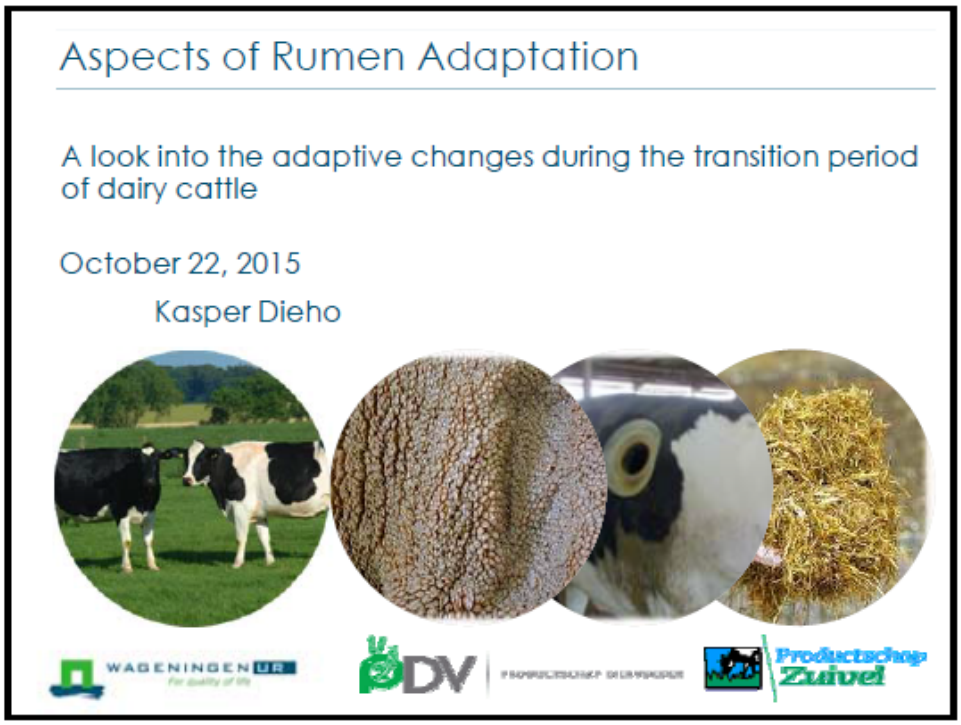
Kasper Dieho

After graduating as a veterinarian at Utrecht University in 2007, Kasper joined the University's 'Buitenpraktijk' and later the 'Universitaire Landbouwhuisdieren Praktijk', combining work as a practitioner and teacher, next to executing a field-study. Late 2010 he joined the Dutch Animal Health Service (De Gezondheidsdienst voor Dieren) working on 'Weerbaar Vee', a (recently concluded) research project looking into natural disease resistance in dairy cattle. In October 2011 he got the opportunity to start working on my PhD research project: 'Adaptation and function of the rumen in dairy cattle' at the Animal Nutrition Group, Wageningen University. As the title suggests, the focus of this project are the microbial, anatomical, and functional changes in the rumen during the dry-period and early lactation. Currently Kasper is in the last phase of the PhD programme: writing and publishing the results, working towards the completion of his thesis scheduled for summer 2016.



Kasper Dieho – Aspects of Rumen Adaptation

Aspects of Rumen Adaptation

A look into the adaptive changes during the transition period of dairy cattle

October 22, 2015

Kasper Dieho

Outline of the talk

- Use my research as back-bone for the story
  - Give a brief description
  - Discuss different aspects of rumen adaptation
    - Microbiome
    - Anatomical changes of the rumen wall
    - Functional changes

The experiment: a typical(?) transition

- 8 week dry period, no far-off /close-up

  (Fairly) Conventional ration:

  27% grass silage, 27% maize silage, 11% soybean meal, 35% straw. Containing (/kg DM): 770 VEM (5.3 MJ NE_L),109 g CP, 90 g Starch, 455 g FOM

VEM = Voeder Eenheid Melk; Dutch energy system (van Es, 1978);

1000 VEM = 6.9 MJ NE_L

FOM = Fermentable Organic Matter; Dutch DVE/OEB system (Tamminga et al., 1994)

The experiment: a typical(?) transition

- At calving abrupt changeover to basal lactation ration

  42% grass silage, 41% maize silage, 17% soybean meal. Containing (/kg DM): 971 VEM (6.7 MJ NE_L), 157 g CP, 139 g Starch, 561 g FOM
- From 3 days pp onwards, differential rate of increase concentrate allowance to max. of 10.9 kg DM/d:

