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Development of an automatic bitemeter for grazing cattle

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Abstract — Biting rate in grazing cattle is difficult to record automatically compared with grazing time, ruminating time, or total jaw movements per day. We tested the feasibility of an automatic system for measuring biting rate based on the sound made by severing of the herbage, which is specific to the bite. The portable device described is based on two sensors: a microphone, located beneath the lower jaw, and a mercury switch to determine the inclination of the head, located in a case attached to the neck of the cow. Bites are detected in real time and data are stored in memory every minute before serial transfer to a computer. The bitemeter was validated during 11 sequences for a total of 514 min on four Holstein dairy cows strip-grazing on vegetative perennial ryegrass (*Lolium perenne* L.) swards by comparing with visual observations, comparison being possible each minute. The mean bias between bitemeter and manual recording varied between sequences from −5.8 to + 3.1 bites·min^{-1} (−12.2 to + 7.5 %) with an average of −1.6 bites·min^{-1} (−3.3 %). It was not related to sward height. The within-sequence variability of this bias was on average 3.5 bites·min^{-1} and was not related to the number of bites·min^{-1}. It is concluded that the automatic recording of biting rate in grazing cattle is possible with a good degree of precision on the basis of the sound created by severing of the herbage. Nevertheless, additional protection of the microphone and a better standardization of its position would appear necessary for a routine use of the bitemeter in experimental trials. (© Elsevier / Inra).

grazing behaviour / cattle / bite / recording / microphone / methodology

Résumé — Développement d'un compteur de bouchées automatique pour bovins au pâturage. L'enregistrement automatique de la fréquence des bouchées chez les bovins au pâturage est plus difficile à réaliser que celui des durées d'ingestion, de rumination, ou même que celui du nombre de coups de mâchoires par jour. Nous avons testé la faisabilité d'un compteur de bouchées permettant de mesurer automatiquement la fréquence des bouchées à partir du bruit d'arrachement de l'herbe, signal vraiment spécifique de la bouchée. Cet appareil est basé sur l'utilisation de deux capteurs, un microphone étanche placé sous la mâchoire inférieure et une bille de mercure placée dans un boîtier que l'animal porte autour du cou afin de mesurer l'inclinaison de la tête. Les bouchées sont

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détectées en temps réel et les données stockées en mémoire chaque minute, avec un transfert sur ordinateur par voie série. La validité des données enregistrées par l'appareil a été testée au cours de 11 séquences pour un total de 514 min par comparaison avec un comptage manuel réalisé au champ. Les tests ont été réalisés sur quatre vaches laitières Holstein en pâturage rationné sur prairies de ray-grass anglais (*Lolium perenne* L.) au stade feuillu. Le biais moyen entre le compteur de bouchées et le comptage manuel a varié selon les séquences de –5,8 à + 3,1 bouchées·min^{-1} (–12,2 à + 7,5 %), pour une moyenne de –1,6 bouchées·min^{-1} (–3,3 %). Ce biais semble indépendant de la hauteur du couvert ou du stade de défoliation de la prairie. La variabilité intra-séquence de ce biais est en moyenne de 3,5 bouchées·min^{-1}, et n'est pas reliée au nombre de bouchées par minute. Il est donc conclu que l'enregistrement automatique du nombre de bouchées chez les bovins au pâturage à partir du bruit d'arrachement de l'herbe est possible avec un degré de précision satisfaisant. Cependant, une protection supplémentaire du microphone et une meilleure standardisation de sa position semblent nécessaires avant d'envisager une utilisation en routine de ce compteur de bouchées à des fins expérimentales.

comportement alimentaire / pâturage / bovins / bouchées / enregistrement / microphone / méthodologie

1. INTRODUCTION

The main objective of recording the different components of feeding behaviour of grazing ruminants is to improve our understanding of the mechanisms of feed intake as well as their possible influence on forage selection, herbage intake level and the production performance of animals.

