Current and future prospects for the automatic recording and control of ruminant foraging on farms

Dr Mark Rutter
Outline

• Measuring ruminant foraging behaviour
  – Current on-farm foraging related PLF
  – Where are the gaps?
  – What technologies might fill the gaps?
• Controlling ruminant foraging behaviour
  – Grazing management
  – Facilitating diet selection
Livestock production has been **intensified** to help us control production (at the **group** level).

**Precision livestock farming (PLF)** is changing this:

- Gather data from **individual animals** so we can then manage them as individuals.
- Much closer monitoring and control.
- Increased use of robotics.
- Greatest **initial** uptake is in the dairy sector.
What about feeding-related behaviours?

Precision farming

Manual data  Sensed data  External data

Data integration/analysis

Semi-automated decision making

Improved manual control  Automated control  External control

Integrate/monitor/document outcomes

Control diagram adapted from Banhazi, 2011
Jaw movement recorder

The development of a noseband sensor allowed the opening and closing of the jaws to be recorded at 20Hz (<2MB per day).

- This formed the basis of the ‘IGER Behaviour Recorder’ and Graze analysis software.
Cattle grazing jaw movements

Jaw movement amplitude

Time

Chews

Bites and “chew-bites”

15 seconds
Rumination jaw movements

Swallows then regurgitates bolus

Chews

1 minute
RumiWatch

- RumiWatch (ITIN+HOCH GmbH) combines a jaw movement sensor with a leg-mounted pedometer
- Oil-filled tube, pressure sensor and accelerometer (10hz)
- Device processes the data
- Summarizes eating, ruminating and drinking
- “Automatic health monitoring”
Accelerometers everywhere!

• The development of cheap triple-axis accelerometers is revolutionizing the capture of animal behaviour data

• Includes human behaviour:
  – Nintendo Wii Remote (games)
  – Smart phones (e.g. VR apps)
  – Smart watches (fitness)
Leg-mounted accelerometers

- Leg-mounted accelerometers are used in several commercial systems
- Used in on-farm oestrus detection and health monitoring
- Record activity, steps, lying and standing behaviour
- e.g. IceRobotics IceQube
- Based on their earlier IceTag which was a research tool
Accelerometer-based foraging recording – ear tags

- SmartBow Eartag
  – Rumination and cow location
- SensOor (Agis Automatisering)
  – Behaviours classified based on ear movement

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Kappa</th>
<th>Concordance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruminating</td>
<td>0.85</td>
<td>0.93</td>
</tr>
<tr>
<td>Eating</td>
<td>0.77</td>
<td>0.75</td>
</tr>
<tr>
<td>Resting</td>
<td>0.86</td>
<td>0.97</td>
</tr>
<tr>
<td>Active</td>
<td>0.47</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Accelerometer-based foraging recording – neck mounted

- FeedPhone (Medria)
  - Collar mounted sensor
  - Eating time and rumination time

Delagarde and Lemonnier, 2015. *Proc. EGF Wageningen*
On-farm feed intake?

- Feed intake recording systems based on feed bins on load cells
- Insentec RIC bins used by researchers
- Grow Safe system is used on some genetic evaluation farms, it is still too expensive for ‘ordinary’ farms
Intake from accelerometers?

- Oudshorn *et al.* (2013) investigated the use of accelerometers to measure grazing time
- Combined this with manually recorded bite counts to estimate herbage intake
- IGER Jaw Movement recorder can discriminate bites vs chews, but it is not practical for on-farm use
- Is there an alternative?

Bioacoustics

Microphone → Radio transmitter → Radio receiver connected to video camera i.e. the sound you will hear in the video is transmitted from the cow's head

Noseband → 'IGER' Behaviour Recorder
Mainly chew-bites

Head up

No. 8 12

Two chews

Mainly chew-bites

Chews
Jaw sensor vs bioacoustics

Disagreement: 4/27
Agreement: 11/27
Partial agreement (ACM includes “chew-bites” which are classified as bites by IBR): 12/27

Partial agreement (ACM includes “chew-bites” which are classified as bites by IBR): 12/27
Jaw sensor vs bioacoustics

• Although the jaw sensor misclassified some chews as bites...
• ...there was **broad correspondence** in the classification of jaw movement between the two
• Microphones are more robust than the noseband sensor so better suited to use on farms
Bioacoustics potential

• Originally needed the human ear to detect bites and chews, but algorithms have been developed to do this automatically
• Research has shown the energy density of chewing sound is proportional to bite mass, so has the potential to monitor intake
• Has the potential to detect different plant species and differences in herbage quality
Bioacoustics are already being used in an on-farm monitoring system.