  Rapid increase (1.0 kg DM/d)

  Gradual increase (0.25 kg DM/d)

Quick re-cap experiment

- Feed intake dry-period ~12 kg DM/d and 5.5 kg FOM/d, lactation increases to ~24 kg DM/d and 14.0 kg FOM/d
- Concentrate treatment resulted in:
  - Higher FOM intake with rapid concentrate increase
  - Double VFA production after calving
  - More propionic acid, less acetic acid production with rapid concentrate increase
- BOTTOM LINE: Quite typical for a (Dutch) dairy cow during transition; aids translation of results to practice

Aspects of rumen adaptation

Microbial | Anatomic | Functional

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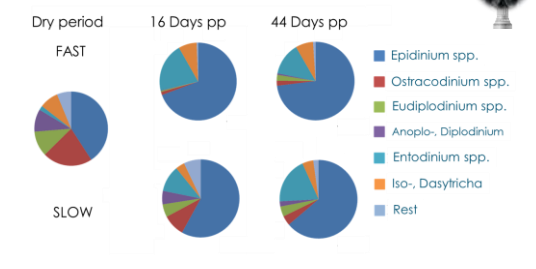
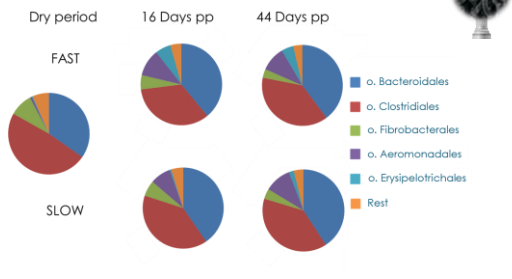
Protozoal composition shifts to few prominent species



pp, post-partum

Changes in bacteria orders clear, but limited

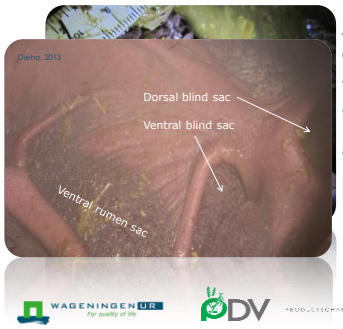


pp, post-partum

Quick recap microbiome changes

- Rapid changes in composition
- Great redundancy in metabolic pathways between species (Weimer et al., 2015 Front. Microbiol. 6:296 1-16)
- Real interest is not so much who does it, but what happens
- New techniques linking abundancy to data on metabolic capability are a recent frontier

The rumen wall



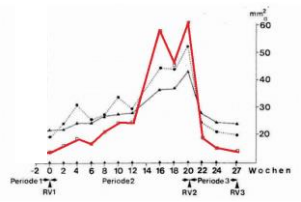
Total absorptive area depends on:

- Papilla density
- Size of individual papillae
- Area of rumen covered by papillae

Classic examples of rumen adaptation research

Setup: 2 dry non-pregnant cows, Low – "High" – Low transition

Repeated sampling, multiple sites



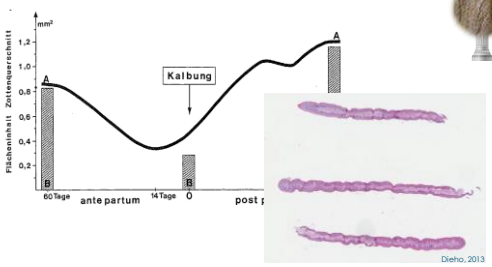
Ration

1). 48 NE_l/d (6700 VEM)
2). 84 NE_l/d (12400 VEM)
3). 41 NE_l/d (6000 VEM)

— Papilla surface area, mm²

Dirksen et al., 1984. Zbl. Vet. Med. A. 31 414-430.

Lactation shows increase in size of histological slides



Liebich et al., 1987. J. Vet. Med. A. 34, 661-672.

