Can Cow Nutrition Affect Performance, Quality and Palatability of Its Calf?

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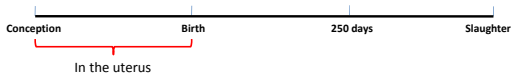
Why is the fetal stage so important for beef cattle?

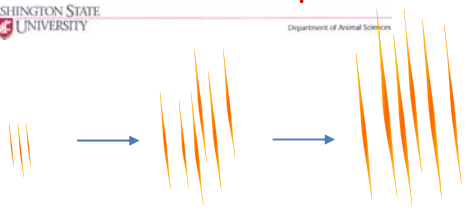
- Beef cattle pregnancy lasts for about 9 and half months, and offspring beef cattle are slaughtered at about 18 months of age.
- In other words, one third of its life is passed inside the uterus.
- All major developmental milestones are accomplished during the fetal stage.



Fetal muscle development

- Muscle mainly develops during the fetal stage.
- There is no increase in the number of muscle fibers after birth.
- For beef cattle, the formation of new muscle fibers largely stops after day 210 of gestation (Term around 283 days).
- Afterwards, growth of skeletal muscle is mainly due to the increase in the diameter and the elongation of existing muscle fibers.

Skeletal muscle development



First 3 months
- Formation of new muscle fibers

3 to 7 months of pregnancy,
- Formation of new muscle fibers
- Growth of muscle fibers

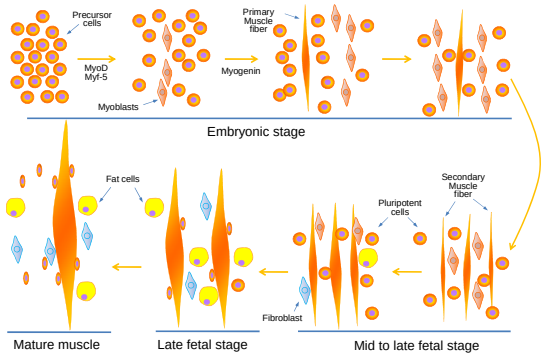
7 months and after,
- Growth of muscle fibers

- Increase of muscle fiber formation during the fetal stage will increase later lean growth.

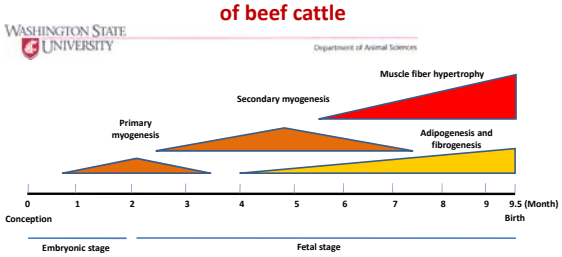
Fetal muscle development

- Besides formation of muscle fibers, fetal muscle development also involves formation of fat cells and fibrogenic cells (connective tissues).
- Fat cells formed during the fetal stage and neonatal stage accumulate lipids during fattening stage, forming marbling.
- Excessive formation of connective tissue makes the meat tough.

Fetal muscle development

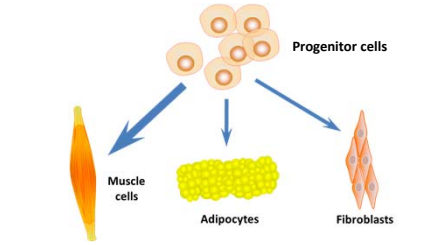


Timeline of fetal skeletal muscle development of beef cattle



- Muscle cells, fat cells and fibrogenic cells (cells forming connective tissue) are all derived from a common pool of progenitor cells.