Over the last ten years, many studies have been carried out on variables such as intake rate, bite mass and bite dimensions (see reviews by Ungar [19] and Prache and Peyraud [15]), due principally to the development of new measuring techniques [1, 8, 13]. The study of feeding behaviour duration dates back to before 1980, being a result of the development of portable equipment for recording animal behaviour [1, 2, 3, 7, 10, 14, 16, 18]. Some types of device store the number of jaw movements or the biting rate during periods of ingestion or rumination [10, 14, 16, 18]. However, very few devices have been developed to count the number of bites at grazing.

Chambers et al. [4] were able to count the bites by means of an accelerometer measuring the head movements linked to severing of the herbage. However, the data logging in their study was not fully automated due to the fact that measurements were carried out solely with an oscilloscope. The device developed by Penning et al. [14] and modified by Rutter et al. [16] records all the jaw movements using the variations in electrical resistance of a sensor placed around the jaws. The bites are defined a posteriori on the basis of the signal trace shape, a procedure which requires a considerable amount of algorithm development (software writing). Although the preliminary validation trials on dairy cows appear satisfactory [5], the experimental results depend partly on the values that are chosen for the parameters during final analysis of the datafile. This is an important potential source of bias with non-specialist operators.

The only signal that is really bite-specific is the sound made by severing of the herbage. To our knowledge, the device described by Luginbuhl et al. [9] is the only one based on the recording of sound signals. However, the reliability of the recordings is not discussed by these authors (op. cit.). Laca et al. [8] have also used a microphone, which they placed on the forehead of the animals. These latter authors state that their method can easily distinguish between biting and other jaw movements, as well as between movements with or without mastication. In their study, however, the measurement acquisition was not automated. More recently, Nonaka and Nakui [11] also tested the feasability of recording automatically the chewing behaviour of cattle with a microphone, but they did not investigate the recording of biting rate.

In view of the portable devices that are already available, we considered it of interest to test the feasibility of an automatic system for measuring biting rate based on the sound made by severing of the herbage. Some preliminary results have already been presented in a short article [6].

2. DESCRIPTION OF THE BITEMETER

2.1. General characteristics

Two sensors are used: a microphone to detect the sound made by the animal severing the herbage and a mercury switch to determine the inclination of the head. The watertight microphone (ELNO, France) is fixed to a head halter and is located beneath the lower jaw at a distance of about 10–15 cm from the mouth. It is connected by cable to a case attached under the neck of the cow. The case contains the mercury switch, an analogue card and a numerical card. The electrical power supply comes from a 12 V battery that currently gives an operating period of 30 h. The microphone unit + case + harness has a total weight of 1.4 kg, and is shown in *figure 1*.

2.2. Signal processing

The analogue card makes it possible to process the raw sound data coming from the microphone. The signal is first passed through a selective filter centered on 3 kHz with a pass band of 400 Hz, then it is amplified and smoothed. This treated signal is then digitized by an analogue-to-digital converter (ADC) with a sampling interval of 3 ms, corresponding to 300 readings per second.

The digital card handles processing of information from the output of the ADC and data storage in memory. The signal output from the ADC is read continuously in order to detect bites according to the precise parameters defined beforehand (see section below). All signals corresponding to the definition of a bite are taken into account, except those occurring either in the head-up position or in the head-down position within a time lapse of 400 ms after detection of the preceeding bite (instantaneous maximum biting rate of 150·min^{-1}). For each new bite that is detected, a counter is incremented accordingly. This latter security avoids recording two bites instead of one when some background noise occurs just

Figure 1. Automatic bitemeter for grazing cattle: microphone under the lower jaw, head collar and case containing the mercury switch.

before or after severing of the grass. It does not lead to an underestimation of the number of bites as the biting rate is mostly lower than 75 bites·min^{-1}, i.e., half of the allowed biting rate (150 bites·min^{-1}). Moreover, for the measurements described in section 2.3. in the field, we never observed a between-bite interval lower than 500 ms.

Finally, the number of bites and the time in seconds that the animal stays in the head-down position, as well as the number of liftings of the head, are all stored in the memory every minute (file of three columns and 1440 lines for 24 h recording). A graphical representative of a complete recording is given in *figure 2*. The transfer of data onto the micro-computer is carried out via a serial port.