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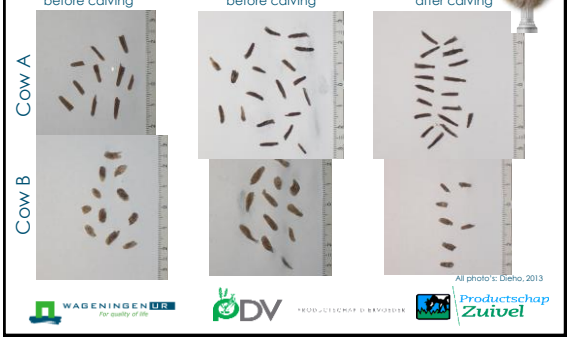
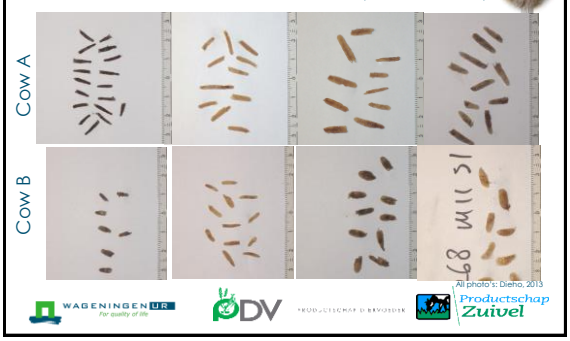
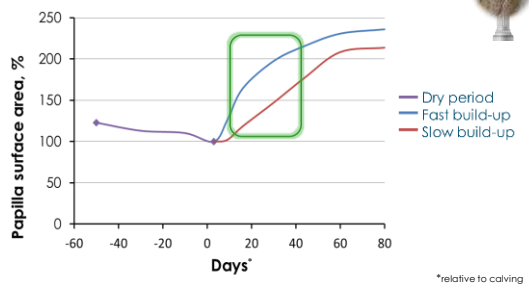
Papillae atrophy during the dry-period



After calving rapid growth in size



Surface area affected by rate of concentrate build-up

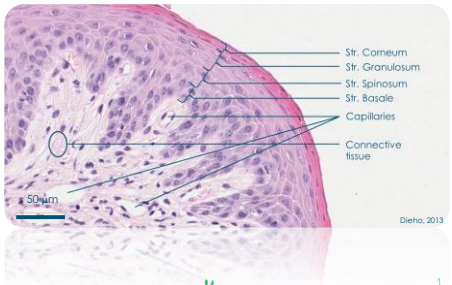


*relative to calving

Quick recap anatomic changes

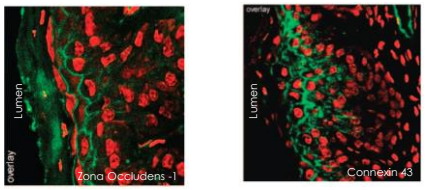
- My recent results support and extent earlier work
  - Response to increase in fermentable organic matter intake similar over broad-range of intake levels
  - Reduction in size appears to be (very) rapid in some cases
  - Papilla grow faster with rapid increase of concentrate after calving
- Papillae show great capacity for adaptation

The rumen's stratified squamous epithelium



Tightly sealed... But permeable...

Green: fluorescent immuno-histological staining of protein
Red: cell nuclei



Seals gaps between cells

Allow transfer of ions, and small molecules (sugars, VFAs, etc.)

C. Graham and N. L. Simmons, 2005, Am J Physiol Regul Integr Comp Physiol 288: R173–R181

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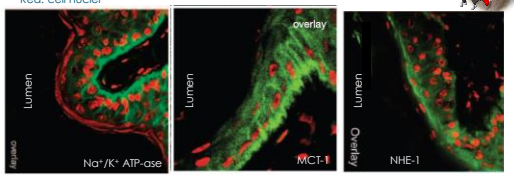
A Distinct distribution of pumps

Green: fluorescent immuno-histological staining of protein
Red: cell nuclei



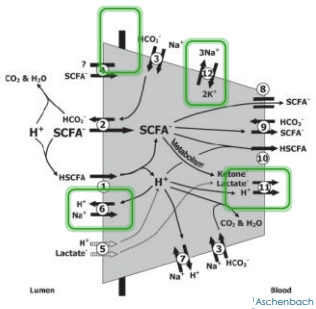
Na⁺/K⁺ concentrate gradient drives many ion exchanges

Mono Carboxylate Transporters transport VFAs

Na⁺/H⁺ exchangers reduce acidity of cell plasma

C. Graham and N. L. Simmons. 2005. *Am J Physiol Regul Integr Comp Physiol* 288: R173–R181
Graham et al., 2007. *Am J Physiol Regul IntegrComp Physiol* 292: R997–R1007

