effect of level of milk replacer over a 56-day period on lifetime performance of Friesian steers

	Milk Replacer (kg)		
	25	50	Difference
Initial wt. (kg)	44	45	
Wt. at 3 months (kg)	96	105	9
Wt. at 8 months (kg)	205	218	13
Wt. at slaughter (25 months)	637	662	25
Carcass wt. (kg)	346	357	11

Source: Harte and Fallon (1986)

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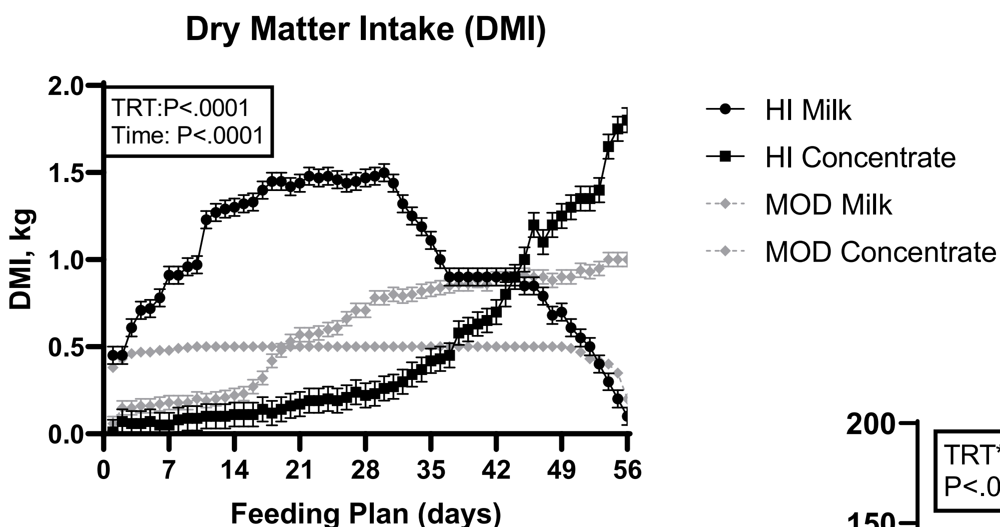
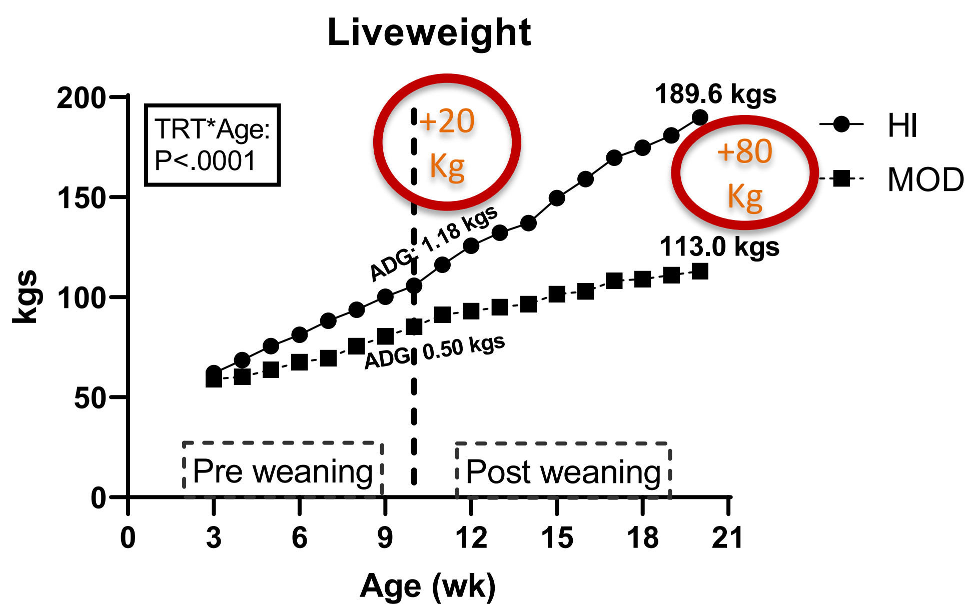
Growth trajectory of calves on an intensified (HI) or moderate (MOD) early life nutritional diet

Kelly et al 2020





Factors affecting early life growth

- Health status of calf

- Cow milk yield/quantity of CMR offered
- Composition of CMR

- **Effective rumen development**

- **Integrate pre and post weaning growth potential**

- Genetic potential

Weaning Challenges:
"Smooth transition from pre-ruminant to ruminant"

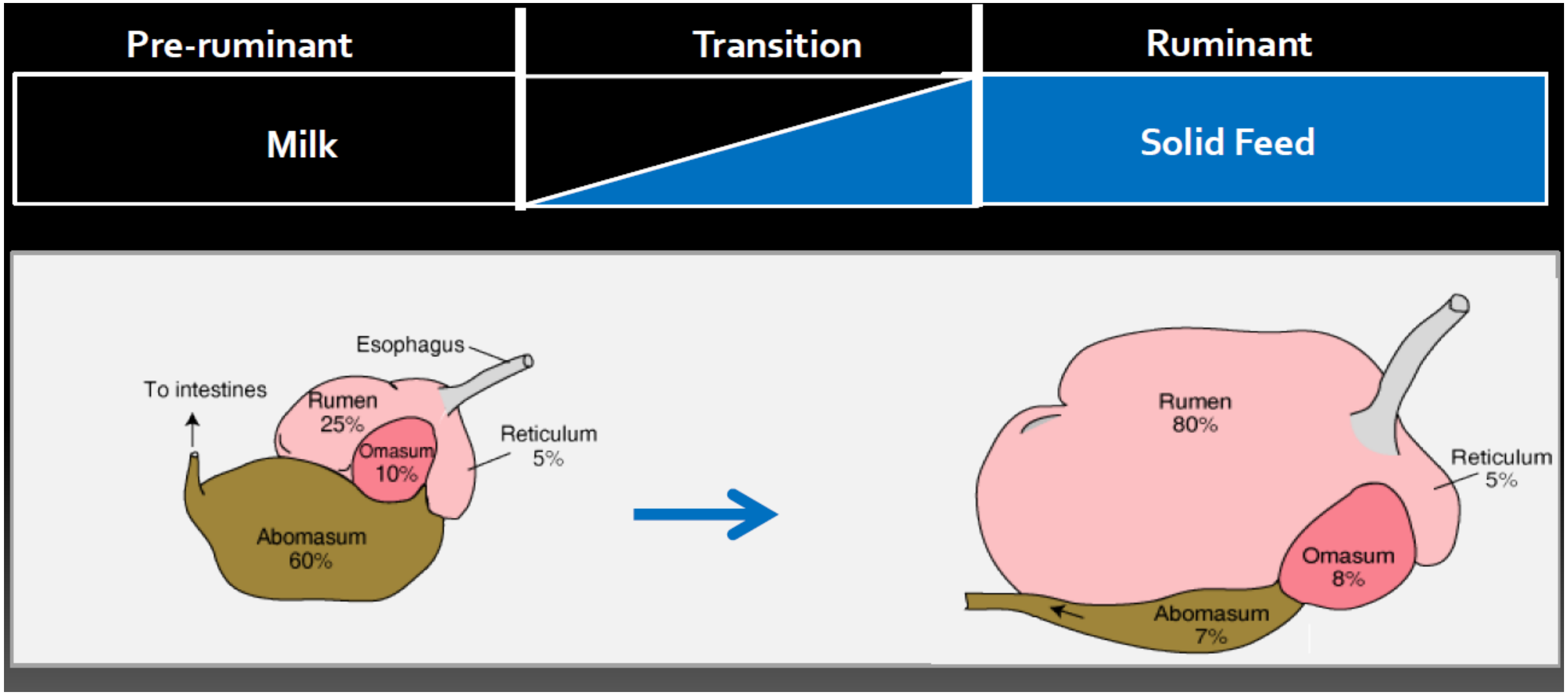
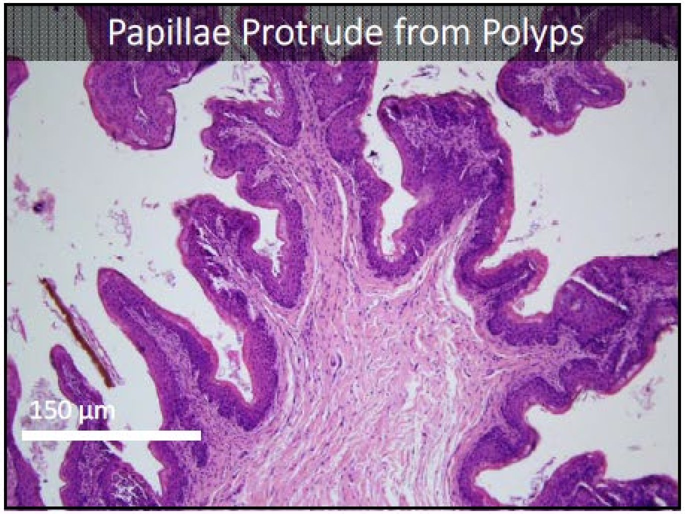