2.3. Choice of parameters

The initial phase of the study consisted of defining the parameters used to characterize bites. To achieve this, we analysed the variability of the signal trace shape for a large number of bites using measurements carried out in the field, the digitized data output from the ADC being stored to memory (32 K, corresponding to about 100 s). *Figure 3* presents an example of the signal obtained during periods of grazing and rumination. The sound produced by most of the bites is clearly distinguishable from the background noise (amplitude ratio of 20:1), but the duration of the signal remains highly variable between bites, ranging from 10 ms to more than 200 ms (with a mean value close to

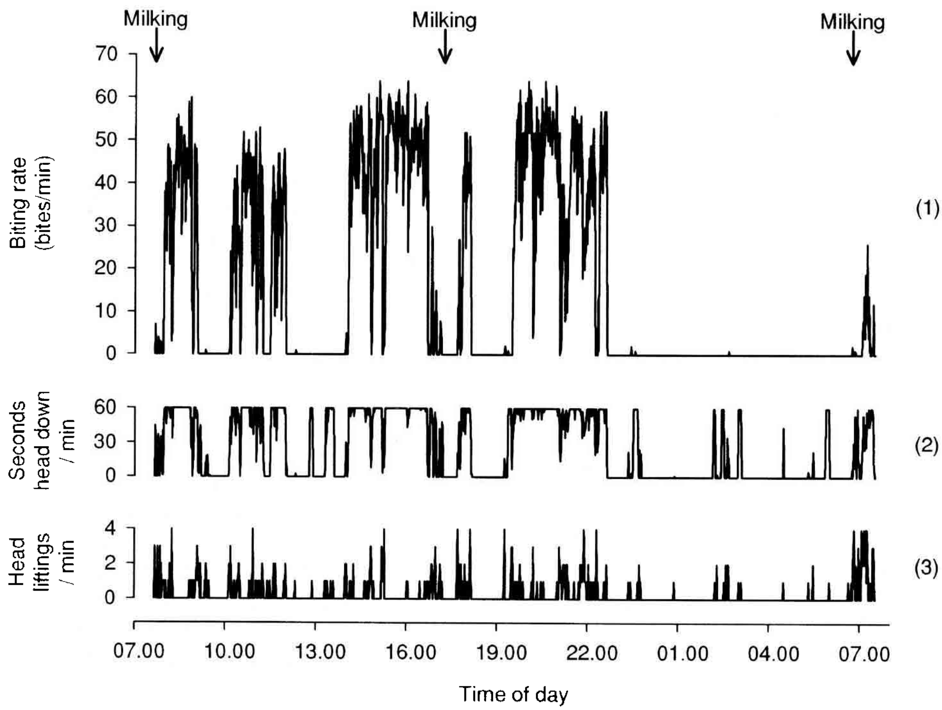

Figure 2. Example of a 24 h-recording from the automatic bitemeter on a grazing dairy cow on 01 July 1996. (1) bites·min^{-1}, (2) seconds per minute in the head down position, (3) number of head liftings per minute.

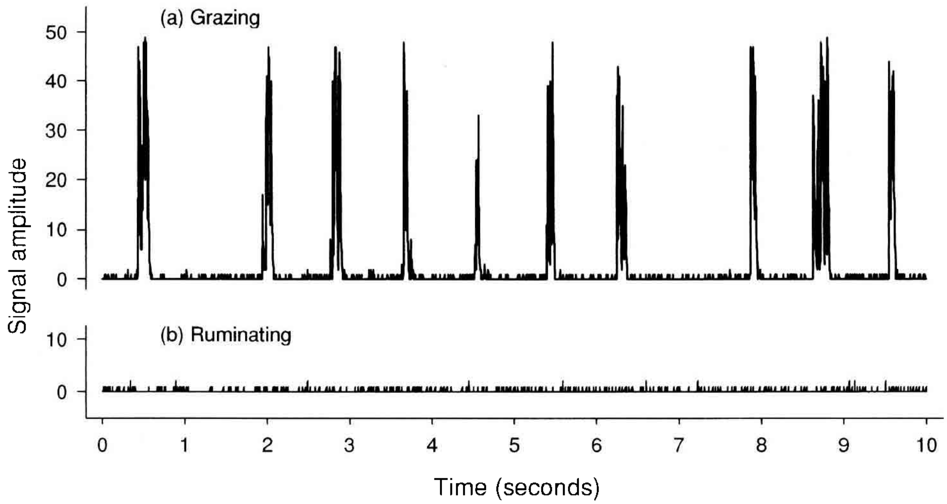

Figure 3. Signal amplitude obtained after filtering, amplification and digitalization of the sound during a period of grazing (a) and a period of ruminating (b).

