IMPACT OF PRE-WEANING NUTRITIONAL REGIMES ON MAMMARY GLAND DEVELOPMENT IN HEIFER CALVES

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Session 34: “Physiological limits of performance due to disproportionate growth".

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CALF REARING IN NEW ZEALAND

- Pasture-based system
- Progeny from dairy farming systems are artificially reared for herd replacements or beef production


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HIGHLY VARIABLE REARING SYSTEMS

- Variable daily milk/MR volume (10-20+% of body weight)
- Concentrates (grain) and/or conserved forage
- Pasture-based + concentrates
- Wean between 6-15 weeks

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GOAL – LIFETIME PRODUCTIVITY

- 70% of NZ dairy heifers below target weight at mating (*McNaughton et al 2012)*
- Improved rearing of heifer replacements 56% now reach target weights at mating *(Handcock et al. 2016)*
- Calving live weight affects first lactation milk production (*van der Waaij et al. 1997; Carson et al. 2002; Macdonald et al. 2005*)
- Potential lifetime productivity effects from enhanced heifer rearing (*Soberon et al. 2012, Khan et al. 2011, Davis Rincker et al. 2011, Geisinger et al. 2016)*

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GOAL – LIFETIME PRODUCTIVITY

- Intensified feeding pre-weaning ↓ age at first calving without negatively affecting milk yield or economics
  (Davis-Rincker et al. 2011)

- Pre-weaning ADG explains ¼ of variation in first lactation milk production (0.1 kg ↑ ADG = 107 kg more milk)
  (Soberon et al. 2012)

- Adequate nutrients + ADG > 0.5 kg/d + good weaning practices can enhance first lactation performance
  (Geisinger et al. 2016)

- Lactation performance - influenced by varying nutrient intake levels during key phases of mammary development
  (Moallem et al. 2010; Khan et al. 2011; Bach 2012)

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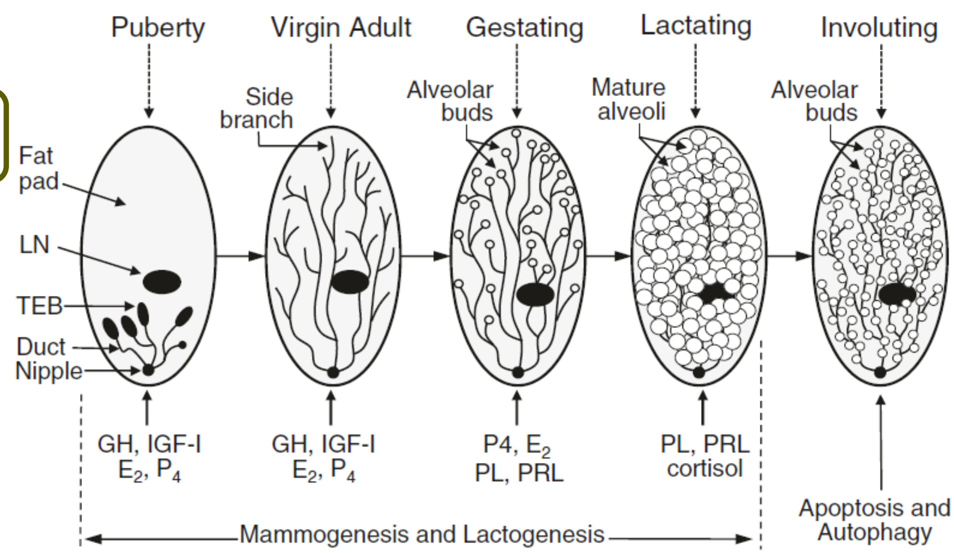
MAMMARY DEVELOPMENT

- Primary dairy industry goal – healthy heifers with mammary glands that synthesise and secrete large amounts of high quality milk
- Structural development of the mammary gland is critical for future milk production
- 5 phases of mammary growth:
    1. Fetal
    2. Pre-pubertal
    3. Post-pubertal
    4. Pregnancy
    5. Lactation



Source: *Rezaei et al. 2016*

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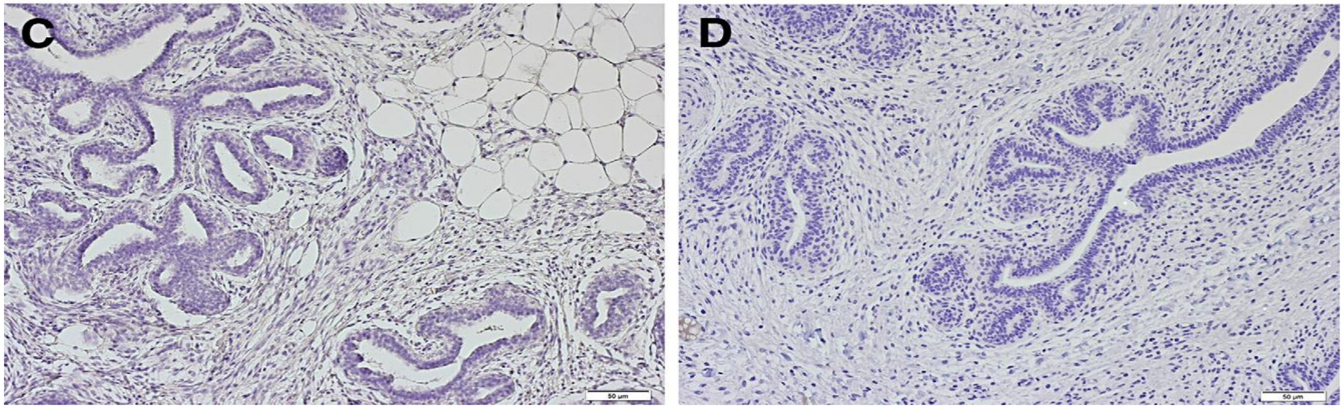
FETAL – EARLY POSTNATAL PERIOD