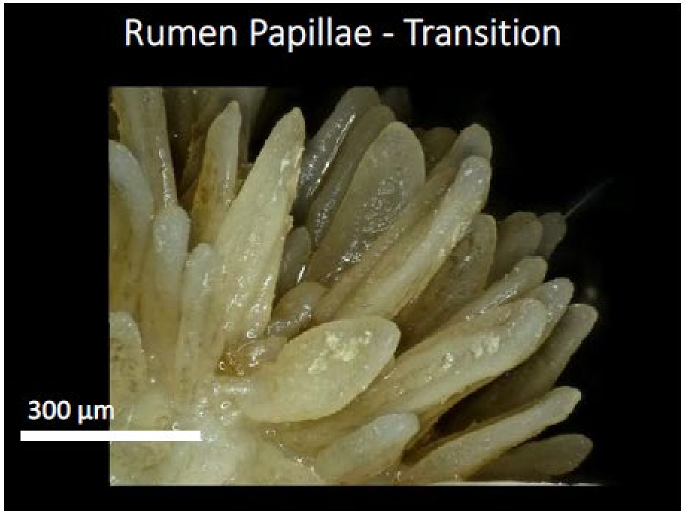
Image courtesy of M Steel

- Rumen size
- Rumen musculature
- Rumen papillae
- Fermentation

Image courtesy of M Steel

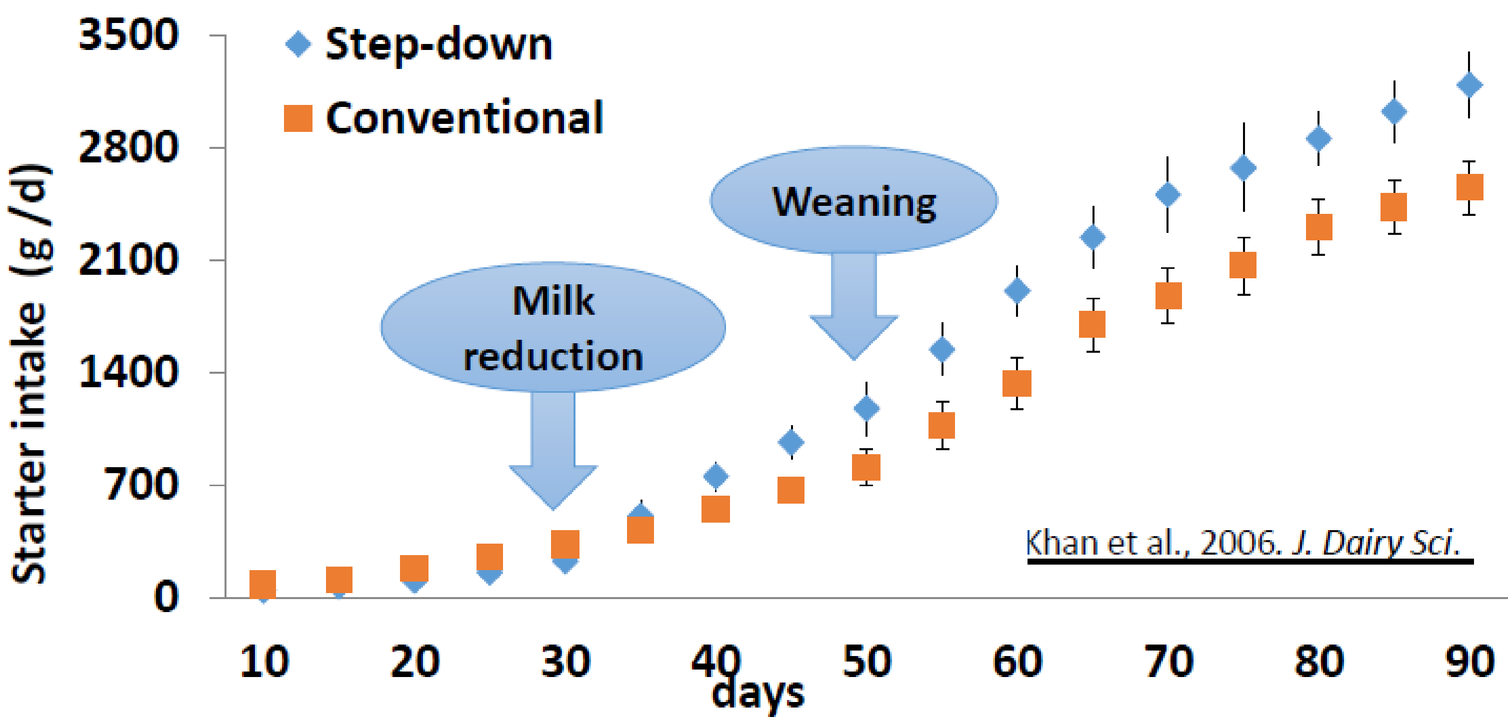


Adequate concentrate intake is key to avoid nutritional stress at weaning



- ***3-4 weeks to develop the rumen papillae from the initial time that concentrate is offered.***
- ***Earlier starch is digested by the calf, greater butyrate production, the faster rumen development***

Gradual reduction encourages solid feed consumption



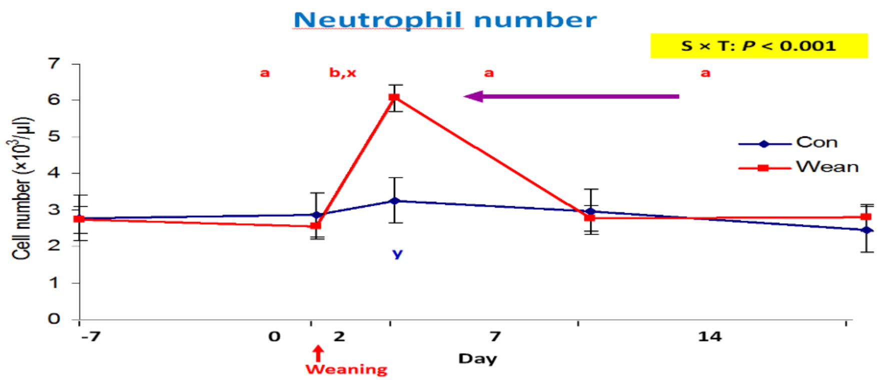
Plane of Nutrition v Immune status

Johnston et al. (2016)

Characterised the immune response to gradual weaning of Holstein-Friesian and Jersey calves on three planes of nutrition

- Haematological profiles
- Expression of immune response genes
- Whole blood mRNA transcriptome

Nutrition	Breed
✗	✓
✗	✓
✗	✓

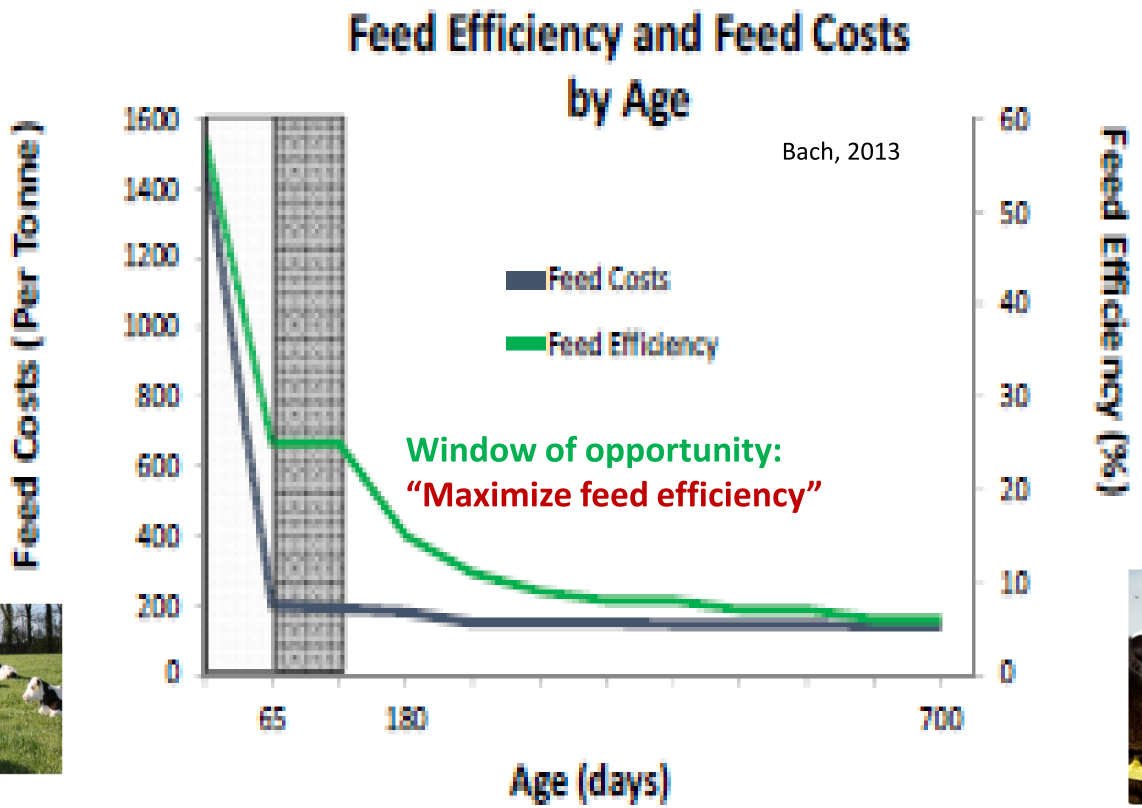


Post Weaning Potential: Area undiscovered

- **An area that has not been studied in detail**
  - **Pre weaned calves** are the **most expensive** dairy beef animals to feed and care for on a cost per day basis.
  - **Post weaning** is the **cheapest group** on a per calf per day basis.