80 ms). Moreover, a single bite is sometimes composed of several more or less distinct peaks. Consequently, we chose a reading window of 200 ms, which corresponds to the maximum duration of a bite-generated sound observed in this study. Finally, a bite is defined as corresponding to a minimum number of values (four in this case, equivalent to 12 ms) above a given threshold within a reading window of 200 ms.

The mercury switch used to detect the inclination of the head is placed in the case and not directly on the animal's head. We observed that the inclination of the head varies little between the head-up and head-down positions, thus making it impossible to discriminate one from the other. Moreover, for just this reason, Penning [12] abandoned use of this sensor on sheep. On the contrary, the inclination of the case when attached round the animal's neck – being linked to the angle between head and neck – is far more sensitive to the head position (0° head up, 40–45° head down) and thus allows its detemination with much greater precision.

The head-down position is defined by an angle of inclination of the case of more than 20° with respect to the horizontal. The position of the mercury switch is read every 64 ms during an interruption in the cycle. Because of the great sensitivity of the sensor, all changes in position lasting less than 0.5 s are not taken into account (e.g., jolts, sudden movements of the head).

3. VALIDATION

3.1. Methods

In June–July 1996, field-trials were performed to validate the measurements recorded with the automatic bitemeter by comparing them with visual observations. Measurements were carried out using Holstein dairy cows strip-grazing vegetative perennial ryegrass (*Lolium perenne* L.) swards. The trials were made using four cows at different times of the day, on ungrazed plots (height measured by rising platemeter: 10.3–18.1 cm) as well as on plots at the end of grazing (height: 5.7–9.0 cm). Manual recordings were made by an observer situated in the plot, who was thus able to distinguish clearly the bites from the other jaw movements on the basis of the sound made by severing the herbage.

The observer was equipped with a semi-automated counter fitted with a push-button instead of a microphone. This equipment, which was worn on a belt, enabled the observer to store the number of bites every minute in an analogous way to the automatic bitemeter attached to the cow. The internal clocks of both devices were synchronized just before each trial to a precision of one second by means of a common clock. In this way, it was possible to compare the data recorded by the automatic system with the data entered manually by the observer over relatively long time series, with a minute-by-minute read-out of the measurements being possible.

3.2. Results

Eleven observation sequences were performed having an average duration of 47 min each (total observation time of 514 min). *Table I* reports the conditions under which these trials were performed, the number of bites recorded by the automatic system and by the observer, as well as the average bias in biting rate, its variability and the mean percentage error. A graphical representation of the entire series of tests carried out is presented in *figure 4*.

The number of bites·min^{-1} recorded by the bitemeter (BIT) is strongly correlated to those counted manually by the observer (MAN), with a determination coefficient (R^2) ranging from 0.72 to 0.98 from one observation sequence to another (*figure 4*). Pooling all the results together and taking into account a sequence effect, we obtain the following relation:

$$BIT = (2.3 + \Delta 1) + (0.93 + \Delta 2)\ MAN$$
$$n = 514,\ syx = 3.35,\ R^2 = 0.95$$

with $\Delta 1$ varying from –3.2 to + 7.0 (NS) and $\Delta 2$ varying from –0.07 to + 0.09 ($P < 0.01$), according to the sequence.