- Mammogenesis initiated in embryonic and fetal life
- Negligible mammary fat pad at birth
- At 9 weeks (~80 kg BW) ~80g fat pad and ~1.5g parenchymal mass *(Daniels et al. 2009)*
- Parenchyma consists of gland cistern + ductal system lined with double-layered epithelium and terminal alveolar structures *(Mayer et al. 1961)*



Pre-pubertal lamb

Pre-pubertal heifer

Source: Rowson et al. 2012

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PRE-PUBERTAL NUTRITION - FUTURE MILK YIELD

- Most studies focus on assessment around puberty
- Nutrient intake = ↑ mammary fat pad
  (Sejrsen et al. 1982; Capuco et al. 1995; Radcliff et al. 1997)
- High energy diets 3-10 months - ↓ mammary growth relative to body weight leading to over-conditioned heifers and ↓ milk production
  (Sejrsen et al. 1982; Petitclerc et al. 1999, Radcliff et al. 2000)

➡ Heifers fed a higher plane of nutrition post-weaning but before puberty – negative effect on mammary development and future milk yield

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PRE-WEANING NUTRITION

- Hormones and nutrition play key roles in mammary development *(Geiger et al. 2016; Brown et al. 2005)*
- From birth to puberty:
  - Variable response of parenchyma to the level of nutrient intake *(Meyer et al. 2006 a,b; Geiger et al. 2016)*
  - Mammary fat pad is responsive to nutrient intake - suggested diet-induced adipocyte hypertrophy *(Meyer et al. 2006a,b)*

→ Enhanced pre-weaning nutrition may promote mammary development and future production

→ More research required to understand underpinning mechanisms

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OVERARCHING GOALS:

To understand ruminant early-life nutritional principles to:

1. Prepare the digestive and metabolic capacities of dairy-beef calves for improved survival, growth and beef production performance on pasture

2. Program key tissues and immune, metabolic and/or endocrine systems

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OBJECTIVE:

To evaluate the effect of contrasting nutritional regimes pre-weaning on calf growth and development

Targets include:

Rumen development
Small intestine development
Immune function
Mammary development
Muscle development
Adipocyte development

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MATERIALS & METHODS

- 64 Hereford x Holstein Friesian heifer calves

Group	Milk Replacer (MR)			Meal	Target outcome
	Feeding level (% BW)	Fat (%)	Protein (%)	CP 19% of DM; ME 13 MJ/kg DM	
Control	12.5	20.4	22.8	Standard *ad lib*	Typical NZ dairy-beef rearing diet
High fat MR	12.5	30.5	22.6	Standard *ad lib*	Mimic obesogenic diet
High starch meal	12.5	20.4	22.8	High fermentable starch *ad lib*	Promote rumen development
Higher volume MR	20	20.4	22.8	Standard restricted	Restrict rumen development

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METHODS

- Calves reared in individual pens for 7 weeks
- Weaned onto pasture – meal removed ~12 weeks, managed as one group
- Weekly live weight
- Mammary gland dissected and weighed at slaughter - 6 weeks & 6 months of age
- Mammary samples (n=2/animal) collected from the fat pad adjacent to parenchymal tissue below the teat – one from each hindquarter

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METHODS

- Tissues were fixed in 4% paraformaldehyde, processed, and 4µm sections stained with H&E
- Fat pad morphology evaluated using image analysis
- At least 100 randomly selected individual fat cells were measured per animal
- Data log transformed to normalise the data and analysed using the REML algorithm in linear mixed effects model with the fixed effect of arrival group *(R Core team 2012)*