- Need to understand strategies to optimize the **integration pre and post planes of nutrition** with **lifetime performance**

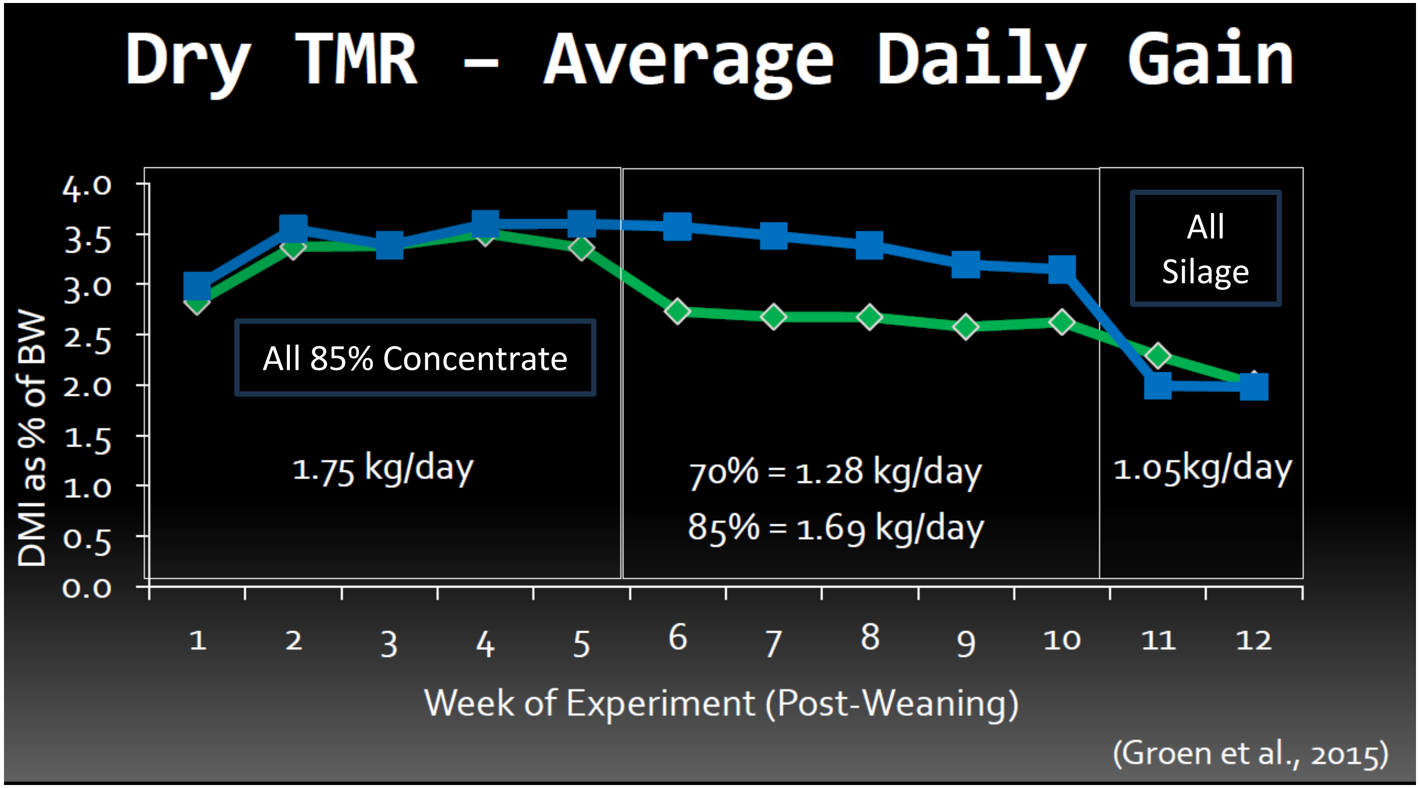
Post Weaning Potential: Area undiscovered



Biological efficient:

- "Conversion of nutrient into BW gain in the most **efficient** in the immediate **post weaning period** "

Post Weaning Potential: Area undiscovered



Window of Opportunity:

"Growth capacity and feed efficiency potential is amazing in young calves"

Effect of pre and post-weaning plane of nutrition on lifetime performance and carcass characteristics of dairy-bred beef calves (Abbott *et al.* 2024)

Integration of pre and post weaning planes of nutrition with lifetime performance

UCD Institute of Food and Health

Integration of pre and post weaning planes of nutrition with lifetime performance and carcass characteristics of dairy-bred beef calves

Holstein-Friesian & Friesian x Angus bred calves (n=80)

10 weeks

Pre Weaning = Moderate
750g MR/ Day

Pre Weaning = High
1500g MR/Day

4 weeks

Post Weaning Moderate (n = 20)
1.5kg concentrates

Post Weaning High (n = 20)
Adlib concentrates

Post Weaning Moderate (n = 20)
1.5kg concentrates

Post Weaning High (n = 20)
Adlib concentrates

Grazing period - 6 months Common to all treatments (n = 80)

Finishing period - 7 months adlib feeding Common to all treatments (n = 80)

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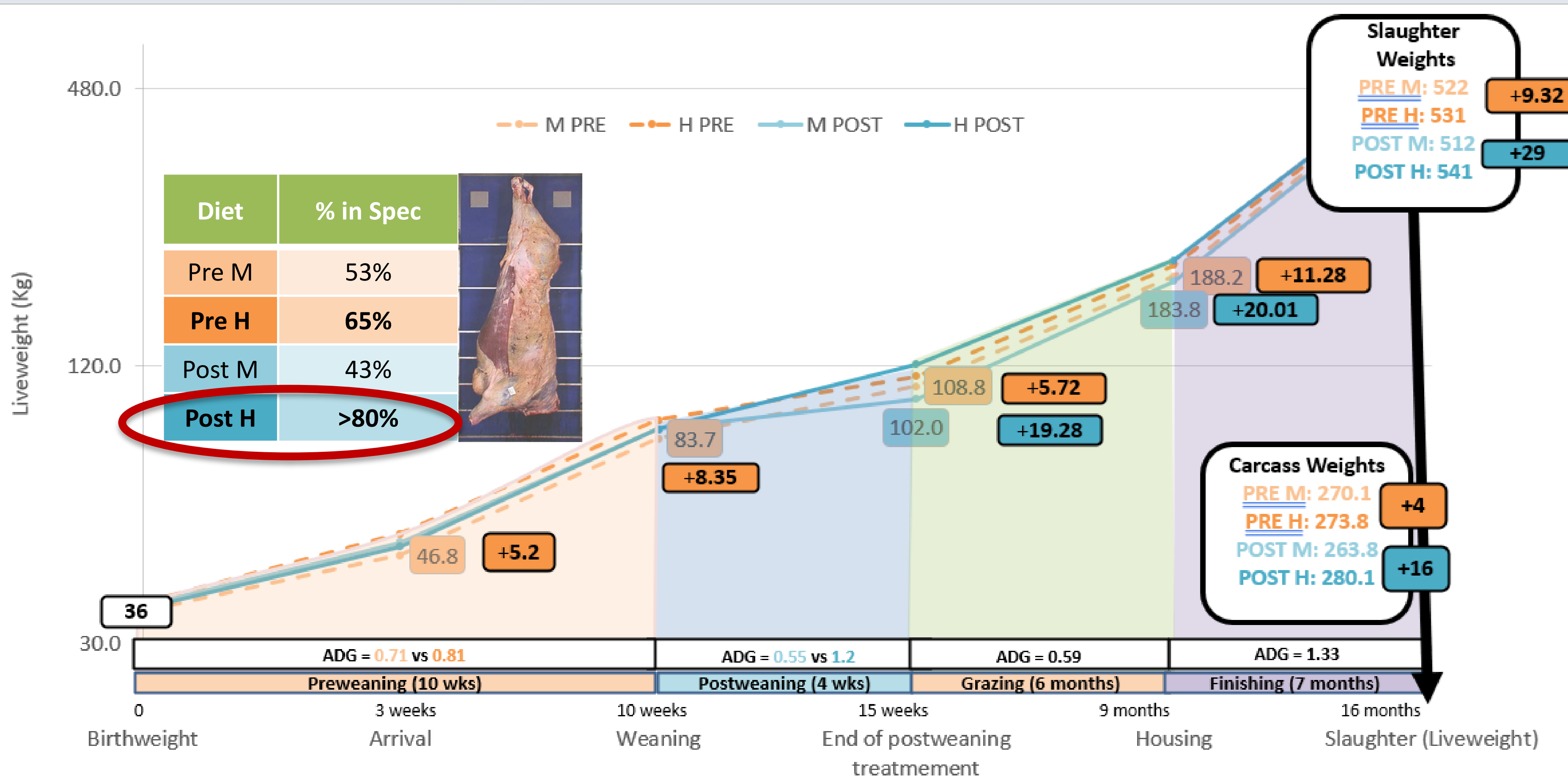
WALSH SCHOLARSHIPS PROGRAMME

Integration of pre and post weaning planes of nutrition with lifetime performance and carcass characteristics of dairy-bred beef calves (Abbott *et al.* 2024)



No interaction between pre and post weaning

Composition of Gain V Composition of CMR

- **Protein**

  - Inconsistencies between studies on effect of CMR protein content on growth performance of calves
  - Interaction with level of feeding?

- **Fat**

  - Little growth response to additional fat (12 – 30% inclusion)
  - Source of fat important – steatosis

- **Composition of gain?**

  - Lack of longer-term studies
  - Does nutrition at different stages of development influence final carcass composition?