On the whole, for the 514 minutes of observation during grazing, biting rate was 48.5 and 46.6 bites·min^{-1} by recording manually and by the bitemeter, respectively (*table I*). The bias varies significantly according to the observation sequence concerned, ranging from –5.8 to + 3.1 bites·min^{-1} (–12.2 to + 7.5 %). The variability of this bias is of the same order of magnitude as its absolute value, ranging from 2.0 to 4.8 bites·min^{-1} between sequences. The within- and inter-sequence variance of this bias was compared using the VARCOMP procedure of the SAS software [17], assuming that the sequence effect is random. Although the within-sequence bias (syx bias = 3.5 bites·min^{-1}) is greater than the inter-sequence variance (syx error = 2.7 bites·min^{-1}), both values are relatively small. The repeatability of the bias from one sequence to another is rather poor (37 %), being calculated as the inter-sequence variance divided by the sum of the variances. Because the sequence effect was not separated from the cow effect (i.e., no repetition), it was impossible to determine in this study whether the sequence or the individual animal has a more important effect. According to our observations, the effect of measuring sequence appears to be more closely linked to mechanical problems in positioning the microphone in relation to the animal's mouth (distance, orientation). It should be possible to reduce the measurement variability linked to the day of observation by improving standardization of the microphone position.

The bias does not vary as a function of sward height as measured by a rising platemeter in the interval 5.7–18.1 cm (*table I*), a clear advantage regarding the use of this technique under a variety of experimental conditions. In practice, this means that the measuring device will not introduce a bias into comparisons between swards having different heights, so, in this sense, no cali-

Table I. Tests of validation of the automatic bitemeter on strip-grazing dairy cows (see also *figure 4*): time, duration, sward conditions, number of bites counted manually (MAN) and by the bitemeter (BIT), mean bias and its variability.

Test	Day	Time	Duration (min)	Cow	Sward height	Grazing period	Number of bites per test		Biting rate for	Bias (4)		
					(cm) (1)	(2)	MAN	BIT	MAN (3)	mean	s.d.	% of MAN
T1	17/06	09.10	55	1	10.3	B	1769	1744	32.2	−0.5	2.02	−1.4
T2	24/06	08.16	45	2	17.2	B	2705	2681	60.1	−0.5	2.78	−0.9
T3	24/06	18.41	54	2	5.7	E	2390	2414	44.3	+ 0.4	4.24	+ 1.0
T4	25/06	08.03	26	2	16.1	B	1647	1600	63.3	−1.8	2.51	−2.9
T5	26/06	08.17	61	2	15.7	B	3567	3374	58.5	−3.2	4.16	−5.4
T6	27/06	08.09	74	3	18.1	B	3104	2771	41.9	−4.5	4.82	−10.7
T7	27/06	15.49	21	3	7.3	E	838	831	39.9	−0.3	2.52	−0.8
T8	28/06	09.15	43	1	16.1	B	1978	2008	46.0	+ 0.7	1.99	+ 1.5
T9	01/07	07.58	39	1	9.0	E	1589	1708	40.7	+ 3.1	2.45	+ 7.5
T10	02/07	08.58	58	4	7.3	E	2755	2419	47.5	−5.8	3.55	−12.2
T11	02/07	17.05	38	4	14.5	B	2607	2428	68.6	−4.7	3.31	−6.9
Mean			47		12.5		2268	2180	48.5	−1.6	3.12	−3.3
Total			514				24949	23978				

(1) Measured with a rising platemeter. (2) B: beginning of a grazing period in the plot (ungrazed sward); E: end of a grazing period in the plot (grazed sward). (3) Number of bites per test divided by the duration of the test. Expressed in bites·min^{-1}. (4) The mean bias is the difference between the mean biting rates measured by the observer (MAN) and by the bitemeter (BIT). Expressed in bites·min^{-1}. The standard deviation of the bias (s.d.) is calculated from the minute by minute variability of this bias.

bration is necessary. In particular, the ingestion of leaf blades (plot at beginning of grazing) or leaf sheaths (plot at end of grazing) would not appear to produce any change of sensitivity of the device. The precision of the measurement would also appear to be independent of the biting rate. It remains especially good for the minutes of low-activ-