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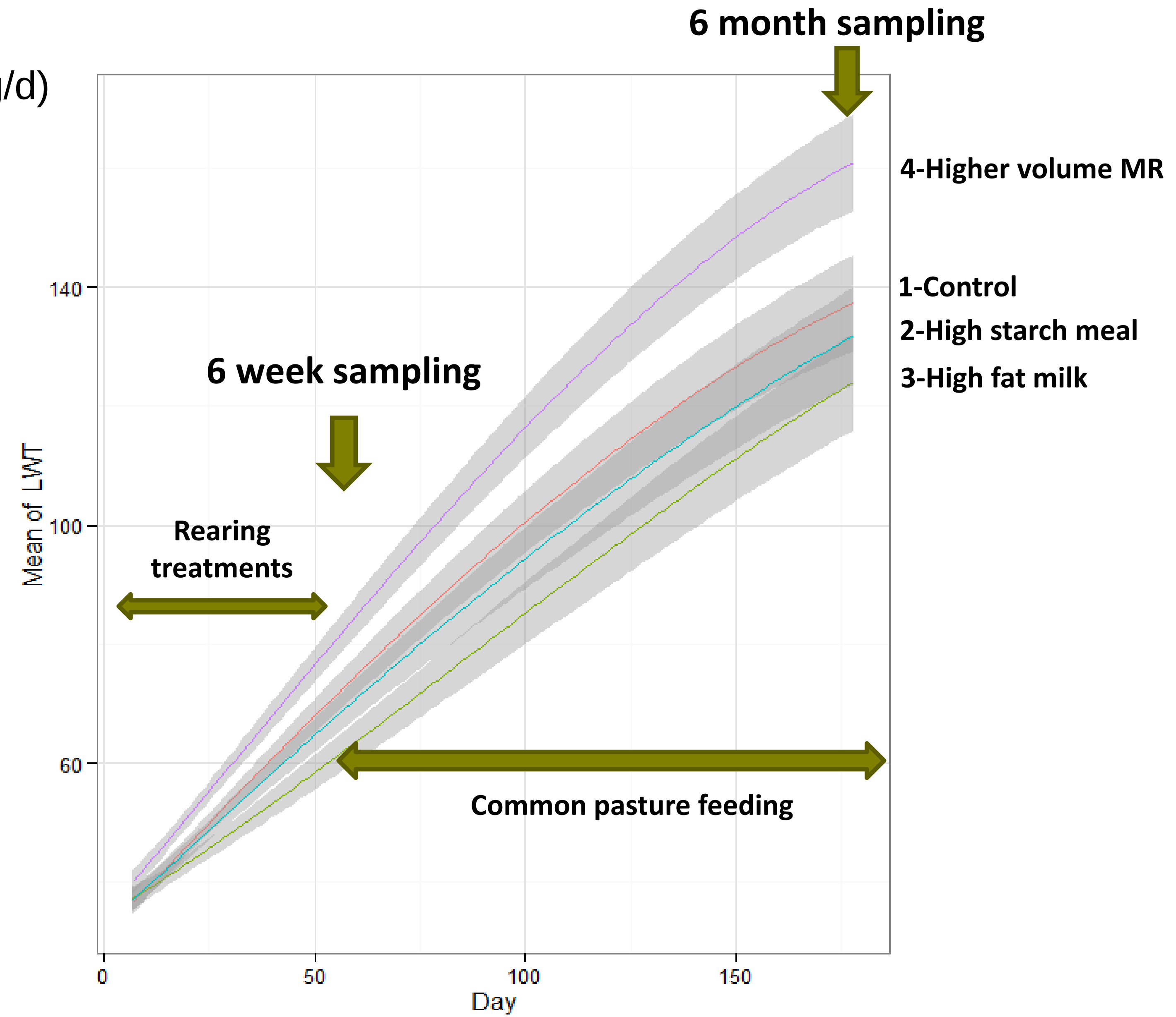
LIVE WEIGHT TO 6 MONTHS OF AGE

Pre-weaning ADG (g/d)
1. 492 ± 15
2. 323 ± 25
3. 474 ± 21
4. 691 ± 10

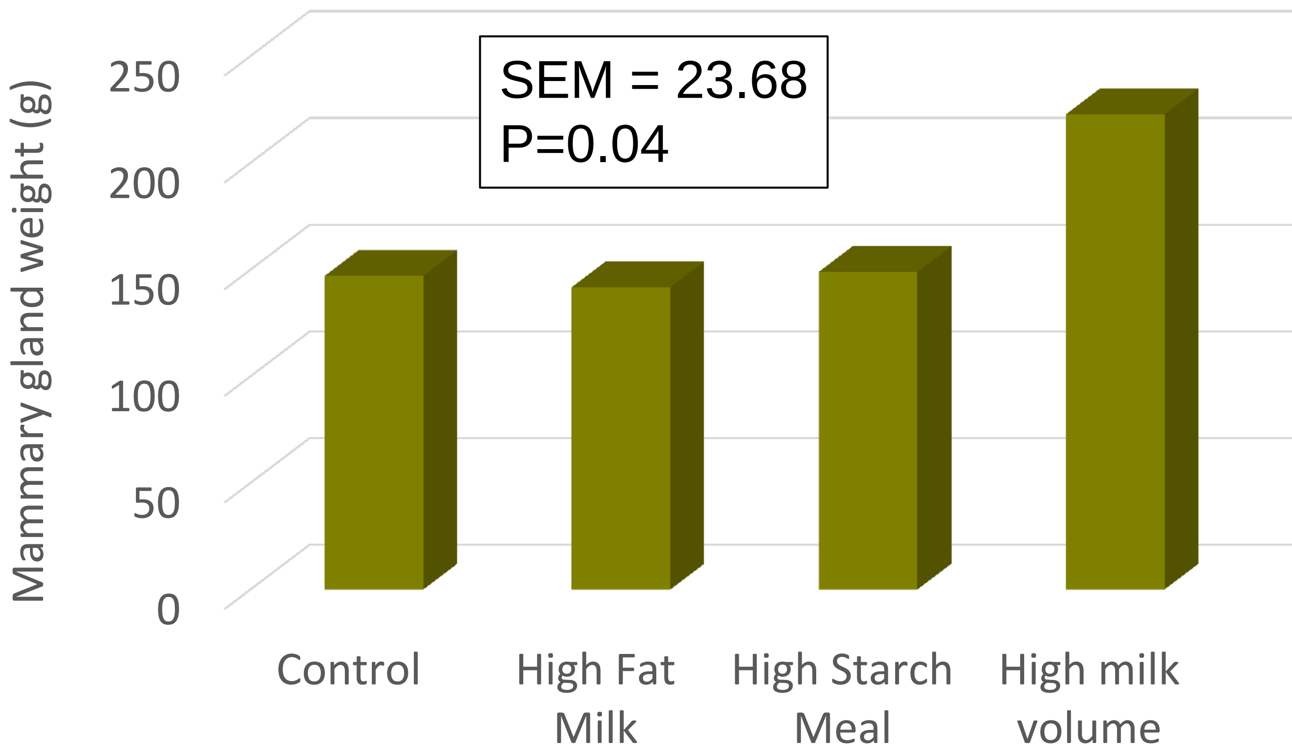
Milk DM intake (kg)
1. 21.0 ± 0.37
2. 20.9 ± 0.41
3. 20.8 ± 0.54
4. 58.6 ± 1.07