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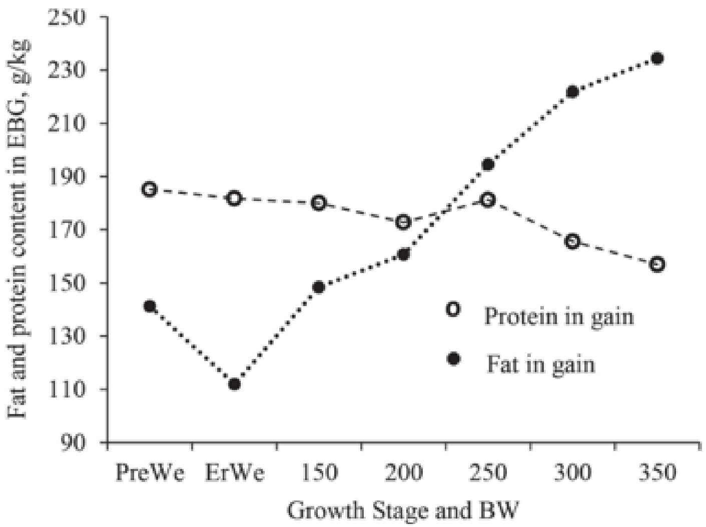

Targets
✓Meet industry carcass specifications
✓High meat yield
✓Cost effective for producer
✓Marketable for processors

Effect of quantity and protein content of CMR on performance of HF bull calves

	23/600	23/1200	30/600	30/1200
Liveweight gain g/d				
1 - 56 days	690	760	720	870
57 - 112 days	1020	1140	1070	1110
1 - 112days	860	950	900	990
Concentrate intake (kg/DM)				
1 - 56 days	34.0	28.2	41.1	23.2
57 - 112 days	180.5	189.6	168.2	211.9
1 - 112days	214.5	217.8	209.3	234.1
CMR intake 1 - 56 days (kg/DM)	30.3	57.4	29.9	56.7

Fallon et al. (2005)

Irish dairy beef data

- **No growth response to increase in crude protein (23% to 30%) content**
- **Response to increased level of feeding in period 1 to 56 days**

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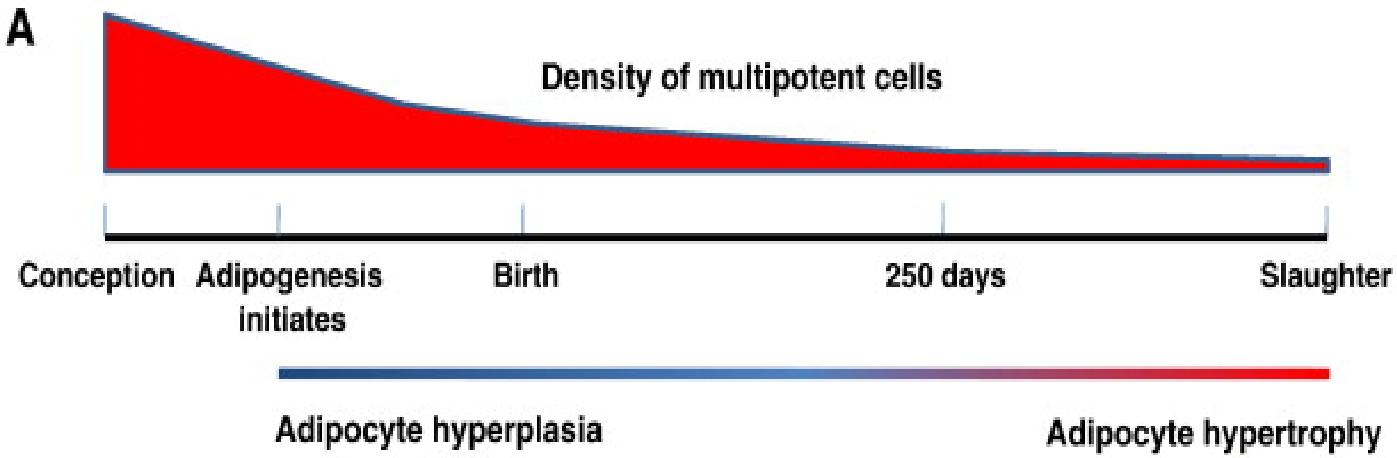
Carcass Fat Development

Preadipocyte differentiation and adipocyte hypertrophy central to establishing overall carcass fatness (Smith, 2007)



Dietary fat v body fat accretion

- Number of fat cells in cattle set in early development (Spalding et al., 2008).
- Strategic nutritional manipulation during early calfhood could increase adipocyte hyperplasia and hypertrophy (Tikofsky et al., 2001)
- Latent effects on subsequent carcass fatness?

The effect of milk replacer fat content on the performance and carcass composition of pre-weaned Holstein Friesian bull calves

Alan K Kelly[2], James R Dick[3], Aidan P Moloney[1] and David A Kenny[1]

[1]Animal & Grassland Research and Innovation Centre, Teagasc, Dunsany, Co. Meath, Ireland. [2]School of Agriculture and Food Science, University College Dublin, Belfield, Dublin 4, Ireland. [3] Institute of Aquaculture, University of Stirling, Stirling, Scotland.

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An Roinn Talmhaíochta, Bia agus Mara

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Materials and Methods

Age 14.7d (±2.4 SD)
Weight 47.8kg
(±4.35 SD)

150 HF bull calves

Milk replacer offered at a rate of 6L/day at 12.5%DM/L.

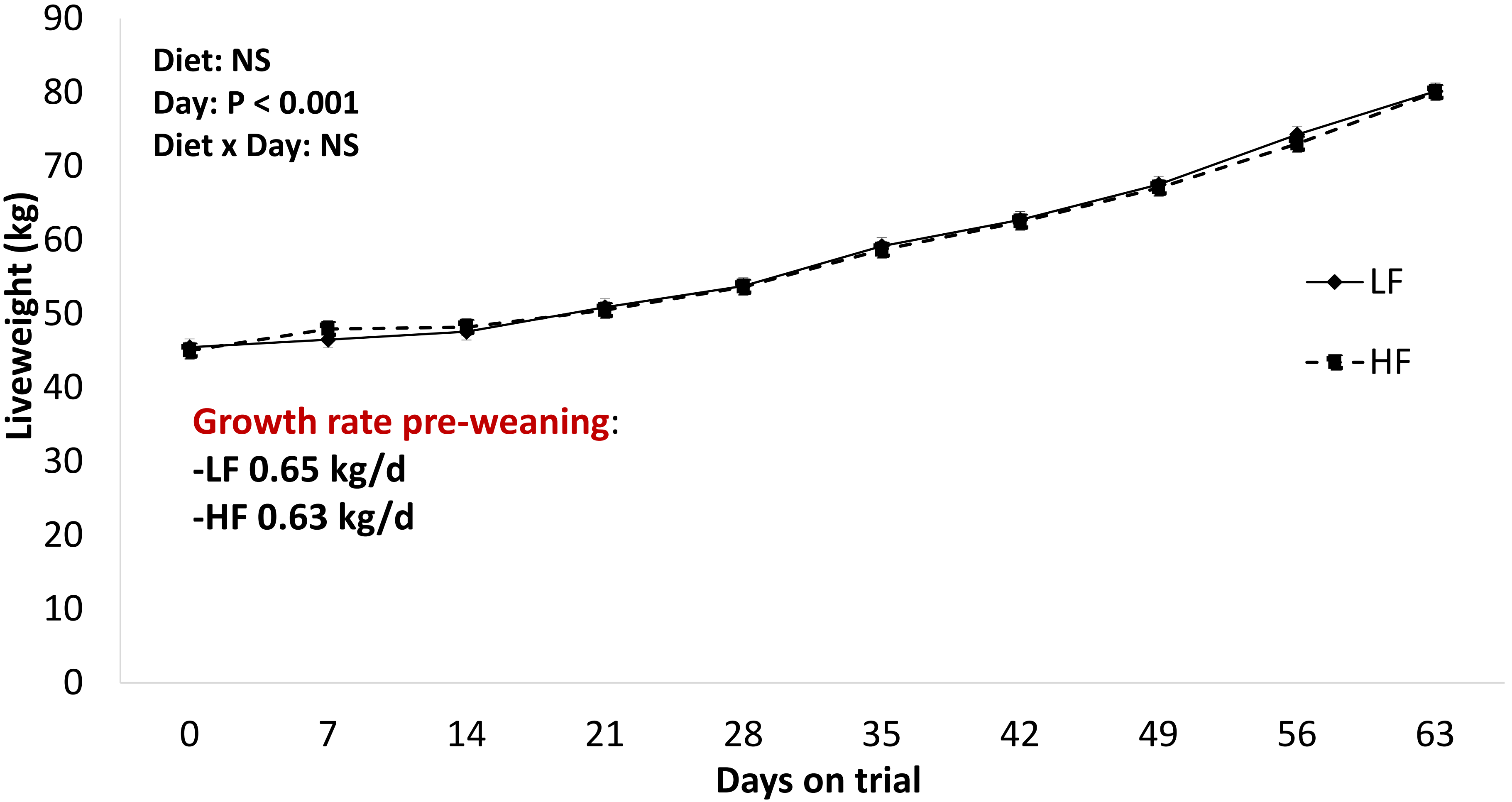
Pelleted concentrate limited to 1kg/day.

CON - 18% Fat (n=75)

HF - 30% Fat (n=75)

- Calves weighed weekly during feeding period
- Systemic metabolic profile determined on three equally spaced occasions
- **Subgroup of calves** selected for **slaughter at d 63** relative to start of trial CON (n= 15; 91kg) and HF (n=15; 85kg)
  - 24hr post mortem cube roll removed and dissected into fat, lean and bone components.

