Classifying cattle ingestive behavior using sound wave analysis

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Abstract

Cattle ingestive behavior is a complex process involving a series of steps including prehension, biting and shearing forage; bolus formation; swallowing and rumination. Each of these events generates sound signatures that may vary depending upon forage species, quality, animal age, sex and diet preferences. Sound wave spectral analysis was used to study ruminal ingestive behavior. Microphones and ultra-high-frequency (UHF) transmitters transmitting on different frequencies were attached to halters that were fitted to four steers prior to grazing events. Corresponding UHF receivers were mounted on digital video cameras to allow synchronized audio and video recording of grazing behavior. Grazing and rumination events were recorded over a number of 120-minute periods throughout the summer. Grazing events were classified by matching sound waves and video events from the tapes. The audio files were processed by Fast Fourier Transformation (FFT). The resultant spectrograms showed that prehensive biting events could be separated from rumination or bolus-formation events for steers grazing alfalfa, pearl millet and mixed pastures. Prehensive bites were characterized in the spectrograms by frequency peaks near 20 kHz, whereas bolus formation and rumination events had frequencies from 1–5 kHz. These data suggest that sound analysis can be used to quantify and discriminate ingestive behaviors.

Introduction

Actual forage intake, is very difficult to measure for free-ranging, grazing livestock, however estimations of actual intake provide the basis to determine residual feed intake, a useful and sensitive measure of forage-use efficiency (Herd et al., 2004). Many different approaches have been used to study ingestive behaviors and to quantify the number of prehension or bites. Techniques include visual observation (Elleguer et al., 1996, Millhousen et al., 2001, Wibroover (1978), electronic grazing clocks (Moszy et al., 1985), video recorders (Friend et al., 1977), and more recently data loggers (Champion et al., 1997). Lara and DeVroon (2000) recorded grazing events and were able to estimate actual intake by grazing cattle by the difference in pre- and post grazing forage biomass. Regardless of the approach taken to estimate forage intake, most methods are extremely tedious or require complicated switch and wire harnesses. Our goal in this study included developing a way to identify, discriminate and quantify ingestive events using non-obtrusive sound recording equipment. The objectives of this study were to 1) develop a solid state audio transmitting and recording system to record the sounds of grazing ingestive behavior; 2) determine the audio signatures of the ingestive behaviors; prehensive biting, bolus formation (bolus formation and rumination); 3) classify the ingestive behaviors for multiple grazing events among a number of grazing steers and forage types; and 4) define the parameters for developing a software discriminator to automate ingestive behavior classification.

Materials and Methods

Four halters were outfitted with high-quality, solid-state lavalier microphones and wireless ultra-high-frequency (UHF) transmitters (Samson Technologies Corp., Syracuse, NY). A single microphone was situated on each halter so that it was adjacent to the mouth and jaw of a grazing steer (Figure 1). Each microphone was connected to a transmitter mounted inside a plastic box and attached to the halter such that the box rode on the steer’s neck behind the ears. Each of the transmitters used a discrete frequency that matched receivers (Samson Technologies Corp., Syracuse, NY) mounted on Canon Elura 85 Mini-DV Video Camcorders (Canon, U.S.A., Inc., Lake Success, NY).

Paddocks (10 m by 10 m) were delineated using energized polywire fencing on existing stands of alfalfa (Medicago sativa L.), mixed pasture (composed of Meeanla (Poa trimorum), L.), reed canary grass (Phalaris arundinacea L.), tall fescue (Festuca arundinacea L.), and white clover (Trifolium repens L.) or pearl millet (Pennisetum glaucum L.). The paddocks were grazed by four steers outfitted with the transmitting halters. Audio and video were recorded for each steer for grazing periods up to two hours. Tape processing took place in the lab where the audio streams were stripped from the video file for manual classification of ingestive events using PEAK audio mastering software (BIAS, Inc., Suite A, Petaluma, CA). Random 1 min samples of the audio files were processed by Fast Fourier Transformation using Signal 4.01 (Engineering Design, Berkeley, CA) to produce power spectrums or spectrograms (Figure 2). Data manually collected from the sound files included start and end times and peak frequency of prehensive bite, bolus formation and rumination events.

Results

The spectrograms illustrate the differences in sounds generated by prehensive biting behavior among the three forages (Figure 2). The observed differences appear to be a function of the shear strength of the forage and/or grazing behavior. Bites of the large tough leaves of pearl millet had twice the duration of bites of the tender leaves and stems of alfalfa (Table 1). Sounds of bolus formation had distinctly lower peak frequencies than sounds of prehensive biting. Differences were also observed among the forages in the mean duration of bolus formation. Alfalfa had the lowest mean bolus formation time of the three forages, possibly reflecting its higher forage quality. Peak frequencies of prehension and bolus formation differed among the forages. Rumination sounds had a regular, low-frequency, rhythmic pattern similar to a sine wave function (data not shown). These data demonstrate that mean event duration and frequency may be useful criteria for software-automated classification of specific ingestive events in grazing livestock.

Conclusions

A solid-state, audio transmitting, receiving and recording system was successfully constructed and tested on grazing steers.

Prehensive biting, bolus formation and rumination generate sounds that have distinct duration and frequency characteristics.

Sounds of ingestive behavior differ among forage types possibly due to differences in forage shear strength and/or grazing behavior.

Manual classification of soundwave or spectrum data is extremely tedious. However, our results suggest that the data are amenable to automated classification. We are in the process of initializing the parameters for discriminating events and developing an automated algorithm to classify these data. This algorithm will allow us to classify streams of data limited only by the limits of media storage.

Literature cited


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Table 1. Sound characteristics of prehensive biting and bolus formation from three forages.

<table>
<thead>
<tr>
<th>Forage</th>
<th>N (dES)</th>
<th>duration (msec)</th>
<th>peak frequency (kHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>89</td>
<td>289.8</td>
<td>11.5</td>
</tr>
<tr>
<td>Mixed pasture</td>
<td>89</td>
<td>215.1</td>
<td>4.3</td>
</tr>
<tr>
<td>Pearl millet</td>
<td>88</td>
<td>355.8</td>
<td>6.7</td>
</tr>
</tbody>
</table>

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