Meal DM intake (kg)
1. 23.7 ± 0.91
2. 15.7 ± 1.86
3. 19.6 ± 5.45
4. 4.7 ± 0.56



MAMMARY GLAND SIZE – 6 WEEKS

Calves fed high milk volume had 1.5X heavier mammary glands - data adjusted to a common body weight.



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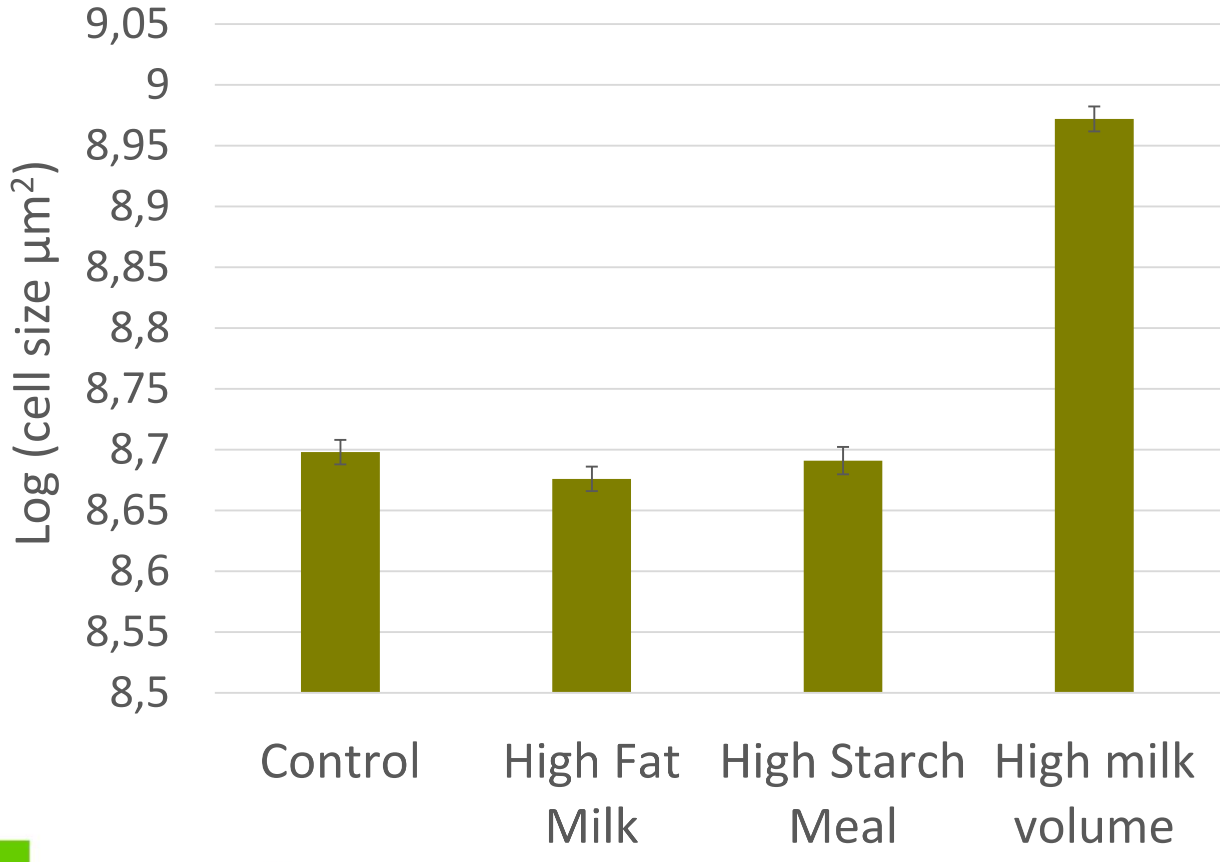
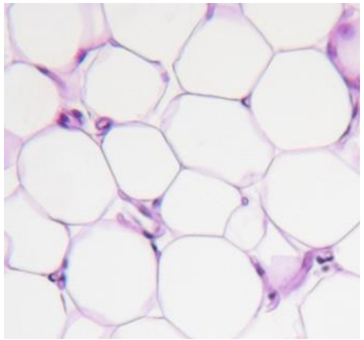
MAMMARY FAT CELL SIZE – 6 WEEKS

Calves fed high milk volume had larger average fat cell size (P<0.001) than all other groups