Effect of milk replacer fat content on liveweight in pre-weaned dairy bull calves



Effect of milk replacer fat content on composition of cube roll (78 days of age)

No dissectible fat in the cut at this early stage

	CON		HF		P – value
Initial weight (kg)	1.03	0.042	0.99	0.035	NS
Bone (kg)	0.29	0.017	0.30	0.014	NS
Soft Tissue (kg)	0.71	0.030	0.66	0.025	NS
Nuchal Ligament (kg)	0.028	0.002	0.025	0.002	NS

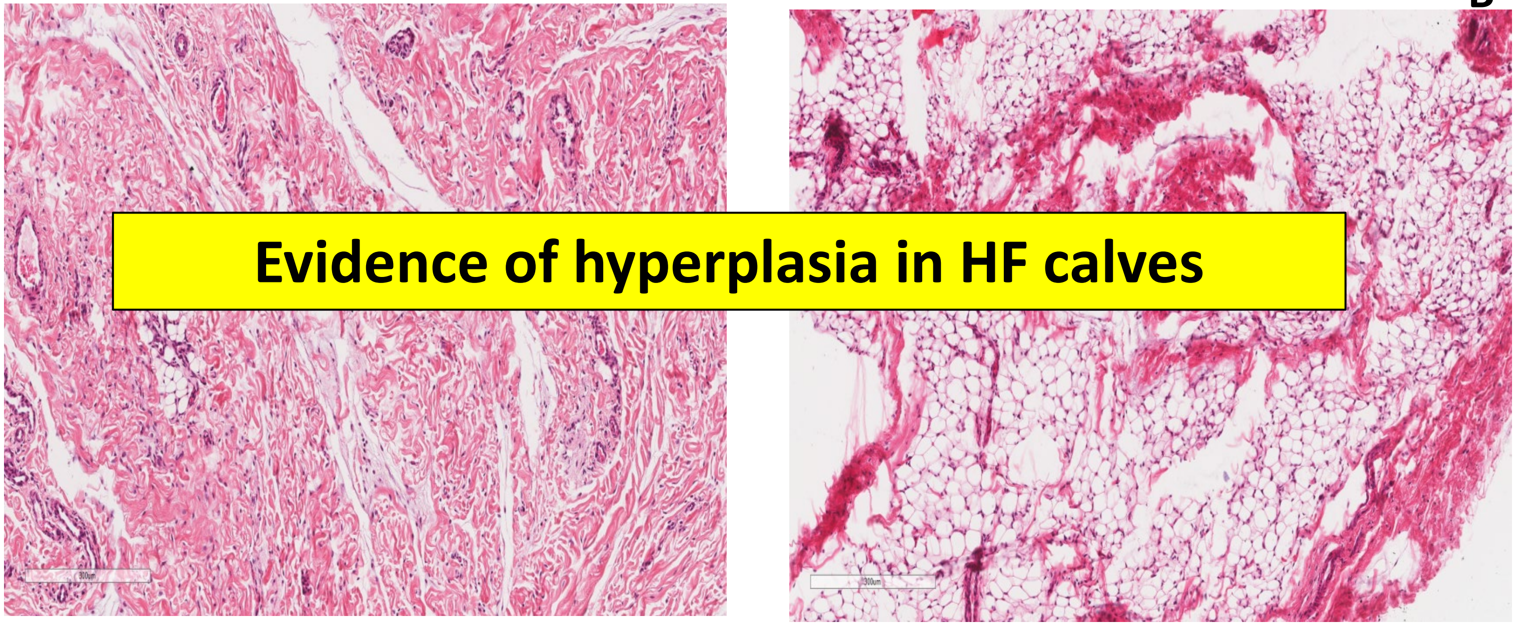
<u>Longissimus Dorsi</u>	CON		HF		P - value
Moisture	77.07	0.30	77.3757	0.26	NS
Fat	0.79	0.09	0.7772	0.07	NS
Ash	1.06	0.02	1.0664	0.02	NS
Protein	20.7	0.40	20.4377	0.34	NS
<u>Other Muscle</u>					
Moisture	73.44	0.73	73.4565	0.61	NS
Fat	6.42	0.81	6.9346	0.68	NS
Ash	1.07	0.05	1.0456	0.04	NS
Protein	18.78	0.19	18.4423	0.16	NS
<u>Nuchal ligament</u>					
Ash	0.66	0.04	0.6293	0.03	NS
Protein	37.46	0.68	37.8946	0.57	NS

Effect of milk replacer fat content on s.c. adipocyte cell size and number

	CON	HF	P value
Adipocyte Number	**138.9**	**584.9**	**<0.05**
Adipocyte Size (µm)	15.64	15.82	NS

A

B

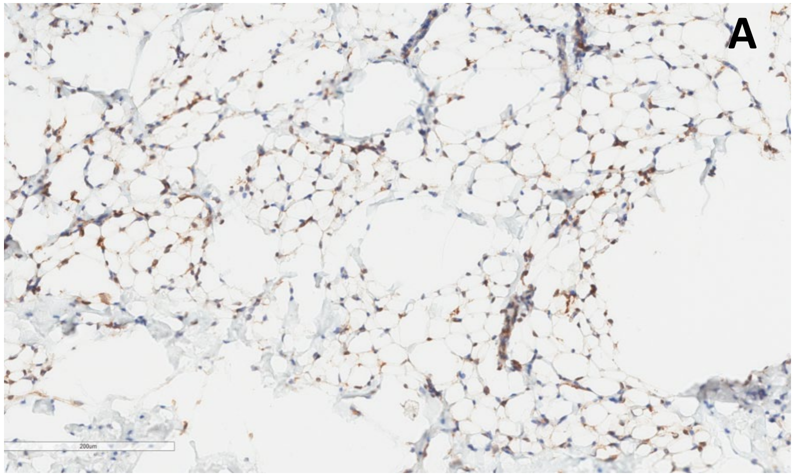


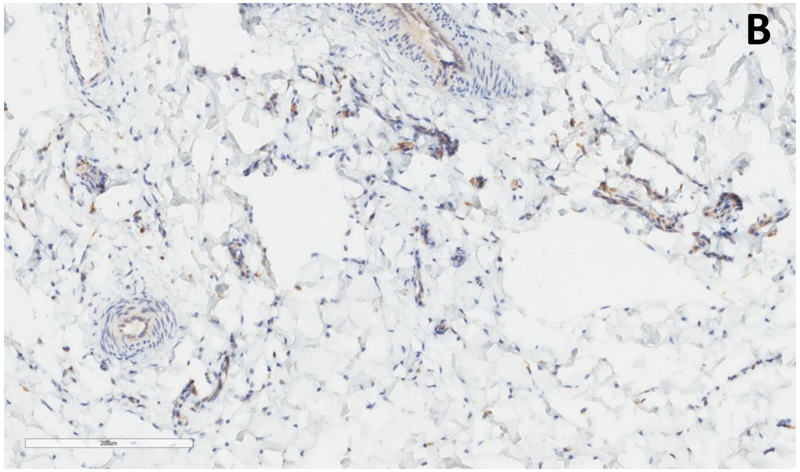
Evidence of hyperplasia in HF calves

Light micrograph (100x) of subcutaneous (s.c.) adipose tissue stained with haematoxylin and eosin. **A.** CON milk replacer had small pockets of adipocytes; **B**. High Fat milk replacer had large areas of adipocytes

Effect of milk replacer fat content on molecular markers of preadipocytes and mesenchymal cells in adipose tissue

	CON	HF	P value
DLK1	**1425.92**	**2140.3**	**0.06**
Ki67	53.21	81.5833	NS
CD34+ SMA-	1818.08	2384.50	NS





IHC staining of s.c. adipose tissue DLK1 (Abcam ab21682; dilution 1:500) positive control bovine placenta. Micrograph from **A**. High fat milk replacer treatment (200x); **B.** CON milk replacer treatment (200x)

- DLK-1 staining was used to access preadipocyte number
- Ki-67 staining and $CD34^{+}SMA^{-}$ double stain was used as indicators of cell proliferation and adipocyte commitment

Effect of milk replacer fat content during calfhood and cereal type and supplemental saturated fat inclusion in the finishing ration on the performance and carcass composition of young Holstein Friesian bulls

120 calves
High Fat
(60)
Low Fat
(60)
M + SF
(15)
M - SF
(15)
B - SF
(15)
B + SF
(15)
M + SF
(15)
M - SF
(15)
B + SF
(15)
B - SF
(15)

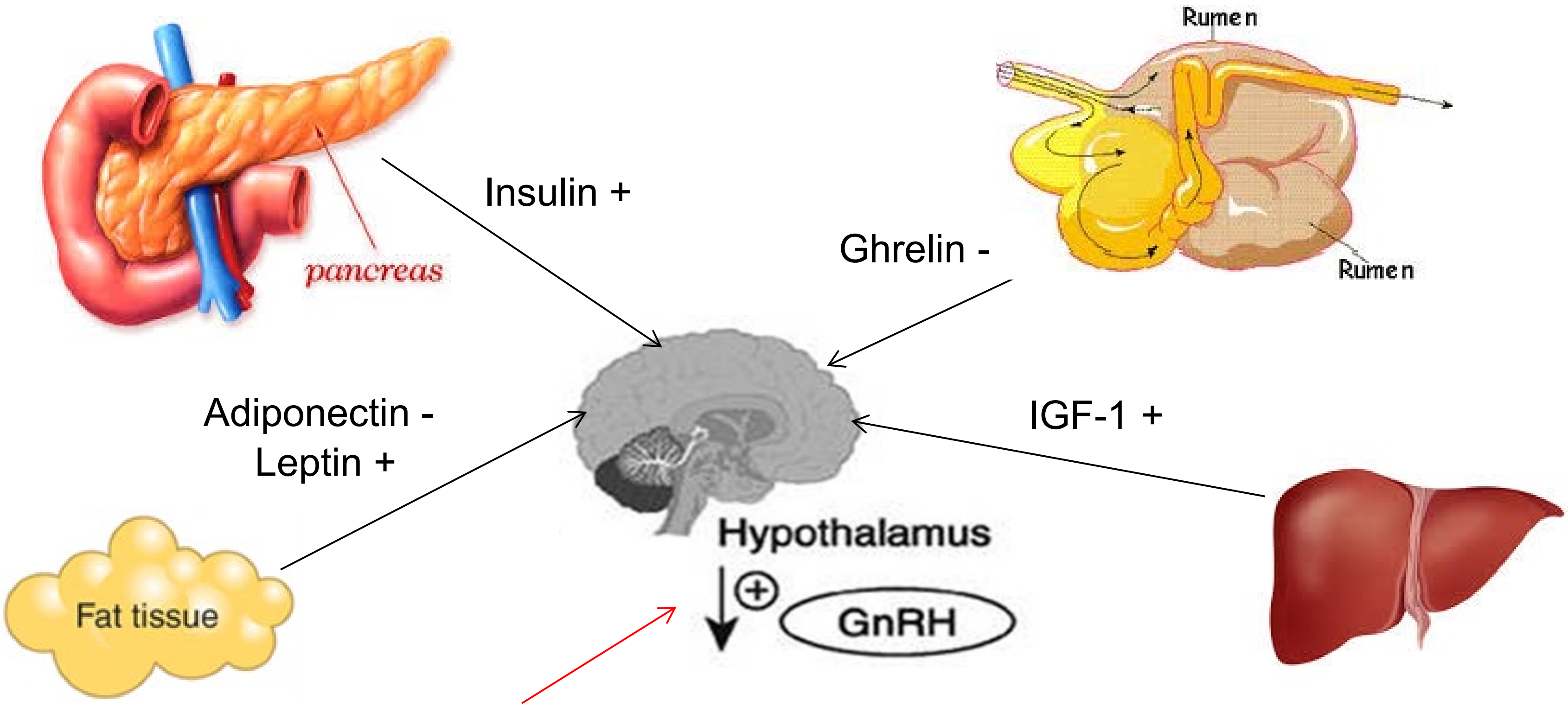
Ferguson et al. (2016)