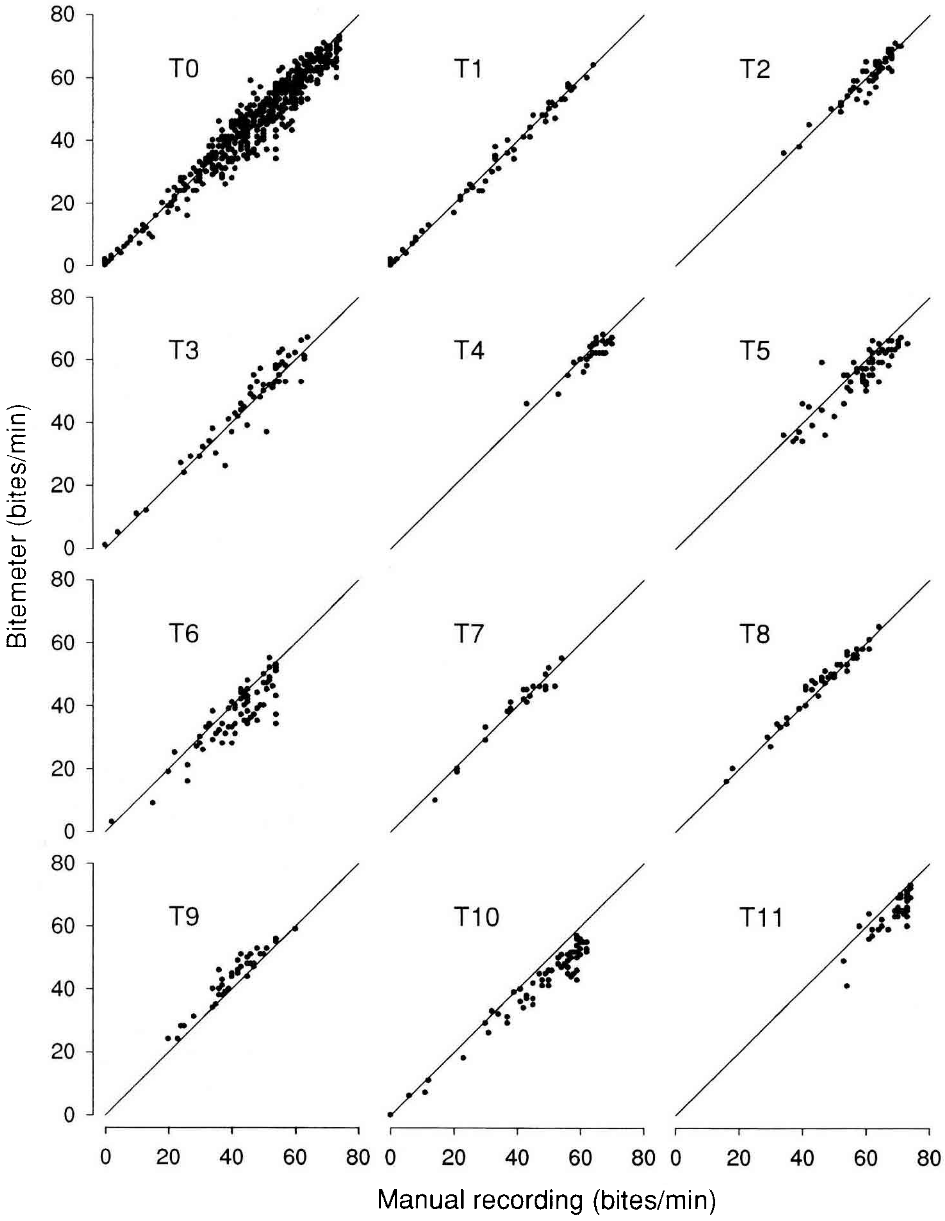

Figure 4. Comparison between the number of bites recorded each minute manually or by the bitemeter during validation tests. Graph T0: all data (n = 514 minutes), Graphs T1 to T11: individual validation tests as described in *table I*.

ity grazing (< 30 bites·min^{-1}) during which the risk of bias is important due to the presence of other activities representing potential sources of background noise.

4. DISCUSSION

The aim of the device is to count bites and not the whole set of jaw movements. This aim would appear to have been attained because the mean discrepancy between the automatic and manual measurements is only 3.3 %, associated with a variance of within- and inter-sequence bias that is relatively low.