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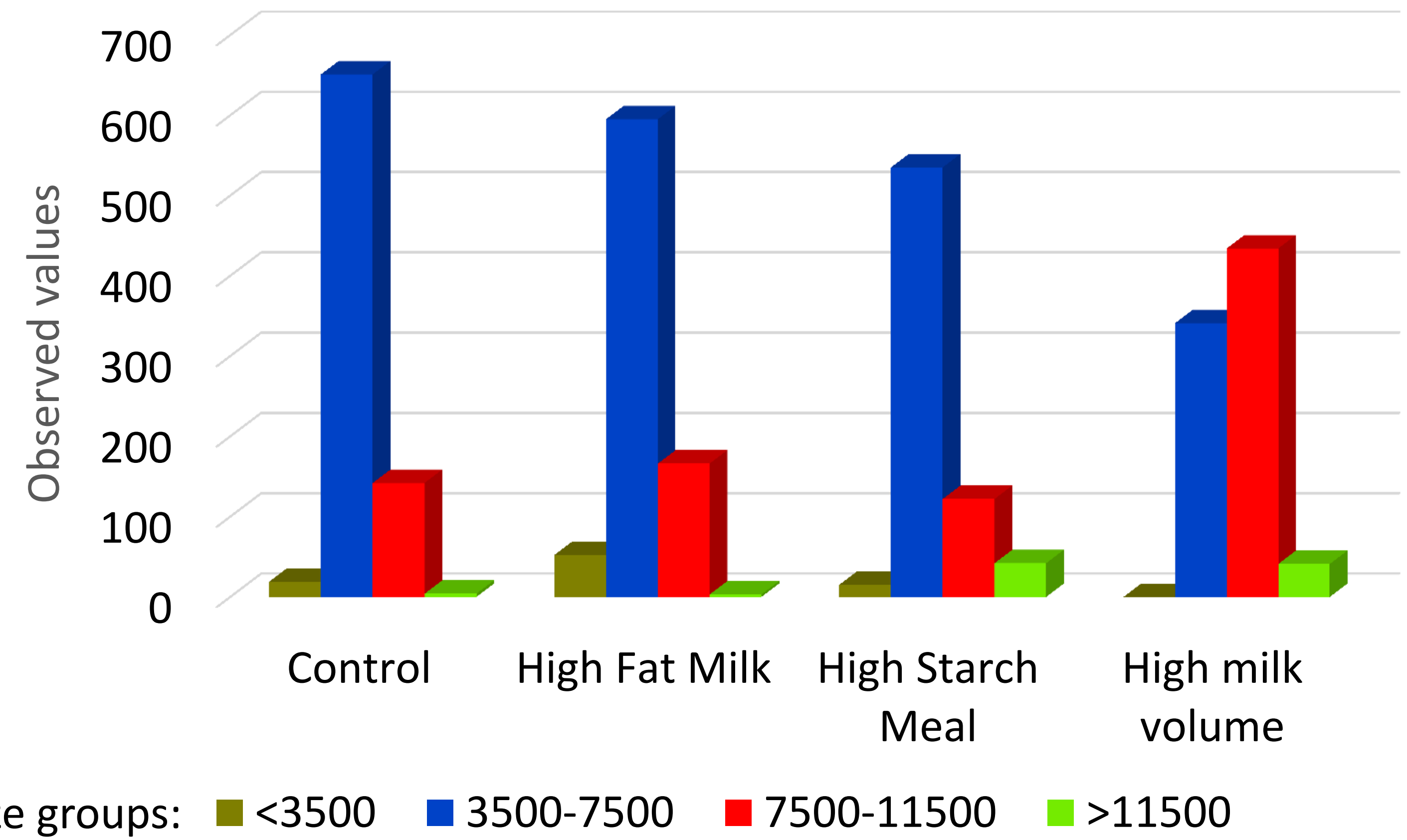
MAMMARY FAT CELL SIZE DISTRIBUTION – 6 WEEKS

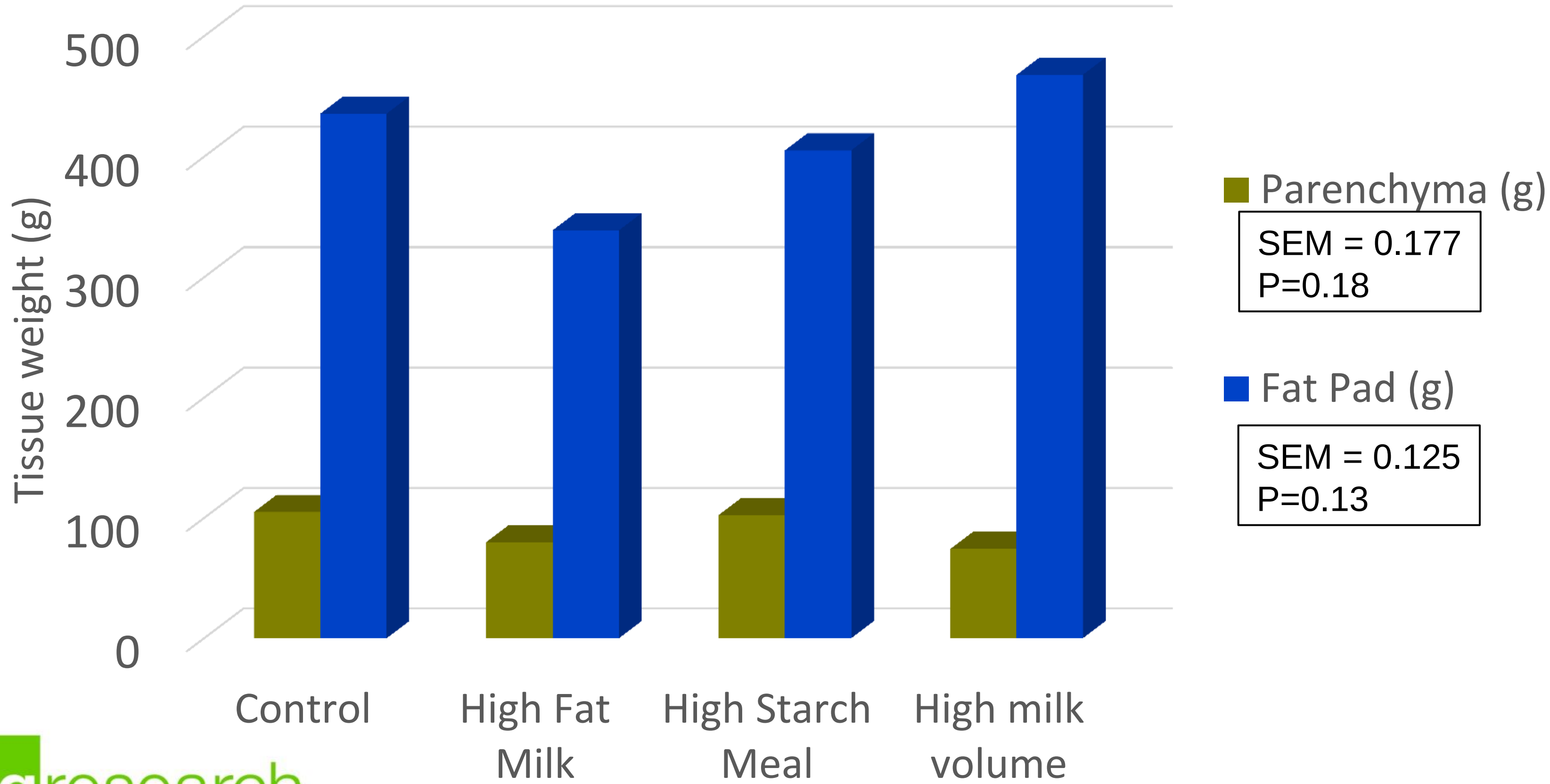
High milk volume fed calves had 2.5 to 3.5X more large fat cells compared to the other groups (P<0.001)