Effect of milk replacer fat content during calfhood and cereal type and supplemental saturated fat inclusion in the finishing ration on the performance and carcass composition of young Holstein Friesian bulls

Variable	Calf		Cereal		Fat	
	Low	High	Barley	Maize	F-	F+
Slaughter Weight (kg)	527.0	531.8	528.4	530.3	**538.4***	**520.3***
Carcase Weight (kg)	272.4	278.0	274.6	275.9	**280.9***	**269.6***
Conformation	4.5	4.7	4.6	4.7	4.9	4.4
Fat Grade	5.9	5.7	5.7	5.9	**6.1***	**5.5***
Fat deposition						
KCF (kg)	8.91	8.67	8.6	8.98	8.71	8.87
Rumen Fat (kg)	16.62	15.82	15.75	16.69	16.94	15.5
Fat Depth (mm)	5.24	5.41	5.21	5.44	**5.69***	**4.96***
Cube Roll Joint (kg)	7.19	7.38	7.28	7.29	**7.47***	**7.1***
Longissimus Dorsi	1.4	1.44	1.42	1.42	1.44	1.4
Fat	1.03	1.02	1.02	1.03	**1.08***	**0.97***
Other muscle	1.01	1.06	1.02	1.05	1.06	1.01
Lean Trim	2.14	2.19	2.17	2.17	2.22	2.11
Bone	1.5	1.54	1.53	1.52	1.55	1.49

- No latent effect ($P > 0.10$) of calf rearing regimen on carcass measurements or meat quality.
- Supplemental fat in the finishing concentrate reduced carcass weight, carcass conformation and carcass fat.

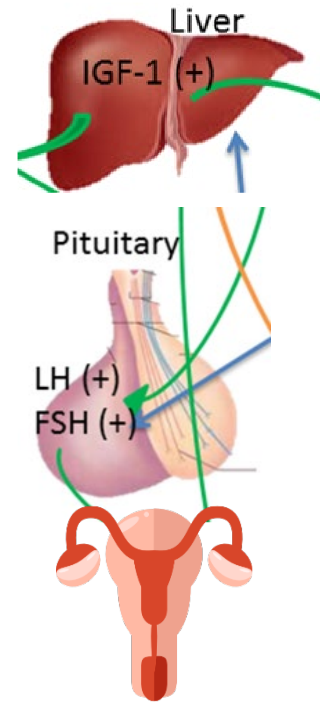
Early life nutrition and underlying biology



Different tissues and organs from the body send signals to the indicating the metabolic status of the animal

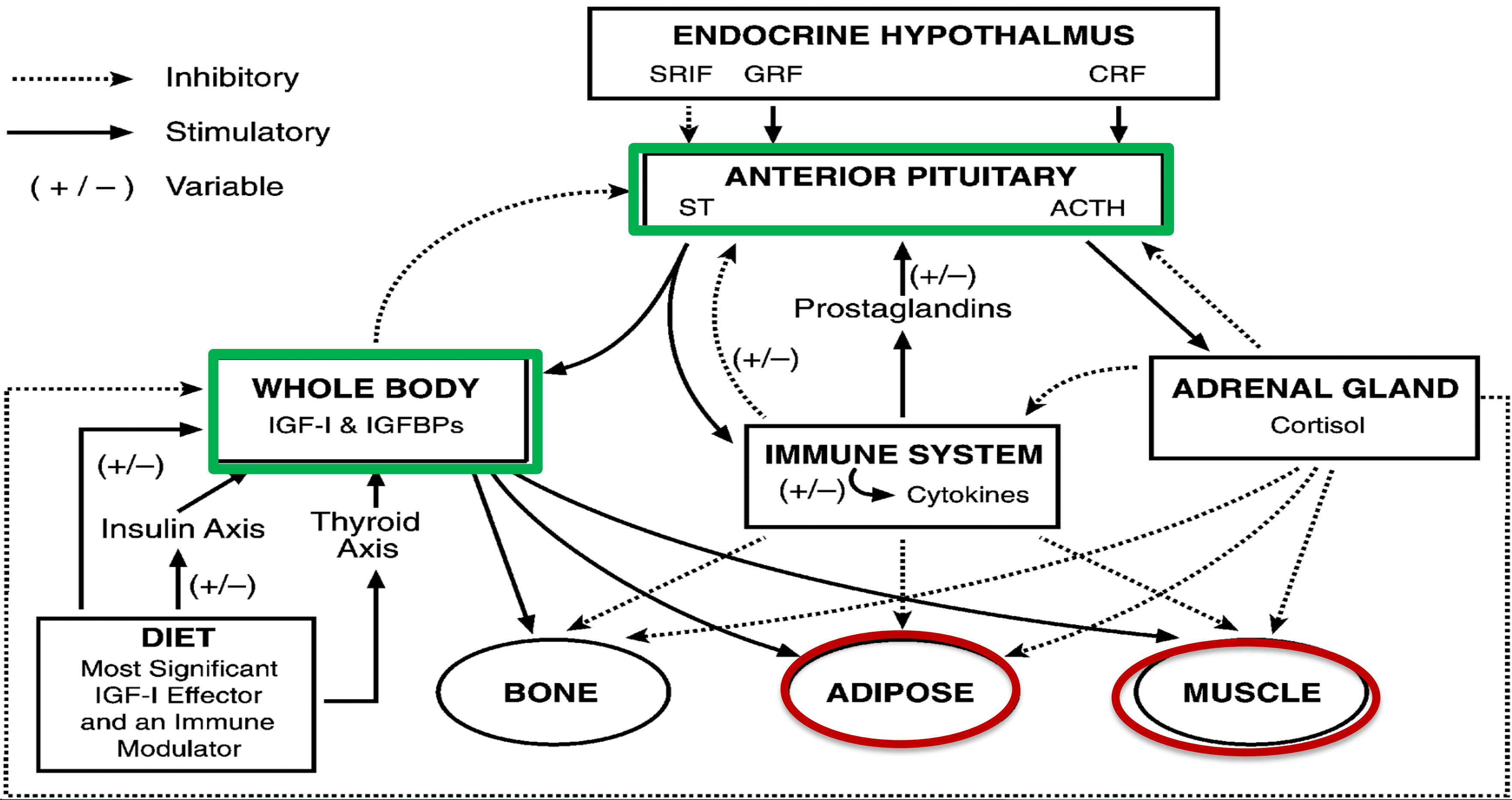
Effect of enhanced early life nutrition on **metabolic organ growth** (Kelly et al 2020)

Trait	Dietary treatments			P-value
	HE	CONT	DIFF	
Heart (kg)	**0.84**	**0.54**	**+0.30**	**0.001**
Heart (% of BW)	0.0044	0.0048	-	NS
Lungs (kg)	**2.25**	**1.27**	**+0.98**	**0.001**
Lungs (% of BW)	0.011	0.011	-	NS
Spleen (kg)	**0.99**	**0.42**	**+0.57**	**0.001**
Spleen (% of BW)	0.005	0.004	-	NS
Liver (kg)	**3.30**	**1.63**	**+1.67**	**0.001**
Liver (% of BW)	**0.018**	**0.014**		**0.001**



*“**Early life growth** was positively associated **ovarian tissue weight,** along with **liver** and **anterior pituitary weight**”.*