Maternal nutrient and marbling



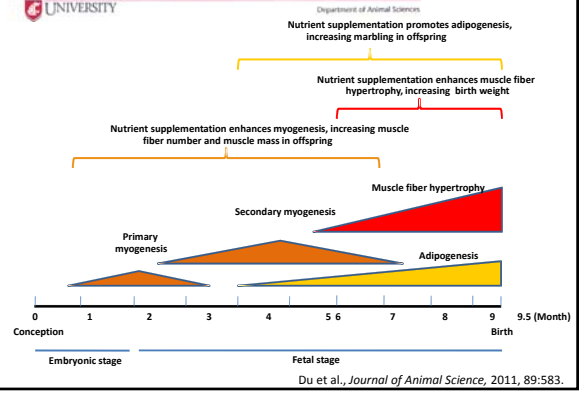
Maternal nutrient restriction and fetal muscle development

- Maternal physiological and nutritional status affects progenitor cell proliferation and development into muscle, fat and fibrogenic cells, affecting the lean/fat ratio, production efficiency and beef quality.
- Examples:
  - Nutrient deficiency during mid-gestation decreases the number of progenitor cells, forming less muscle fibers, decreasing muscle mass and lean/fat ratio.
  - Runt piglets always have a lower lean:fat ratio compared to their littermates.

Muscle growth and lean:fat ratio

- By contrast, nutrient restriction during late gestation and neonatal stage only affects muscle fiber sizes, which are largely recoverable.
- Late gestation is also critical for intramuscular adipogenesis, and nutrient deficiency reduces marbling.

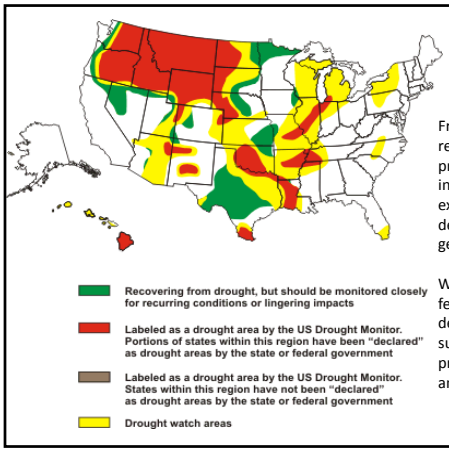
Timeline of fetal muscle development in beef cattle



Du et al., *Journal of Animal Science*, 2011, 89:583.

Maternal nutrient restriction and fetal muscle development

- Due to frequent drought and other physiological stresses, beef cattle frequently experience nutrient deficiency during mid to late gestation.
- Maternal nutrient supplementation is needed to improve production efficiency and quality of offspring.



Frequent drought reduces forage production, and cows in many areas experience nutrient deficiency during gestation.

What is the impact on fetal skeletal muscle development and the subsequent production efficiency and beef quality?

Nutrition during mid-gestation affects progeny performance

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Animals

- At 120 to 150 d of gestation, cows were allotted randomly to one of two dietary treatment, either native range (**NR,** n = 12) or improved pasture (**IP,** n = 14) with increased forage production, for 60 days.
- Esophageal extrusa samples:
  - IP varied from 11.1% crude protein of organic matter early in the test period to 6.0% at the end of the grazing period.
  - NR ranged from 6.5% crude protein of organic matter during early grazing to 5.4 % at the end.

Effects of cows grazing either native range or improved pasture from 120 to 180 days of gestation on growth of steer progeny

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	Treatment		
Item	Native range[1]	Improved pasture[2]	*P*-value
Birth weight, kg	38.7 ± 2.0	36.6 ± 1.9	0.46
Weaning weight, kg	242.1 ± 3.7	256.2 ± 3.5	0.02
Final body weight, kg	538.0 ± 8.3	560.2 ± 7.7	0.07
Average daily gain, kg/d	1.489 ± 0.067	1.656 ± 0.062	0.05
Total body weight gain, kg	180.2 ± 8.0	200.37 ± 7.5	0.05
Live weight at slaughter, kg	520.6 ± 7.7	543.9 ± 7.1	0.04

Underwood et al., *Meat Science,* 86:588-593.

Effects of cows grazing either native range or improved pasture from 120 to 180 days of gestation on carcass characteristics of steer progeny

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	Treatment		
Item	Native range[1]	Improved pasture[2]	*P*-value
Kidney, Pelvic and Heart fat, % of HCW	3.96 ± 0.25	3.59 ± 0.24	0.32
HCW, kg	329.5 ± 4.8	348.2 ± 4.5	0.01
Yield grade	3.54 ± 0.18	3.84 ± 0.17	0.23
Marbling score[3]	420 ± 16	455 ± 15	0.12

Underwood et al., *Meat Science,* 86:588-593.