In the present study, it is clear that the experimental bias originates from the automatic device and not from the observer. In fact, the bites made by dairy cows are very easy to detect by hearing the sound produced by severing of the herbage. We have never observed any effect on bite counting due to the observer in the field. However, certain difficulties arise with sheep because of the high frequency of jaw movements as well as the smaller size of their bites [4, 14, 16].

Because the automatic device counts the bites by default rather than by excess, independent of biting rate, jaw movements not associated with biting are not confused with bites. Moreover, this is in good agreement with the criteria chosen for defining a bite because the smallest bites (< 12 ms) are excluded from the recorded data. In the field, it was possible to study the selectivity of the device with respect to bites by setting it to emit a weak sound signal every time a bite was detected. This signal made it possible to check in situ that any jaw movement not associated with biting during a series of bites can be picked out and excluded from the recording. Otherwise, even without prior warning, an observer can easily recognize in a matter of a few minutes any malfunction of the device. The good selectivity with respect to bites would appear to be clearly attributable to a choice of recorded signal (i.e., sound of severage) that is specific to biting-related behaviour.

Even in the case of erroneous counting of bites (badly positioned microphone, loss of sensitivity), the number and duration of each meal – and thus also the total grazing time – will always be known with precision. In fact, on the time-scale of a day, no confusion of detection is possible with ruminating activity. In the frequency range selected here, mastication during rumination produces no sound and takes place mostly in the head-up position. Under no condition were bites falsely detected by the device during a period of rumination. Thus, while the device is selective in detecting bites during periods of grazing, it is even more efficient for the identification of meals on the time scale of a day. The automatic bitemeter makes it possible to measure the total grazing time to a precision of about one minute. It also enables measurement of the effective grazing time, which is defined as the time spent in the head-down position during meals. On the other hand, the bitemeter is not able to measure the effective grazing time when defined as the time spent masticating during meals. This is because the device does not record masticatory activity, in contradistinction to the equipment developed by Brun et al. [2] and Rutter et al. [16].

The acoustic filtering at 3 kHz eliminates a large amount of the background noise such as that produced by mastication during grazing and ruminating, breathing and movement of animals, as well as by the wind. Certain background noises have a signal similar to that of a bite; these include drinking, licking a salt block and the direct rubbing of hard herbage against the microphone. Drinking noise is a minor problem because this activity takes up a very short time in any day. According to our observations (n = 7), an extra 25–30 bites could be counted at each drinking episode, which corresponds to a total of 100–200 bites·d^{-1}

representing less than 1 % of the total number of bites. On the contrary, licking a salt block may give rise to a large bias because animals sometimes spent long periods of time in this activity. Futhermore, none of the devices described in the literature provide a resolution to this problem. To avoid the recording of bites during licking of a salt block, the latter can be placed on a tripod 1 m above the ground so as to ensure that the case is in the head-up position.

In its present state, the device would not appear to be reliable for counting bites in a sward during the reproductive stage. In fact, background noises are recorded under such conditions that are due to rubbing of the microphone against seed heads and stems. When rubbing occurs during the vegetative stage, it does not produce any sound because the soft grass, in contrast to the stems, offers little resistance.

During the spring and autumn of 1997, the automatic bitemeter was used on grazing dairy cows in order to test its robustness as well as its flexibility during routine use. The number of complete 24-hr datafiles recovered represents 83 % of the number of times devices were fitted to the animals (30 out of 36). Nevertheless, the repeated use of a device always equipped with the same microphone led to a regular decrease in its sensitivity, with a progressively less efficient detection of bites. We observed a gradual soiling of the acoustic membrane by soil as well as a deterioration of the sealing of the microphone. Changing the microphone at the end of the season led to a full recovery of sensitivity. To increase the service life of the microphone and reduce rubbing against the herbage, a potential source of background noise, it will be necessary to use a protective mesh to prevent the microphone from coming into direct contact with the grass. The microphone should also be repositioned farther from the mouth while at the same time increasing the sound amplification gain.