Hormonal Control of Growth



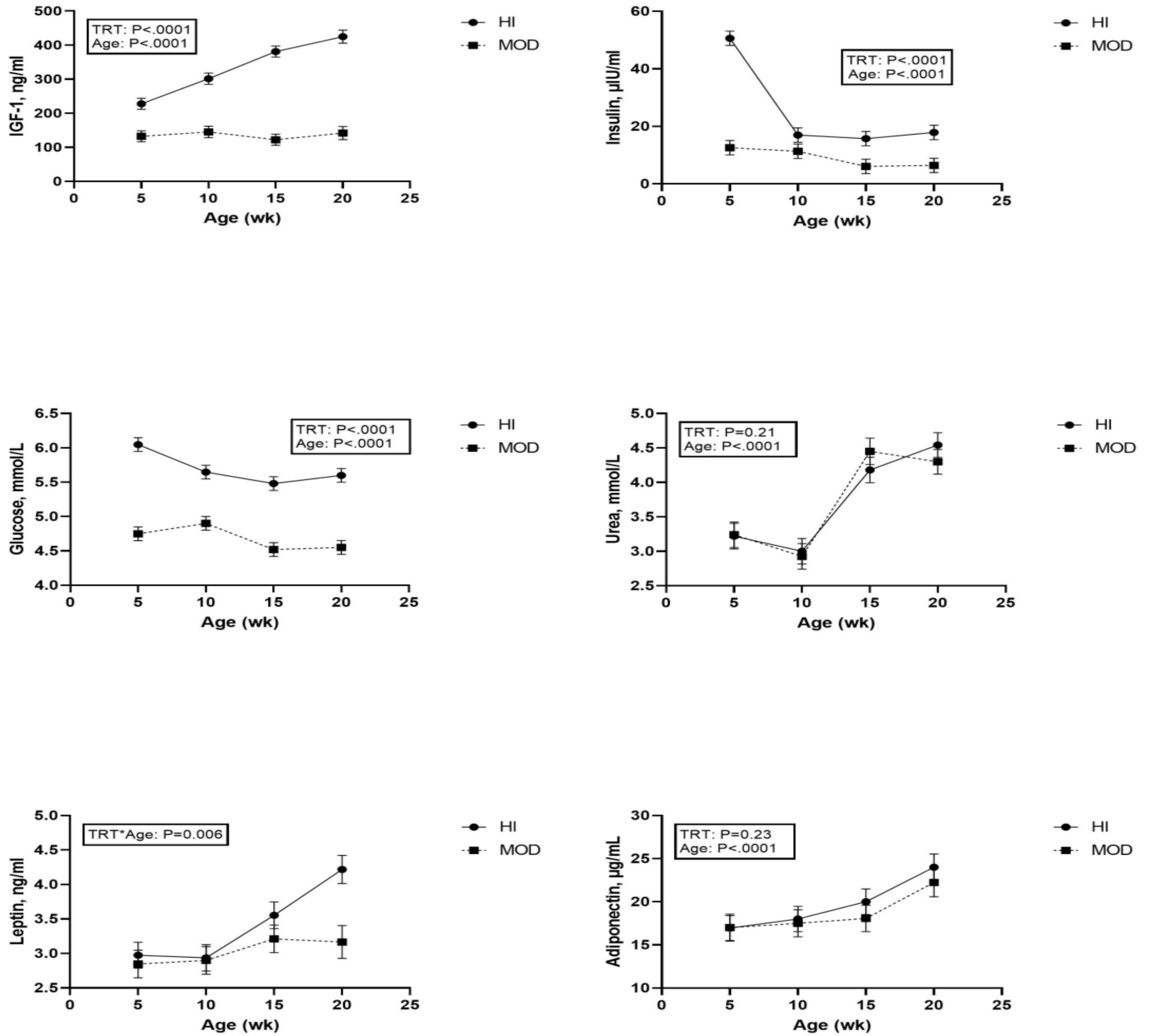
UCD DUBLIN
UCD Institute of Food and Health

Early life nutritional status programmed the sensitivity of the liver to growth hormone, and resulted in long-term effects on the functioning of the somatotropic axis.

Guggeri et al. (2018)

Metabolic hormonal and metabolite profiles in early life from on a high (HI) or moderate (MOD) plane of nutrition

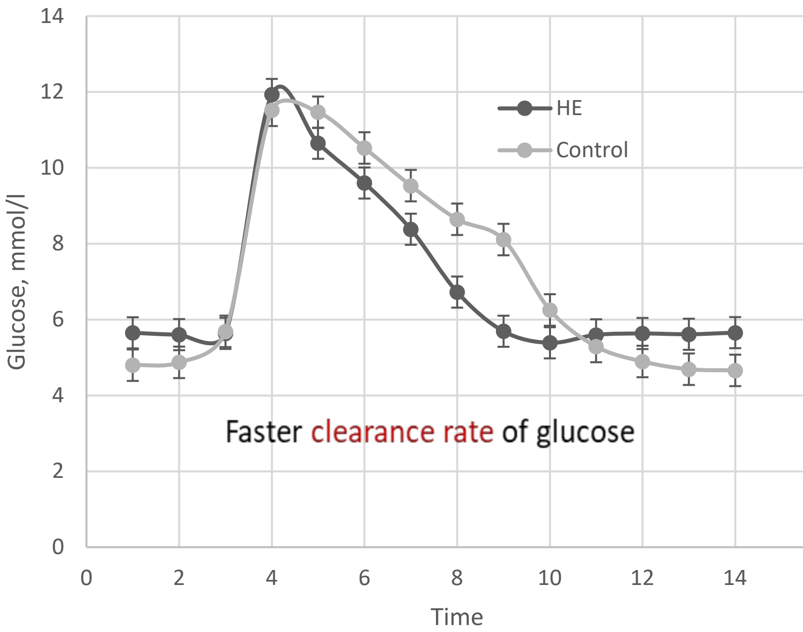
Kelly et al 2020

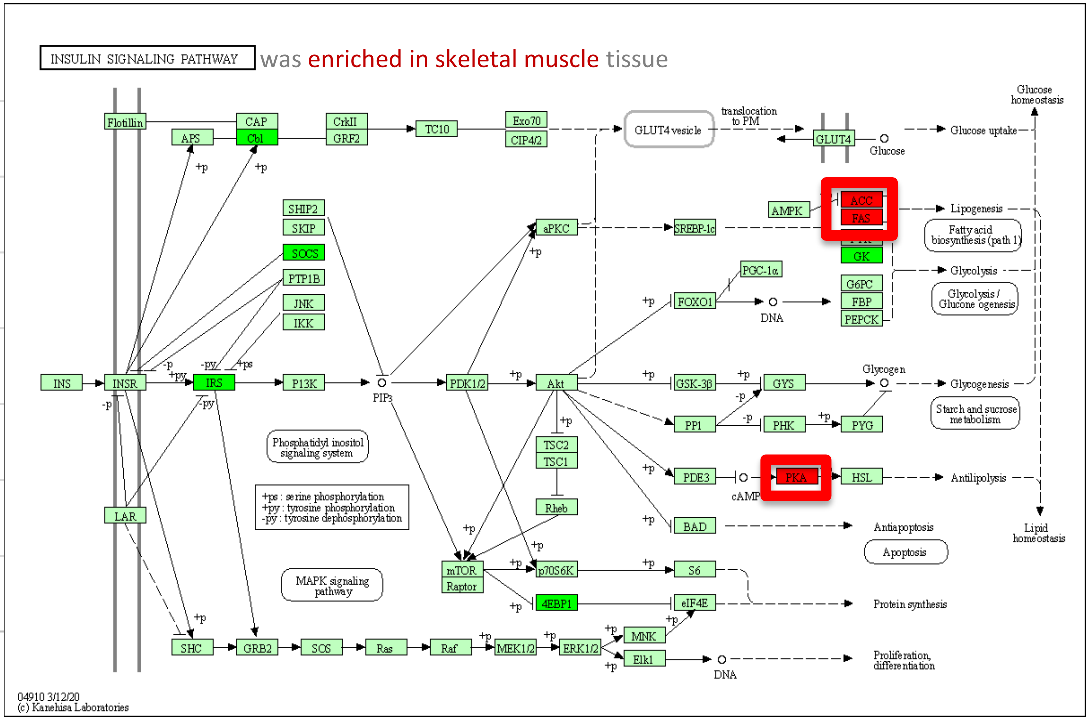


UCD Institute of Food and Health

Effect of enhanced early life growth on glucose clearance and insulin signaling pathway genes in muscle (Kelly et al., 2022)

Glucose Tolerance Test at 18-19 weeks of Age





HI compared to Mod calves

Genes involved in fatty acid biosynthesis up-regulated

- ACACA: fatty acid biosynthesis
- FASN: fatty acid synthesis
- PRKAR2B: regulation of lipid metabolism

Genes involved in insulin reception and glucose transport

- CBLB: glucose transport by insulin
- HK2: glucose metabolism
- IRS2: insulin receptor stimulation

Muscle (430 DEGs)