The SCR ‘VocalTag’ uses bioacoustics to detect rumination behaviour.

Used to monitor health and help predict oestrus.
Commercial bioacoustics

- Comparison of rumination collars (R) with the IGER Behaviour Recorder (I) showed variable results i.e. collars need to be correctly fitted

Rutter et al. 2011 Proc. ISAE Indianapolis
A bioacoustic problem

- The microphone can pick up the sound of conspecifics grazing alongside the subject...
- ...so may need to be combined with other sensors e.g. accelerometers
Microphone or accelerometer?

- Japanese researchers (pers. comm.) are using head mounted triple-axis accelerometers to determine bites vs chews
- Is a microphone just a single-axis accelerometer mounted to a diaphragm?
- Can an accelerometer held against the skull give the same information as ‘bioacoustics’ if the sampling frequency is high enough?
Controlling pasture access

- Technology is also available to help automate controlled access to grass:

  - Electronic gates
  - Timed release gates
  - Robotic fences
Current strip grazing

• Measure herbage mass (e.g. plate meter) then set an electric fence to offer just enough grass to last to e.g. the next milking

• This is quite difficult, and it is easy to under- or over-estimate and give too little or too much grass

• Is there a technological solution?
Herbage availability

High herbage availability
Few bites · Many chews

Low herbage availability
Many bites · Few chews
Automated strip grazing

- Set up several strip paddocks, each with a remote release gate
- Monitor grazing behaviour, including bites:chews ratios and possibly bite mass using bioacoustics
- Once the optimal residual sward height is achieved the system opens the gate to the next paddock
- This can happen at any time, not just after the cows have been milked
- Can be ‘smart’ e.g. does not give fresh grass just before the animals are due to be milked
Diet preference studies

- Diet selection and preference studied in sheep and cattle grazing adjacent monocultures of ryegrass and white clover
- Partial preference for clover, typically 70% clover and 30% grass
- Higher proportion of clover in diet of lactating animals
Diurnal pattern of preference

Cumulative intake of legume (%)

- Lactating ewes
- Dry ewes
- Lactating cows
- Dry heifers

Hour of day

(Rutter 2006)
Evolutionary basis?

• Optimal microbial protein synthesis *in vitro* with 70% clover 30% grass
• Current theory suggests a balance between four evolutionary drivers:
  – animals are trying to optimize their own efficiency of nutrient capture
  – to maintain rumen function
  – to avoid eating high levels of plant toxins
  – to minimise the risk of predation
TMRs prevent diet selection

• Total Mixed Ration’s thwart the ability of animals to:
  – Select the diet that they want
  – Optimize their own efficiency of nutrient capture

• This is bad because:
  – It is inefficient, wasting feed and creating pollution
  – It is a welfare problem as the animal is frustrated

• So why do we use TMRs?
  – Domestic ruminants evolved in an environment where ‘concentrate’ feed was rare so it made sense to eat as much as you could
A technological solution?

- One possible solution is to give the animals two feeds:
  - Grass silage based and clover silage based?
  - A protein-rich TMR and an energy-rich TMR?
- Multiple diets facilitated by robotic feed systems
- Let the animals select their own diet from the two
- They might still occasionally make nutritionally ‘unwise’ choices (too much of one feed = acidosis)
  - Possibly guard against this by controlling access to the feeds (via auto-gates) combined with rumen pH monitoring
Conclusions

• Technology is already starting to have a big impact in intensively managed dairy systems

• Although still needing further R&D, bioacoustics (combined with accelerometry) appears to offer the greatest potential for monitoring variables relevant to the on-farm measurement of eating behaviour

• Precision approaches should improve the ease and efficiency of grazing management

• Technology could help facilitate diet selection and so improve nutrient use efficiency and animal welfare
Any questions?

Dr Mark Rutter
smrutter@harper-adams.ac.uk