Muscle characteristics of steers from cows grazing either native range or improved pasture from 120 to 180 days of gestation

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	Treatment		
Item	Native range[1]	Improved pasture[2]	*P*-value
Longissimus muscle area, cm^2	75.4 ± 2.2	78.7 ± 2.0	0.26
Semitendinosus, % of HCW	1.16 ± 0.07	1.20 ± 0.07	0.19
Longissimus muscle WBSF, N	37.29 ± 1.28	31.00 ± 1.19	0.004
Collagen content, µg/mg of *Ld* muscle	19.2 ± 1.9	15.7 ± 1.9	0.08
Ether extract (fat, %)	4.82 ± 0.53	6.00 ± 0.49	0.06

Likely, the difference in tenderness is due to the reduction in collagen content and increase in lipid content, associated fetal development ---- production and quality problems having a fetal origin.

Underwood et al., *Meat Science,* 86:588-593.

Summary

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- Maternal nutrition alters fetal development which has long-term effect on the growth performance of offspring.
- Grazing on improved pasture appears to enhance intramuscular adipogenesis and marbling, while reduces collagen content, resulting in tender meat.
- Poor maternal nutrition reduces growth potential and muscle development in offspring.
- How could we solve this production problem?
  - If we supplement cows with proteins, would that increase muscle growth?

Maternal protein supplementation diverts adipogenesis to myogenesis in beef steers

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- Nutrition deficiency during the fetal stage is expected to affect muscle and adipose tissue development, altering carcass characteristics of steers.
- Thirty six crossbred beef cows were randomly placed on a control diet (100% NRC requirements, n = 12, **C**), nutrient restricted (70% of requirements, n = 12, **NR**), or a nutrient restricted diet with protein supplement (**NRP**, n = 12) designed to equal flow of amino acids to the small intestine of C diet from d 45 to 185 of gestation.
- Then, all groups of cows were placed together, managed to meet requirements and allowed to calve.
- Steers were slaughtered at 405 days of age.

Maternal protein supplementation diverts adipogenesis to myogenesis in beef steers

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	Treatment			*P*-value
Item	C[1]	NR[2]	NRP[3]	Treatment
Live BW, kg	567 ± 22[a]	588 ± 15[a]	615 ± 18[a]	0.240
HCW, kg	375.8 ± 13.8[a]	377.4 ± 9.6[a]	398.2 ± 11.2[a]	0.313
LM area, cm^2	86.4 ± 4.2[a]	88.0 ± 3.0[a]	90.3 ± 3.4[a]	0.762
St muscle (kg)	2.44 ± 0.15[b]	2.55 ±0.10[ab]	2.87±0.12[a]	0.067
St muscle % HCW	1.25±0.05[b]	1.35±0.03[ab]	1.44±0.04[ad]	0.02
KPH, % HCW	3.05 ± 0.25[a]	2.88 ± 0.17[a]	2.30 ± 0.20[b]	0.050

Underwood et al., *Unpublished data*.

Summary

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- Fetal programming has a major role in determining the production efficiency of beef cattle, as well as beef quality.
- Nutrition during pregnancy affects lean/fat ratio, feed efficiency and beef quality.
- Through manipulation of nutritional, genetic and other environmental factors, we will be able to maximize the growth potential and meat quality of offspring.

Beef quality is mainly determined by the degree of marbling

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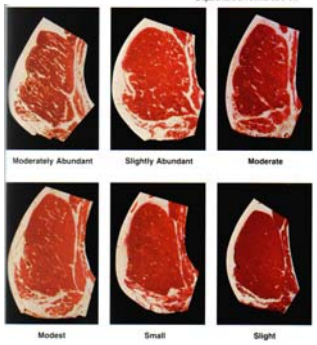

Enhance marbling through nutritional management of calves

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- Can we also induce marbling through nutritional management of calves?
- There is a "marbling window", when feeding an high grain diet to calves can effectively enhance marbling.