Chi-square test for association between treatment & size group

MAMMARY GLAND DUCT/PARENCHYMA AND FAT PAD MASS – 6 MONTHS

Mammary gland parenchyma and fat pad mass did not differ between groups after adjusting for body weight



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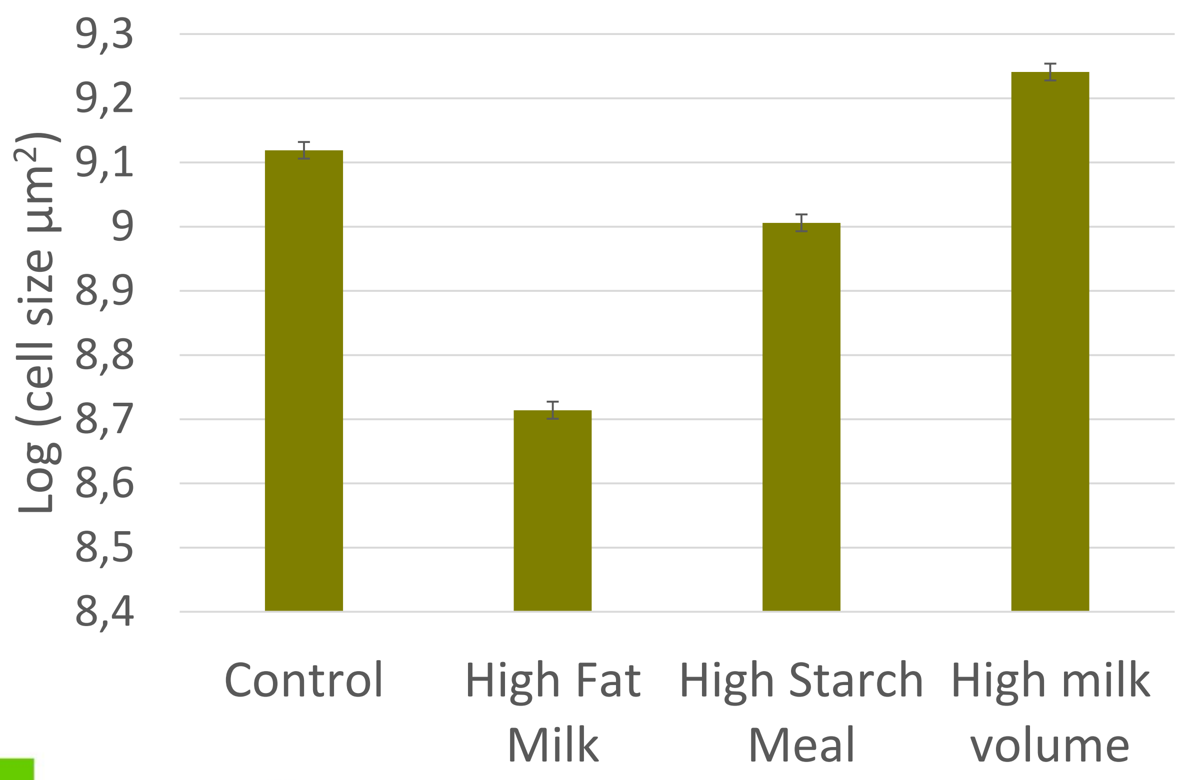
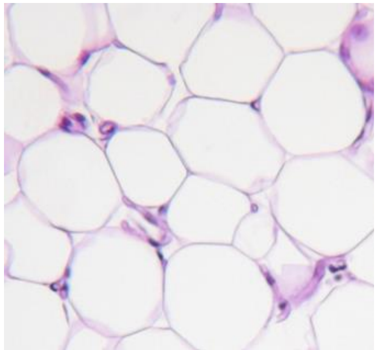
MAMMARY FAT CELL SIZE – 6 MONTHS

