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".
Calf rearing in New Zealand

- Pasture-based system
- Progeny from dairy farming systems are artificially reared for herd replacements or beef production
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
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)
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)
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
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 \( (Mayer \ et \ al. \ 1961) \)

Source: Rowson et al. 2012
Most studies focus on assessment around puberty

Nutrient intake = \uparrow \text{mammary fat pad}
\hspace{1cm} (Sejrsen et al. 1982; Capuco et al. 1995; Radcliff et al. 1997)

High energy diets 3-10 months - \downarrow \text{mammary growth relative to body weight leading to over-conditioned heifers and \downarrow milk production}
\hspace{1cm} (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
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
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
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
MATERIALS & METHODS

- 64 Hereford x Holstein Friesian heifer calves

<table>
<thead>
<tr>
<th>Group</th>
<th>Milk Replacer (MR)</th>
<th>Meal</th>
<th>Target outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feeding level (% BW)</td>
<td>Fat (%)</td>
<td>Protein (%)</td>
</tr>
<tr>
<td>Control</td>
<td>12.5</td>
<td>20.4</td>
<td>22.8</td>
</tr>
<tr>
<td>High fat MR</td>
<td>12.5</td>
<td>30.5</td>
<td>22.6</td>
</tr>
<tr>
<td>High starch meal</td>
<td>12.5</td>
<td>20.4</td>
<td>22.8</td>
</tr>
<tr>
<td>Higher volume MR</td>
<td>20</td>
<td>20.4</td>
<td>22.8</td>
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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
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)
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
Calves fed high milk volume had 1.5X heavier mammary glands - data adjusted to a common body weight.

SEM = 23.68
P=0.04

MAMMARY GLAND SIZE – 6 WEEKS
MAMMARY FAT CELL SIZE – 6 WEEKS

Calves fed high milk volume had larger average fat cell size (P<0.001) than all other groups.
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 parenchyma and fat pad mass did not differ between groups after adjusting for body weight.
MAMMARY FAT CELL SIZE – 6 MONTHS

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

Chi-square test for association between treatment & size group
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)
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?
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
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
ACKNOWLEDGEMENTS

AgResearch
- Reuben Harland
- Nina Wards
- Kevin Taukiri
- Jason Peters
- Greg Skelton
- Sarah Lewis
- Marjoke Scherpenzeel
- Jason Archer

On-Farm Research:
- Beverley Thompson
- Noel Smith
- Stuart McMillan
- Kay Ward
- Regan Smith

ANZCO Foods:
- Alan McDermott

Funding:
- AgResearch Core Funding

10/18/2012
Thank you