Maternal nutrition and marbling

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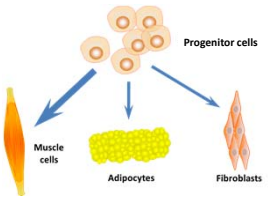
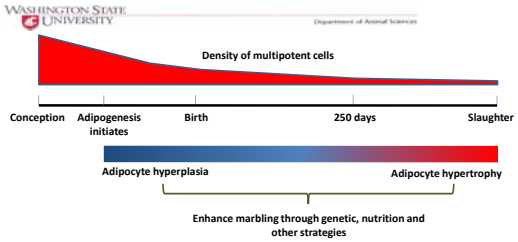
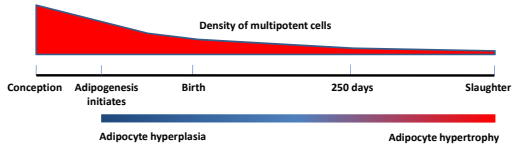
- Marbling is critical for the eating quality of beef.
- Marbling, or intramuscular fat, is due to formation of adipocytes and their accumulation of lipids.



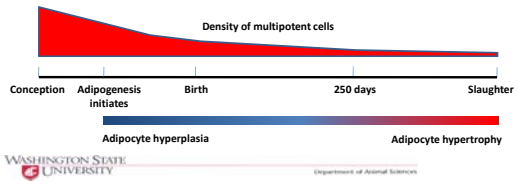
Increases adipocyte number and marbling



- Enhancing adipocyte formation increases marbling.
- The number of multipotent cells decreases as animals become older.
- Thus, to increase adipocyte number in beef cattle, fetal and early post-weaning stages are the most effective stages.

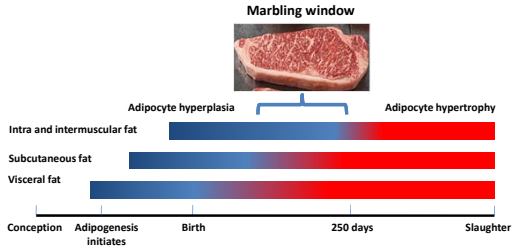


- For beef cattle, increase of adipocyte number occurs between mid-gestation to about 250 days of age.
- These adipocytes accumulate lipids during the later stage.
- "Fattening" stage in feedlots: cattle is fed a grain-based diet, increasing adipocyte size.



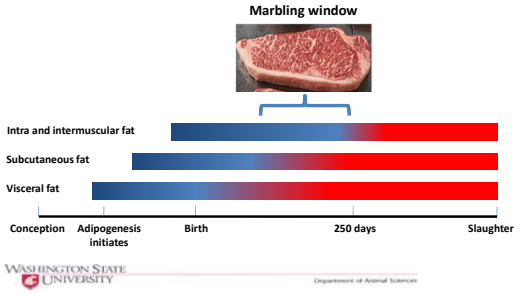
- However, the increase in adipocyte size occurs in all fat depots.
- The majority of lipids accumulates in visceral and subcutaneous fat, but only limited amount goes to intramuscular fat.
- If we can specifically increase intramuscular adipocyte number, we will be able to increase marbling without increasing overall adiposity.

Challenges to specifically increase marbling?



- Nutrient supplementation during "marbling window" specifically increases intramuscular adipocyte number.

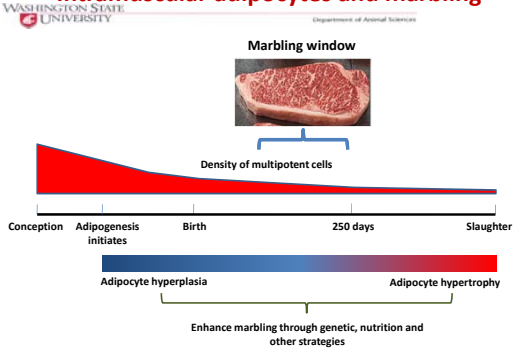
Du et al., *Journal of Animal Science,* 2013, 91:1419.



- Increases intramuscular adipocytes without overall increase in adiposity.
- During fattening stage, lipid accumulation in intramuscular adipocytes forms abundant marbling.

Du et al., *Journal of Animal Science,* 2013, 91:1419.

Intramuscular adipocytes and marbling



- Marbling window: Early weaning to around 250 days

Du et al., *Journal of Animal Science,* 2013, 91:1419.