All treatment groups were different from one another ($P<0.001$) - High milk > Control > High Starch > High Fat





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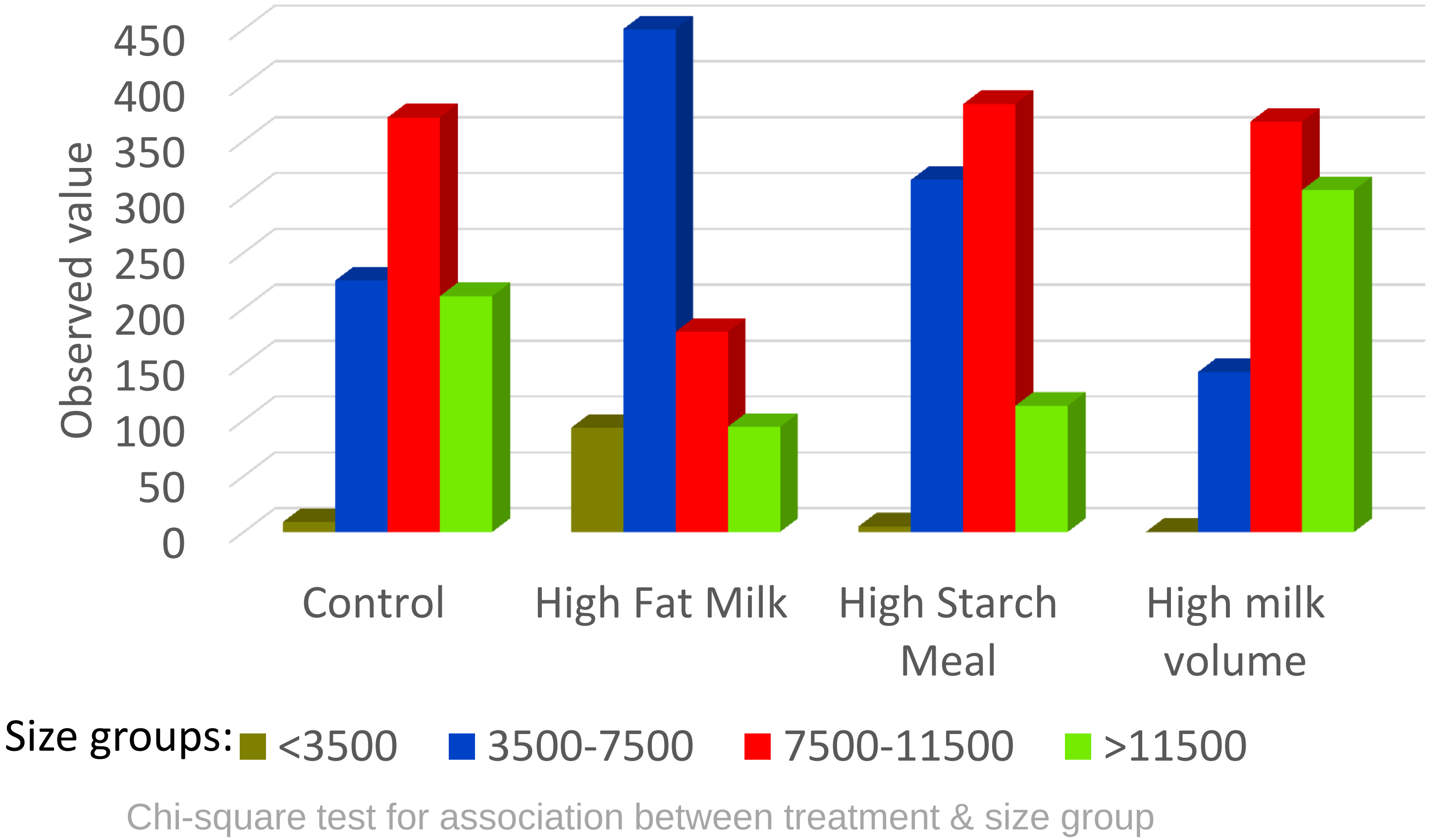
MAMMARY FAT CELL SIZE DISTRIBUTION – 6 MONTHS

High milk volume fed calves had 1.4 to 3.5X more large fat cells, and fewer small fat cells (P<0.001)

High fat milk calves had the most small fat cells (P<0.001).



DISCUSSION

- 0-3 months after birth - isometric phase of mammary growth
- High milk volume (8L *vs.* 4L) - disproportionate mammary growth relative to the other diet groups at 6 weeks
  - ↑ fat cell size and proportion of large cells
  - Induction of early allometric growth? Accelerated maturity?
  - Associated with elevated pre-weaning ADG
- Mammary fat pad is a hormone-producing tissue *(Walden et al. 1998, Meyer et al. 2006)*
- Adipocyte-epithelial cell interactions critical for mammary duct growth and morphogenesis *(Hovey et al. 1999)*