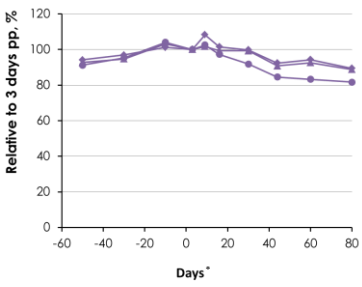
A model for VFA absorption[1]



- Mediated & passive uptake of VFA (1, 2, 4)
- Expulsion of HCO_3^- into the lumen (2, ~60% of total influx into the rumen[2])
- Na^+ influx driving force (3, 6, 7)
- ATP driven expulsion of Na^+ (12)

[1]Aschenbach et al., 2011 J. Anim. Sci. 89:1092–1107
[2]Dijkstra et al., 2012. Anim. Feed Sci. Tech. 172 (1-2): 22-33

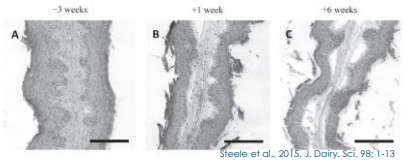
Changes in rumen epithelium from dry to lactation



Thickness
◆ Papilla tip
● Papilla middle
▲ Epithelium

*relative to calving

Recap microscopic adaptation

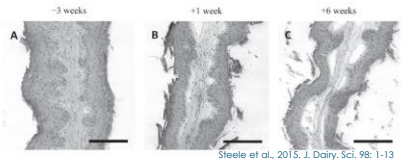


Steele et al., 2015. J. Dairy. Sci. 98: 1-13

- Papillae and epithelium at their thickest around calving
- Thickness decreases with increase in papilla size
- Microscopic structure not affected by concentrate treatment under 'normal' transition conditions
- Epithelium appears to function as one layer (syncytium)[1]

[1]C. Graham and N. L. Simmons. 2005. *Am J Physiol Regul Integr Comp Physiol* 288: R173–R181

From form to function



Steele et al., 2015. J. Dairy. Sci. 98: 1-13

- If papillae are larger, and epithelium is similar...

... there should be an advantage of larger papillae for VFA absorption...

Functional changes: VFA absorption capacity

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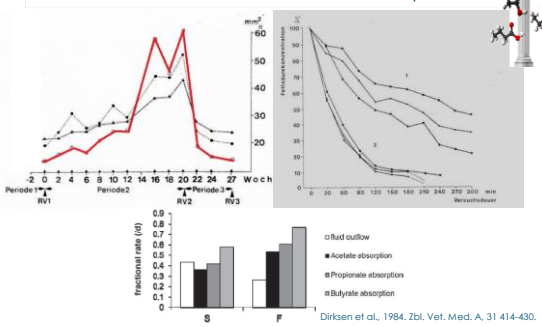
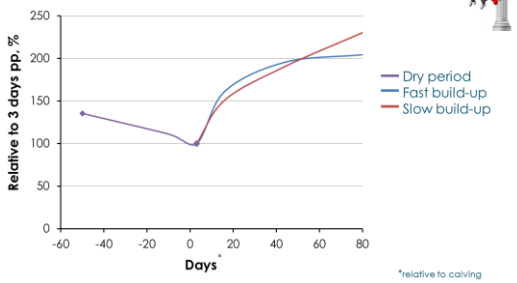
Dirksen et al., 1984... Also classic VFA absorption data



Dirksen et al., 1984. Zbl. Vet. Med. A, 31 414-430.
Bannink et al., 2012. Anim. Feed Sci. Tech. 172-1: 80-94

Changes in fractional VFA absorption capacity



*relative to calving

Quick recap functional changes

- Absorption capacity changes like papilla surface area during the dry period and lactation
- No effect of rapid increase of concentrate after calving on fractional VFA absorption rate!
- Effect of epithelial blood flow might be an explanation

(Storm et al., 2012. J. Dairy Sci. 95:6 2919-2934)

A look into rumen adaptation gives a clear picture...

- Rumen shows large capacity for adaptation
  - Microbes adapt quickly to changes in ration composition
  - Rumen papillae respond to level of feed intake
  - Epithelium maintains structure during growth
  - Gross changes in function follow changes in rumen papillae
  - No effect of rapid increase of concentrate on fractional VFA absorption rate!

Or does it...?

- 'Lack of effect' of concentrate build-up on fractional VFA absorption rate intriguing...
  - No need or no capacity to increase faster?
  - Can function be specifically stimulated?
  - What role does rumen blood flow have?

Aspects of Rumen Adaptation

Thank you for your attention!