5. CONCLUSION

The automatic bitemeter described here is simple in its design, assembly and use. The first validation trials in the field yield satisfactory results for dairy cows grazing perennial ryegrass in the vegetative stage. The sensors used in this device appear very well adapted to the objective set here for cattle, owing to a design which allows correct measurement of the head position as well as the recording of sound signals that are clearly audible and distinct from other ambient noise. Nevertheless, additional protection of the microphone and a better standardization of its position would appear necessary for a routine use of the bitemeter in experimental trials. In the future, the reliability of the system will be tested with different forages, as characteristics of the sound during severage may differ between species.

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REFERENCES

[1] Black J.L., Kenney P.A., Factors affecting diet selection by sheep. II Height and density of pasture, Aust. J. Agric. Res. 35 (1984) 551–563.

[2] Brun J.P., Prache S., Béchet G., A portable device for eating behaviour studies, in: Amstrong R., Doney J. (Eds.), Vth Meeting of European Grazing Workshop, Hill Farming Research Organisation, Midlothian, 1984.

[3] Castle M.E., McDaid E., Watson J.N., The automatic recording of the grazing behaviour of dairy cows, J. Br. Grassl. Soc. 30 (1975) 161–163.

[4] Chambers A.R.M., Hodgson J., Milne J.A., The development and use of equipment for the automatic recording of ingestive behaviour in sheep and cattle, Grass Forage Sci. 36 (1981) 97–105.

[5] Champion R.A., Rutter S.M., Delagarde R., Recent developments with the IGER behaviour recorder, Proceedings of the IXth European Intake Workshop, 18–20 November 1998, North Wyke, 1998, pp. 31–34.

[6] Delagarde R., Caudal J.P., Peyraud J.L., Automatic recording of biting rate in grazing cattle, Proceedings of the IXth European Intake Workshop, North Wyke, 18–20 November 1998, North Wyke, 1998, pp. 75–76.

[7] Jones R.J., Cowper L.J., A lightweight electronic device for measurement of grazing time of cattle, Trop. Grasslands 9 (1975) 235–241.

[8] Laca E.A., Ungar E.D., Demment M.W., Mechanisms of handling time and intake rate of a large mammalian grazer, Appl. Anim. Behav. Sci. 39 (1994) 3–19.

[9] Luginbuhl J.M., Pond K.R., Burns J.C., Fisher D.S., Russ J.C., A computer interface system to monitor the ingestive and ruminating behavior of grazing ruminants, Anim. Sci. Res. Rep. MP–133 (1991) 177.

[10] Matsui K., A new ambulatory data logger for a long-term determination of grazing and rumination behaviour on free-ranging cattle, sheep and goats, Appl. Anim. Behav. Sci. 39 (1994) 123–130.

[11] Nonaka K., Nakui T., Adaptability of an acoustic emission sensing system for monitoring chewing behaviour of cattle, Proceedings of the 31st International Congress of the International Society for Applied Ethology, 13–16 August 1997, Prague, Czech Republic, 1997, pp. 198.

[12] Penning P.D., A technique to record automatically some aspects of grazing and ruminating behaviour in sheep, Grass Forage Sci. 38 (1983) 89–96.

[13] Penning P.D., Hooper G.E., An evaluation of the use of short-term weight changes in grazing sheep for estimating herbage intake, Grass Forage Sci. 40 (1985) 79–84.

[14] Penning P.D., Steel G.L., Johnson R.H., Further development and use of an automatic recording system in sheep grazing studies, Grass Forage Sci. 39 (1984) 345–351.

[15] Prache S., Peyraud J.L., Préhensibilité de l'herbe pâturée chez les bovins et les ovins, INRA Prod. Anim. 10 (1997) 377–390.

[16] Rutter S.M., Champion R.A., Penning P.D., An automatic system to record foraging behaviour in free-ranging ruminants, Appl. Anim. Behav. Sci. 54 (1997) 185–195.

[17] SAS Institute Inc, SAS/STAT Guide for Personal Computer, Version 6, Cary, NC, US, 1987.

[18] Stobbs T.H., Cowper L.J., Automatic measurement of the jaw movements of dairy cows during grazing and rumination, Trop. Grasslands 6 (1972) 107–112.

[19] Ungar E.D., Ingestive behaviour, in: Hodgson J., Illius A.W. (Eds.), The ecology and management of grazing systems, CAB International, Wallingford, 1996, pp. 185–218.