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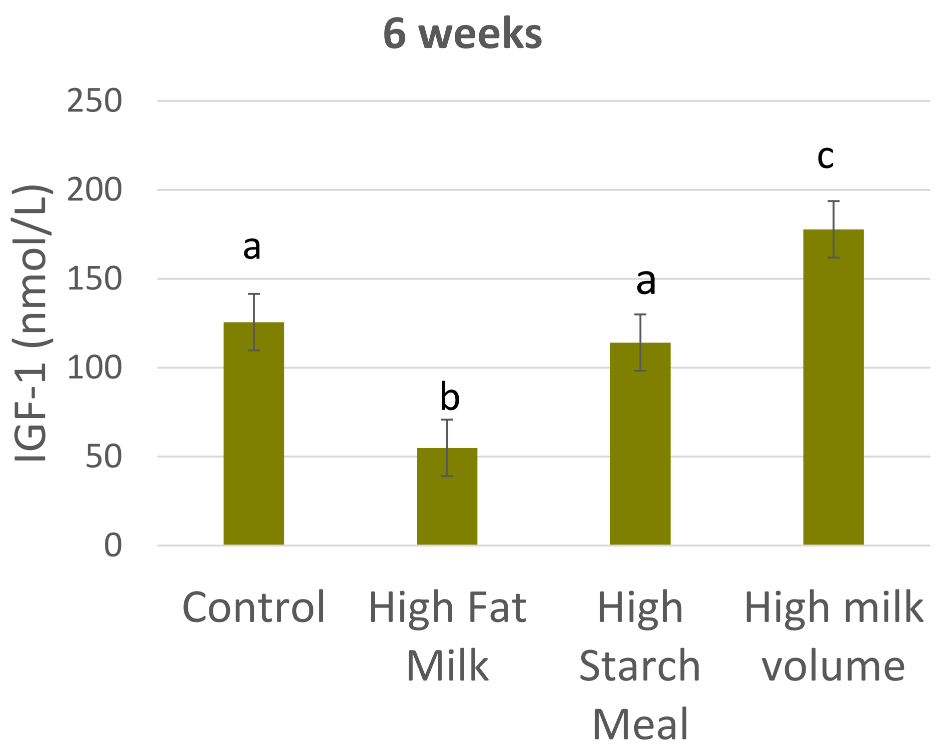
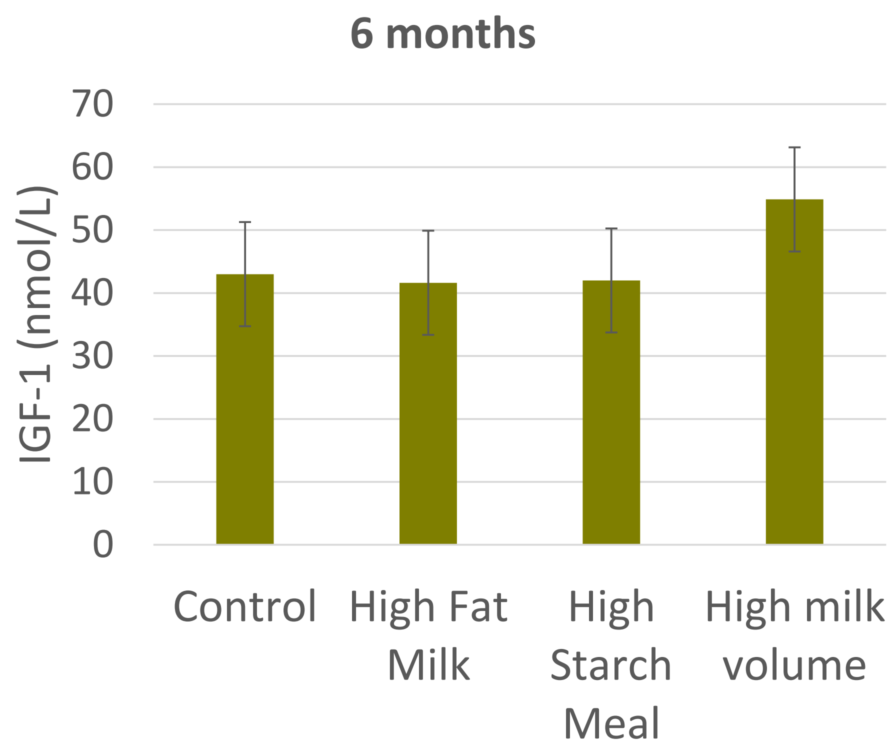
PARACRINE – ENDOCRINE CONTROL

- IGF-1 and ovarian axis contribute to regulation of pre-pubertal mammary development in heifers *(Akers et al. 2005)*
- Potential for greater fat pad development in early life to contribute to mammary development in a paracrine and endocrine manner *(Mollaem et al. 2010)*
- Local IGF-1 axis and the ovary interact to optimize availability and effectiveness of IGF-1 in the gland to support growth *(Berry et al. 2003)*





- Circulating IGF-1 influenced by feeding at 6 weeks but not 6 months
- Local IGF axis?

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KEY OBSERVATIONS

- The amount of nutrients from milk/MR, and the fat content of the milk/MR influences mammary development in the growing heifer
- Elevated milk/MR feeding induced accelerated ADG pre-weaning and mammary fat pad growth by inducing adipocyte hypertrophy
  - Mechanism remains to be elucidated – ovarian and IGF-1 axis?
- Inclusion of highly fermentable starch in the starter diet does not influence mammary development

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CONCLUSIONS

- Milk/MR feeding level and composition pre-weaning can influence mammary fat pad development
- Mechanism mediating the effect of pre-weaning nutrition on mammary growth warrants further research
- Nutritional regulation of mammary development as a mechanism to mediate the effect of high milk/MR feeding on future milk production potential remains to be elucidated

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