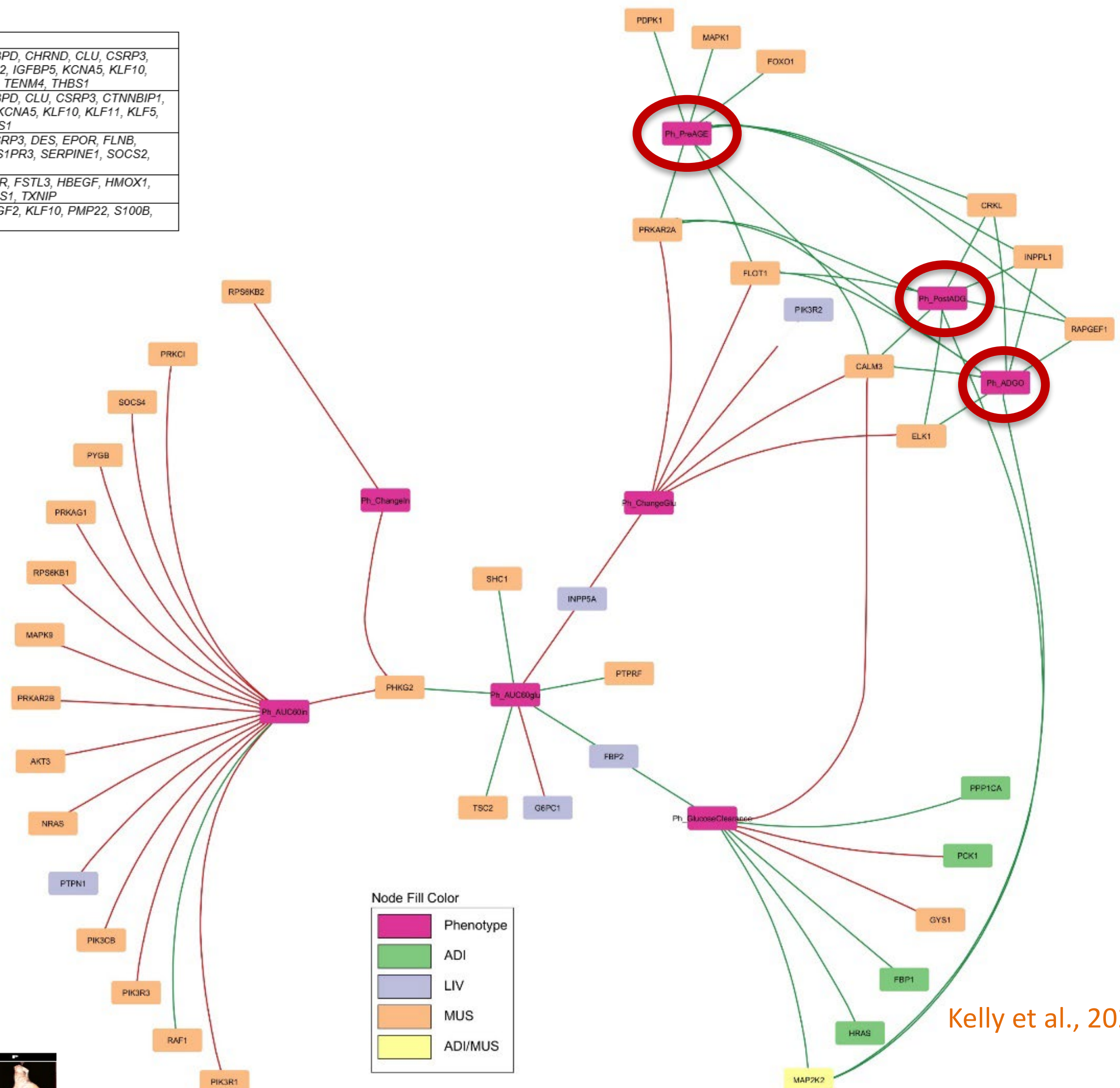
Keogh et al., 2024

Table 1. Genes differentially expressed between HI and MOD calves in skeletal muscle tissue involved in skeletal muscle system development and function.

Function Annotation	p-value	Molecules
Growth of muscle tissue	2.4E-10	*ADIPOQ, ALDH1A2, ANGPT1, APOD, APOE, AR, BIRC5, CDKN1A, CEBPD, CHRND, CLU, CSRP3, CTNNBIP1, E2F3, GDF11, GPX1, HBEGF, HMOX1, HOXA4, IGF1R, IGF2, IGFBP5, KCNA5, KLF10, KLF11, KLF5, MYC, NAMPT, NPR3, NQO1, PRRX1, S1PR3, SERPINE1, TENM4, THBS1*
Proliferation of muscle cells	7.15E-10	*ADIPOQ, ALDH1A2, ANGPT1, APOD, APOE, AR, BIRC5, CDKN1A, CEBPD, CLU, CSRP3, CTNNBIP1, E2F3, GDF11, GPX1, HBEGF, HMOX1, HOXA4, IGF1R, IGF2, IGFBP5, KCNA5, KLF10, KLF11, KLF5, MYC, NAMPT, NPR3, NQO1, PRRX1, S1PR3, SERPINE1, TENM4, THBS1*
Formation of muscle	2.23E-07	*ACTC1, ALDH1A2, ANGPT1, APOE, AR, ARID5B, CASQ2, CDKN1A, CSRP3, DES, EPOR, FLNB, FOSL2, HBEGF, IGF1R, IGF2, IGFBP5, KLF10, MYH3, PMP22, S100B, S1PR3, SERPINE1, SOCS2, TCF15, THBS1, TP63, VCAM1, XIRP2*
Function of muscle	3.01E-06	*ADIPOQ, APOE, AR, CASQ2, CBLB, CDKN1A, CLU, CSRP3, DES, EPOR, FSTL3, HBEGF, HMOX1, IGF1R, IGFBP5, INHBB, KLF5, MB, MYH4, PLIN5, S100A1, SULF1, THBS1, TXNIP*
Formation of muscle cells	3.94E-06	*ACTC1, AR, CASQ2, CDKN1A, CSRP3, DES, FOSL2, HBEGF, IGF1R, IGF2, KLF10, PMP22, S100B, SERPINE1, SOCS2, VCAM1*

Processes: skeletal muscle system development and function

✓ **Evidence: Key developmental window in early life are proposed to influence carcass composition and development.**



Kelly et al., 2024

Adipose (928 DEGs)

Keogh et al., 2023

Table 2. Genes mapped to the adipogenesis pathway identified as differentially expressed in visceral adipose tissue between calves fed high or moderate energy diets during the early life period un to 21 weeks of age.

Gene ID	Gene Name	Fold Change[1]	FDR
AGPAT2	1-acylglycerol-3-phosphate O-acyltransferase 2	1.652	0.0139
AKT1	AKT serinethreonine kinase 1	-1.515	0.000398
ARNTL	Aryl hydrocarbon receptor nuclear translocator like	1.586	0.0172
FGF1	Fibroblast growth factor 1	5.182	4.83E-15
FGFR3	Fibroblast growth factor receptor 3	-2.088	0.00267
GTF2H5	General transcription factor IIH subunit 5	1.522	0.0214
HIF1A	Hypoxia inducible factor 1 subunit alpha	-1.954	0.00512
KLF5	Kruppel like factor 5	-2.21	0.00167
LEP	Leptin	2.757	7.02E-05
PER2	Period circadian regulator 2	-2.257	0.0028
PPIP5K1	Diphosphoinositol pentakisphosphate kinase 1	1.619	0.00871
TXNIP	Thioredoxin interacting protein	-1.703	0.0175

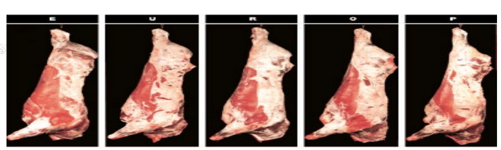
[1]Fold change values are up- or down-regulated in HI group compared to the MOD group

Processes

-Greater Adipogenesis

-Leptin and AGPAT gene

-Pre-adipocyte stage of differentiation



Network: significant connections; associations > 0.5 in connection network

Effect of enhanced early life growth on adipocyte cell number and diameter at 18 weeks in dairy beef bull calves (English et al., 2022)

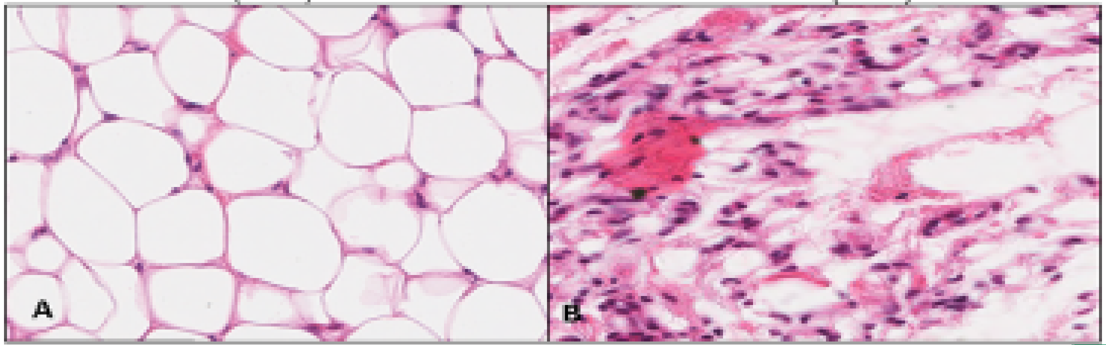
Adipocyte Morphology

Effects of a high or low plane of nutrition on adipocyte cell number and diameter at 18 weeks of age in Holstein-Friesian bull calves (mean ± sem)

	High	Low	Significance
Cell Number (per 1.25 mm^2)	291 ± 47.2	7.5 ± 4.0	***
Cell Diameter (µm)	36.9 ± 2.89	3.7 ± 1.94	***

*** = P<0.001,

HIGH (x400) LOW (x400)



P<0.001

English (2018). *BMC Genomics* 19(1):281.

Evidence of hyperplasia and hypertrophy

Overall summary and conclusion

Economic Efficient:

- Beef productions systems early life growth is the most economic efficient
- Feed costs per unit of BW gain: lowest in the first 6 month of life

Biological Efficient:

- Conversion of nutrient into BW gain in the most efficient in the first 6 months of life
- Maintenance costs are higher and growth efficiency lower at heavier weights

Important of Early Life Growth Advantage/Weight for Age:

- Growth advantage in early life generally retained to slaughter
- Consistent across artificially reared and suckled calves
- Little or no evidence for compensatory growth in calves (< 6mths)
- Effects of **CMR composition** or **supplements** less clear
- Lack of information on **latent effects** on **carcass composition and meat quality**

Metabolic Imprinting *Evidence*

- Critical windows of postnatal developmental plasticity in which nutritional interventions may result in long-term consequences on animal growth and carcass composition .
- Identifying and implementing strategies targeting this period of development offers an opportunity to enhance efficiency and profitability of beef production systems.

Thank you